RESEARCH CENTER

FIELD
Applied Mathematics, Computation and Simulation

Activity Report 2019

Section Partnerships and Cooperations

Edition: 2020-03-21

NUMERICAL SCHEMES AND SIMULATIONS
1. ACUMES Project-Team 5
2. CAGIRE Project-Team 9
3. CARDAMOM Project-Team 13
4. DEFI Project-Team 17
5. ECUADOR Project-Team (section vide) 19
6. ELAN Project-Team 20
7. GAMMA Project-Team 21
8. MATHERIALS Project-Team 22
9. MEMPHIS Project-Team 24
10. MEPHYSTO Team 25
11. MINGUS Project-Team 26
12. MOKAPLAN Project-Team 30
13. NACHOS Project-Team 31
14. NANO-D Team 35
15. POEMS Project-Team 38
16. RAPSODI Project-Team 40
OPTIMIZATION AND CONTROL OF DYNAMIC SYSTEMS
17. CAGE Project-Team 44
18. COMMANDS Project-Team 46
19. DISCO Project-Team 47
20. FACTAS Project-Team 51
21. I4S Project-Team 54
22. MCTAO Project-Team 60
23. NECS Team 61
24. QUANTIC Project-Team 65
25. SPHINX Project-Team 68
26. TRIPOP Project-Team 71
27. TROPICAL Project-Team 73
28. VALSE Project-Team 75
OPTIMIZATION, MACHINE LEARNING AND STATISTICAL METHODS
29. BONUS Project-Team 76
30. CELESTE Project-Team 79
31. GEOSTAT Project-Team 80
32. INOCS Project-Team 82
33. MISTIS Project-Team 86
34. MODAL Project-Team 90
35. RANDOPT Project-Team 96
36. REALOPT Project-Team 97
37. SEQUEL Project-Team 98
38. SIERRA Project-Team 104

39. TAU Project-Team 105
STOCHASTIC APPROACHES
40. CQFD Project-Team 107
41. MATHRISK Project-Team 110
42. SIMSMART Project-Team 111
43. TOSCA Team 113

ACUMES Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

- **Project OPERA** (2019-2021): Adaptive planar optics
  This project is composed of Inria teams NACHOS, ACUMES and HIEPACS, CNRS CRHEA lab. and company NAPA. Its objective is the characterization and design of new meta-surfaces for optics (opera web site).

8.2. European Initiatives

8.2.1. Collaborations in European Programs, Except FP7 & H2020

Program: COST

Project acronym: CA18232

Project title: Mathematical models for interacting dynamics on networks

Duration: October 2019 - September 2013

Coordinator: University of Ljubljana (Prof. Marjeta Kramar Fijavz)

Other partners: see https://www.cost.eu/actions/CA18232/#tabslName:parties

Abstract: Many physical, biological, chemical, financial or even social phenomena can be described by dynamical systems. It is quite common that the dynamics arises as a compound effect of the interaction between sub-systems in which case we speak about coupled systems. This Action shall study such interactions in particular cases from three points of view:

- the abstract approach to the theory behind these systems,
- applications of the abstract theory to coupled structures like networks, neighbouring domains divided by permeable membranes, possibly non-homogeneous simplicial complexes, etc.,
- modelling real-life situations within this framework.

The purpose of this Action is to bring together leading groups in Europe working on a range of issues connected with modelling and analysing mathematical models for dynamical systems on networks. It aims to develop a semigroup approach to various (non-)linear dynamical systems on networks as well as numerical methods based on modern variational methods and applying them to road traffic, biological systems, and further real-life models. The Action also explores the possibility of estimating solutions and long time behaviour of these systems by collecting basic combinatorial information about underlying networks.

8.3. International Initiatives

8.3.1. PHC Utique

Program: Program Hubert Curien PHC Utique (Tunisia)

Project acronym: NAMReD

Project title: Novel Algorithms and Models for Data Reconstruction

Duration: January 2018 - December 2020

Coordinator: A. Habbal and M. Kallel (Univ. Tunis al Manar)

Abstract: The project goal is the design of new and efficient algorithms tailored for data reconstruction involving ill-posed problems. We rely on an original use of game theory and p-Kirchhoff methods. We apply these approaches for missing data recovery and image restoration.

8.3.2. PHC Procope

Program: Program Hubert Curien Procope (Germany)

Project title: Non-local conservation laws for engineering applications

Duration: January 2019 - December 2020

Coordinator: P. Goatin and S. Göttlich (Univ. Mannheim)

Abstract: This project tackles theoretical and numerical issues arising in the mathematical study of conservation laws with non-local flux functions. These equations appear in a variety of applications, ranging from traffic flows to industrial processes and biology, and are intended to model macroscopically the action of non-local interactions occurring at the microscopic level. The team, bi-located in France and Germany, has complementary skills covering the analysis, numerical approximation and optimization of non-linear hyperbolic systems of conservation laws, and their application to the modeling of vehicular and pedestrian traffic flows, manufacturing systems and other industrial problems. Based on the members expertise and on the preliminary results obtained by both teams, the project will focus on the following interconnected aspects: The treatment of boundary conditions, both from the analytical and the numerical point of views, in order to provide a sound basis to address specific problems arising in the applications. The development of efficient, high-order finite volume numerical schemes for the computation of approximate solutions of non-local equations. The investigation of optimal control problems with corresponding optimality systems and the design of appropriate and adaptive optimization algorithms. Targeted applications include vehicular traffic (mainly in connection with vehicle-to-vehicle communication and consumption/pollution estimation), crowd motion (in connection with safe building evacuation procedures), and manufacturing systems (intelligent production). The impact of the project is therefore twofold: while addressing major mathematical advances in the theory and numerical approximation of highly non-standard problems, it puts the basis for innovative tools to handle modern applications in engineering sciences.

8.3.3. Inria International Labs

Inria Chile

Associate Team involved in the International Lab:

8.3.3.1. NOLOCO

Title: Efficient numerical schemes for non-local transport phenomena

International Partner (Institution - Laboratory - Researcher):

Universidad del Bio-Bio (Chile) - Luis Miguel Villada Osorio

Start year: 2018

See also: https://team.inria.fr/acumes/assoc-team/noloco/

This project tackles theoretical and numerical issues arising in the mathematical study of conservation laws with non-local flux functions. These equations include in a variety of applications, ranging from traffic flows to industrial processes and biology, and are intended to model macroscopically the action of non-local interactions occurring at the microscopic level.

The team, bi-located in France and Chile, has complementary skills covering the analysis, numerical approximation and optimization of non-linear hyperbolic systems of conservation laws, and their application to the modeling of vehicular and pedestrian traffic flows, sedimentation and other industrial problems.

Based on the members' expertise and on the preliminary results obtained by the team, the project will focus on the following aspects:

- The development of efficient, high-order finite volume numerical schemes for the computation of approximate solutions of non-local equations.
- The sensitivity analysis of the solutions on model parameters or initial conditions.

The impact of the project is therefore twofold: while addressing major mathematical advances in the theory and numerical approximation of highly non-standard problems, it puts the basis for innovative tools to handle modern applications in engineering sciences.

8.3.4. Inria International Partners

8.3.4.1. ORESTE

Title: Optimal REroute Strategies for Traffic managEment

International Partner (Institution - Laboratory - Researcher):

University of California Berkeley (United States) - Electrical Engineering and Computer Science (EECS) (EECS) - Alexandre M. Bayen

Duration: 2018 - 2022

Start year: 2018

See also: https://team.inria.fr/acumes/assoc-team/oreste

The rapidly changing transportation ecosystem opens new challenges in traffic modeling and optimization approaches. We will focus in particular on the two following aspects:

Route choice apps impact. The vast use of personal route choice systems through phone applications or other devices is modifying the traditional flow of networks, requiring new models for accounting of the guidance impact. Indeed, routing apps have changed traffic patterns in the US and Europe, leading to new congestion patterns where previously no traffic was observed. Over the last decade, GPS enabled smart phones and connected personal navigation devices have disrupted the mobility landscape. Initially, the availability of traffic information led to better guidance of a small portion of motorists in the system. But as the majority of the driving public started to use apps, the systematic broadcasting of "selfish" best routes led to the worsening of traffic in numerous places, ultimately leading to the first lawsuit against one specific company in particular (Waze) accused to be the cause of these problems. This is just the beginning of an evolution, which, if not controlled and regulated, will progressively asphyxiate urban landscapes (already nearly hundreds of occurrences of this phenomenon are noticed by the popular media, which indicates the presence of probably thousands of such issues in the US alone). Traffic managers are typically not equipped to fix these problems, and typically do not fund this research, as in order to be able to regulate and fix the problem, fundamental science needs to be advanced, modeling and game theory in particular, so remediation can happen (for which the traffic managers are equipped). In this project, we will mainly focus on the development and study of new macroscopic dynamical models to describe the aforementioned phenomena, and we will explore control strategies to mitigate their impact.

Autonomous vehicles. Besides, the foreseen deployment of connected and autonomous vehicles (CAVs) opens new perspectives both in traffic modeling and control. Indeed, CAVs are expected to modify the classical macroscopic traffic dynamics due to their peculiar motion laws, which are more uniform than human drivers' and follow different rules. Besides, due to their extended information on neighboring traffic conditions, the resulting dynamics would have a non-local character, justifying the use of rapidly developing non-local models. In any case, the different behavior of autonomous vehicles requires the design of new multi-class models capable of accounting for different vehicle classes characteristics and mutual interactions. Moreover, CAVs could be used as endogenous variable speed limiters, thus providing new action points to control traffic flow. Preliminary results show that the presence of few controlled vehicles can positively affect traffic conditions. In this setting, the interaction of AVs with the surrounding traffic can be described by strongly coupled PDE-ODE systems, which have been largely studied by the ACUMES team. Yet, the study of CAVs impact in realistic situations requires further research, in particular towards model validation, for which the Berkeley team will provide the necessary data.

8.3.4.2. Informal International Partners

University of Milano Bicocca, Mathematics and Applications (M. Garavello: https://sites.google.com/site/maurogaravello/)

University of Rutgers - Camden, Department of Mathematical Science (B. Piccoli: https://piccoli.camden.rutgers.edu/)

Argonne National Laboratory, Mathematics and Computer Science Division (Jonathan Ozik: https://www.anl.gov/profile/jonathan-ozik, Stefan Wild: https://www.anl.gov/profile/stefan-m-wild)

Virginia Polytechnic Institute and State University (Robert B. Gramacy: https://www.stat.vt.edu/people/stat-faculty/gramacy-robert.html)

University of Texas Arlington (S. Roy, https://mentis.uta.edu/explore/profile/souvik-roy)

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- J. Friedrich (January, June-July, November 2019, Univ. Mannheim, Germany): non-local traffic flow models.
- J. Kotz (November 2019, Univ. Mannheim, Germany): augmented macroscopic traffic flow models at junctions.
- L.M. Villada (November 2019, University of Bio-Bio): finite volume schemes for non-local systems of conservation laws.
- R. Ordonez (November-December 2019, Univ. Concepcion, Chile): finite volume schemes for non-local systems of conservation laws.
- R. Bürger (December 2019, Univ. Concepcion, Chile): finite volume schemes for non-local systems of conservation laws.
- M. Kallel (December 2019, Univ. Tunis al Manar, Tunisia): Game theory for inverse problems.

8.4.2. Visits to International Teams

8.4.2.1. Research Stays Abroad

- F.A. Chiarello visited Mannheim University (S. Göttlich) for 3 months in March-May 2019.

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.

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 [44] 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. This year, the evaluation of the capability of the compressible module of Yales2 has started.

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: Pascal Bruel, Rémi Manceau, Franck Mastrippolito.

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 Medecine, Loughborough University.

Abstract: For decades, most of the aviation research activities have been focused on the reduction of noise and NOx and CO2 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. Franck Mastrippolito, the post-doc recruited by mid-january 2019, performed simulations aimed at reproducing the experiment of ONERA Toulouse carried out in the same workpackage. The configuration is that of an effusion plate with a gyration angle of 90 degrees and the turbulence model is EBRSM. Franck presented his results in October 2019 during the ITR meeting in Florence (Italy).

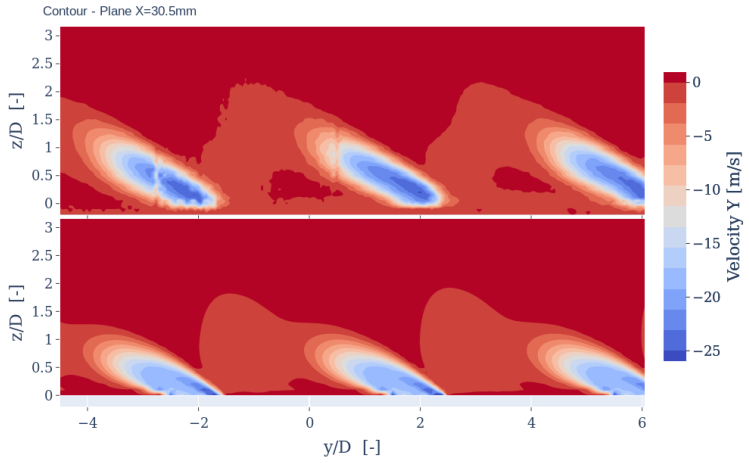


Figure 2. Simulation of the ONERA SOPRANO configuration: example of experimental (top) vs numerical (bottom) results concerning the mean velocity field.

9.4. International Initiatives

9.4.1. Informal International Partners

- Institute of Mathematics and Mathematical Modelling, Almaty, Kazakhstan
  Participant: Pascal Bruel.

  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 ([10]). This year, Pascal Bruel spent two weeks in Almaty in the framework of this partnership.
- University of Evora, Evora, Portugal
  Participant: Pascal Bruel.

  Collaboration with Dr. P. Correia related this year to the partial rewriting of a Fortran code implementing a pressure-based approach for simulating low Mach flows as well as to the promotion of such a pressure-based approach ([25]). This year, Pascal Bruel spent 5 days in Evora in the framework of this partnership.
- University of Ghent, Ghent, Belgium
  Participant: Pascal Bruel.

  Collaboration with Prof. E. Dick related to the development and the promotion of a pressure-based approach for simulating low Mach and all-Mach flows. ([25], [14])

9.4.2. Participation in International Programs

- National University of Córdoba (UNC), Córdoba, Argentina: ECOS-Sud A17A07 project
  Participant: Pascal Bruel.

  2019 was the second year of this project devoted to the simulations of the wind around aerial fuel tanks and related experiments. Pascal Bruel spent two weeks at UNC in the framework of this project.

9.5. International Research Visitors

- Prof. Sergio Elaskar (2 weeks) and PhD student Mauro Grioni (1 month) from University of Córdoba (Argentina) visited the team in the framework of the A17A07 Ecos-Sud project.
- Dr. Paulo Correia from University of Evora spent two weeks in the team in May 2019.

9.5.1. Visits of International Scientists

9.5.1.1. Internships

Mauricio Garcia Zulch from Chile spent 3 months in the team.

CARDAMOM Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

Title: ETRURIA: Robust simulation tools for non-hydrostatic free surface flows

Type: Apple à Projets Recherche Région Nouvelle Aquitaine

Coordinator: M. Ricchiuto

Other partners: BRGM, UMR EPOC (P. Bonneton)

Abstract: The objective of this project is to combine high order continuous finite elements, with embedded methods and mesh adaptation in the simulation of coastal and urban inundation. Realistic validation cases will be provided by BRGM. This project co-funds (50%) the PhD of S. Michel.

8.2. National Initiatives

8.2.1. ANR VISCAP

Title: VIrtual Self-healing Composites for Aeronautic Propulsion

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. 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. 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.

8.2.2. 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 ergonomy 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

8.2.3. 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 environnement : 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 plateform, able to provide a complete design of these systems.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

Program: FETHPC-02

Project acronym: ExaQute

Project title: Exascale quantification of uncertainties for technology and science simulation

Duration: June 2018 - April 2019

Coordinator: CIMNE (Spain)

Other partners: BSC (Spain), TUM (Germany), IT4 (Czech Republic), EPFL (Switzerland), UPC (Spain), Structure (Germany).

Abstract: The ExaQUte project aims at constructing a framework to enable Uncertainty Quantification and Optimization Under Uncertainties in complex engineering problems, using computational simulations on Exascale systems. 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 the 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 exist.

8.3.2. Collaborations in European Programs, Except FP7 & H2020

Program: OCEANEraNET

Project acronym: MIDWEST

Project title: Multi-fIdelity Decision making tools for Wave Energy SysTems

Duration: December 2015 - April 2019

Coordinator: Mario Ricchiuto

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

Abstract: 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.

8.4. International Initiatives

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

8.4.1.1. HAMster

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

International Partner (Institution - Laboratory - Researcher):

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

Inria Bordeaux -SO (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 fronts (e.g. shock waves) present in the flow. The two teams involved in the project have developed over the years complementary strategies, one focusing more on an Eulerian description aiming at capturing fronts on adaptive unstructured grids, the other is 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 enormous flexibility when considering complex cases, 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.

8.4.2. Inria International Partners

8.4.2.1. Inria International Chairs

IIC ABGRALL Rémi

Title: Numerical approximation of complex PDEs & Interaction between modes, schemes, data and ROMs

International Partner (Institution - Laboratory - Researcher):

ETH Zurich (Switzerland) - Institut fur Mathematik & Computational Science - Rémi Abgrall

Duration: 2019 - 2023

Start year: 2019

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Claes Eskilsson, associated professor at Aalborg University, visited Mario Ricchiuto in Jul 2019.
- Francois Morency, Professeur at Ecole de Technologie Supérieure de Montréal has visited Héloïse Beaugendre to work on aircraft icing, roughness modeling and performance degradation, in January 2019 and July 2019.
- Masahito Ohta, Professor at Tokyo University of Science visited Mathieu Colin in Dec 2019.
- Nicolas Perinet, Postocdoral fellow at University of Chile has visited Mario Ricchiuto to work on the benchmarking of the SLOWS CODE in October 2019.
- Guglielmo Scovazzi, Prof. at Duke University, has visited M. Ricchiuto in the summer to work on the shifted boundary method;
- Davide Torlo, PhD candidate at U. Zurich, visited M. Ricchiuto in June 2019 to work on relaxation finite element approximations of the shallow water equations

8.5.1.1. Internships

- Mirco Ciallella (Inria, M. Sc. Student). Until Jan 2019.
- Simon Le Berre (Inria, M. Sc. Student). From Apr 2019 until Sep 2019.

DEFI Project-Team

7. Partnerships and Cooperations

7.1. Regional Initiatives

7.1.1. EVE

- Title : Virtual prototyping of EVE engines
- Type : Co-funded from Region Aquitaine and Inria
- Duration : 36 months
- Starting : October 2018
- 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.i 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.

7.2. European Initiatives

7.2.1. FP7 & H2020 Projects

7.2.1.1. UTOPIAE

Program: H2020 MSCA-ITN
Project acronym: UTOPIAE
Project title: Handling the unknown at the edge of tomorrow
Duration: January 2017- December 2020
Coordinator: M. Vasile (Strathclyde University)
Other partners: see http://utopiae.eu/ for additional details
UTOPIAE is a European research and training network looking at cutting edge methods bridging optimisation and uncertainty quantification applied to aerospace systems. The network will run from 2017 to 2021, and is funded by the European Commission through the Marie Skłodowska-Curie Actions of H2020. The network is made up of 15 partners across 6 European countries, including the UK, and one international partner in the USA, collecting mathematicians, engineers and computer scientists from academia, industry, public and private sectors.
Mission statement : To train, by research and by example, 15 Early Stage Researchers in the field of uncertainty quantification and optimisation to become leading independent researchers and entrepreneurs that will increase the innovation capacity of the EU. To equip the researchers with the skills they will need for successful careers in academia and industry. To develop fundamental mathematical methods and algorithms to bridge the gap between Uncertainty Quantification and Optimisation and between Probability Theory and Imprecise Probability Theory for Uncertainty Quantification to efficiently solve high-dimensional, expensive and complex engineering problems.

7.3. International Initiatives

7.3.1. Inria International Labs

P.M. Congedo is the Inria Coordinator of the CWI-Inria Inria International Lab.

IIL CWI-Inria

Associate Team involved in the International Lab:

7.3.1.1. COMMUNES

Title: Computational Methods for Uncertainties in Fluids and Energy Systems

International Partner (Institution - Laboratory - Researcher):

CWI (Netherlands) - Scientific Computing Group - Daan Crommelin

Start year: 2017

See also: https://project.inria.fr/inriacwi/projects/communes/

This project aims to develop numerical methods capable to take into account efficiently unsteady experimental data, synthetic data coming from numerical simulation and the global amount of uncertainty associated to measurements, and physical-model parameters. We aim to propose novel algorithms combining data-inferred stochastic modeling, uncertainty propagation through computer codes and data assimilation techniques. The applications of interest are both related to the exploitation of renewable energy sources: wind farms and solar Organic Rankine Cycles (ORCs).

7.3.1.2. Informal International Partners

University of Zurich : R. Abgrall. Collaboration on high order adaptive methods for CFD and uncertainty quantification.

Politecnico di Milano, Aerospace Department (Italy) : Pr. A. Guardone. Collaboration on ALE for complex flows (compressible flows with complex equations of state).

von Karman Institute for Fluid Dynamics (Belgium). With Pr. T. Magin we work on Uncertainty Quantification problems for the identification of inflow condition of hypersonic nozzle flows.

Rutgers University. Collaboration with Pr. F. Cakoni on transmission eigenvalues.

University of Delaware. Collaboration with Pr. D. Colton on inverse scattering theory

Ecole Nationale des Ingénieurs de Tunis. Collaboration with Pr. M. Bellasoued on inverse scattering problems

Faculté des Sciences de Sfax. Collaboration with Pr. S. Chaabane on inverse problems for singular parameters

University of Sousse. Collaboration with Pr. M. Khenissi on transmission eigenvalues

Colorado School of Mines. Collaboration with F. Pourahmadian on differential LSM

ns of solution derivatives.

7.4. International Research Visitors

7.4.1. Visits of International Scientists

- Fioralba Cakoni and David Colton, 1 week, March 2019

7.4.1.1. PostDocs, Internships

- PostDoc, Xiaoli Liu, Sampling methods for time dependent problems, H. Haddar
- Master thesis, Marwa Mansouri, Inside-outside duality with artificial backgrounds, L. Chesnel and H. Haddar.
- PostDoc, Imen Mekkaoui, In-vivo cardiac diffusion magnetic resonanace imaging: simulations and parameters estimation, Jing Rebecca Li and Jan Hesthaven.
- Master thesis, Try Nguyen Tran, French-Vietnam Master Program in Applied Mathematics, Jing Rebecca Li
- Master thesis, Nouha jenhani, ENIT, LAMSIN, H. Haddar
- Master thesis, Amal Labidi, ENIT, LAMSIN, H. Haddar

ECUADOR Project-Team (section vide)

ELAN Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. National Collaborations

- Long-term collaboration with Christophe Prud'homme and Vincent Chabannes (Université de Strasbourg and Centre de modélisation et de simulation de Strasbourg).

8.2. European Initiatives

8.2.1. FP7 & H2020 Projects

8.2.1.1. GEM

Title: from GEometry to Motion, inverse modeling of complex mechanical structures

Programm: H2020

Type: ERC

Duration: September 2015 - August 2021

Coordinator: Inria

Inria contact: Florence BERTAILS-DESCOUBES

With the considerable advance of automatic image-based capture in Computer Vision and Computer Graphics these latest years, it becomes now affordable to acquire quickly and precisely the full 3D geometry of many mechanical objects featuring intricate shapes. Yet, while more and more geometrical data get collected and shared among the communities, there is currently very little study about how to infer the underlying mechanical properties of the captured objects merely from their geometrical configurations. The GEM challenge consists in developing a non-invasive method for inferring the mechanical properties of complex objects from a minimal set of geometrical poses, in order to predict their dynamics. In contrast to classical inverse reconstruction methods, my proposal is built upon the claim that 1/ the mere geometrical shape of physical objects reveals a lot about their underlying mechanical properties and 2/ this property can be fully leveraged for a wide range of objects featuring rich geometrical configurations, such as slender structures subject to frictional contact (e.g., folded cloth or twined filaments). To achieve this goal, we shall develop an original inverse modeling strategy based upon a/ the design of reduced and high-order discrete models for slender mechanical structures including rods, plates and shells, b/ a compact and well-posed mathematical formulation of our nonsmooth inverse problems, both in the static and dynamic cases, c/ the design of robust and efficient numerical tools for solving such complex problems, and d/ a thorough experimental validation of our methods relying on the most recent capturing tools. In addition to significant advances in fast image-based measurement of diverse mechanical materials stemming from physics, biology, or manufacturing, this research is expected in the long run to ease considerably the design of physically realistic virtual worlds, as well as to boost the creation of dynamic human doubles.

8.3. International Initiatives

8.3.1. Inria International Partners

8.3.1.1. Declared Inria International Partners

- Long-term partnership with Rahul Narain (University of Minnesota, USA, and IIT Delhi, INDIA) and Rahul Narain's PhD student Jie Li (University of Minnesota, USA).
- Long-term partnership with Alexandre-Derouet-Jourdan (OLM Digital, JAPAN).

GAMMA Project-Team

6. Partnerships and Cooperations

6.1. National Initiatives

6.1.1. ANR

6.1.1.1. ANR IMPACTS 2018-2021

Ideal Mesh generation for modern solvers and comPuting ArchiteCTureS.

- Coordinateur : Adrien Loseille
- The rapid improvement of computer hardware and physical simulation capabilities has revolutionized science and engineering, placing computational simulation on an equal footing with theoretical analysis and physical experimentation. This rapidly increasing reliance on the predictive capabilities has created the need for rigorous control of numerical errors which strongly impact these predictions. A rigorous control of the numerical error can be only achieved through mesh adaptivity. In this context, the role of mesh adaptation is prominent, as the quality of the mesh, its refinement, and its alignment with the physics are major contributions to these numerical errors. The IMPACTS project aims at pushing the envelope in mesh adaptation in the context of large size, very high fidelity simulations by proposing a new adaptive mesh generation framework. This framework will be based on new theoretical developments on Riemannian metric-field and on innovative algorithmic developments coupling a unique cavity-operator with an advancing-point techniques in order to produce high quality hybrid, curved and adapted meshes.

MATHERIALS Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

The project-team is involved in several ANR projects:

- S. Boyaval is the PI of the ANR JCJC project SEDIFLO (2016-2021) to investigate new numerical models of solid transport in rivers.
- V. Ehrlacher is the PI of the ANR project COMODO (2020-2024) which focuses on the development of efficient numerical methods to simulate cross-diffusion systems on moving domains, with application to the simulation of the fabrication process of thin film solar cells. It includes research teams from Inria Lille, Inria Sophia-Antipolis and Germany.
- V. Ehrlacher is a member of the ANR project ADAPT (2018-2022), PI: D. Lombardi, Inria REO team-project. This project is concerned with the parallelization of tensor methods for high-dimensional problems.
- F. Legoll is a member of the ANR project CINE-PARA (2015-2020), PI: Y. Maday, Sorbonne Université. This project is concerned with parallel-in-time algorithms.
- T. Lelièvre is responsible of the node "Ecole des Ponts" of the ANR QuAMProcs (2019-2023), to which G. Stoltz also participates, PI: L. Michel, Université de Bordeaux.
- G. Stoltz is the PI of the ANR project COSMOS (2014-2019) which focuses on the development of efficient numerical techniques to simulate high-dimensional systems in molecular dynamics and computational statistics. It includes research teams from Institut Mines-Telecom, Inria Rennes and IBPC Paris.

Members of the project-team are participating in the following GdR:

- AMORE (Advanced Model Order REduction),
- CORREL (correlated methods in electronic structure computations),
- DYNQUA (time evolution of quantum systems, with applications to transport problems, nonequilibrium systems, etc.),
- EGRIN (gravity flows),
- MANU (MAthematics for NUclear applications),
- MASCOT-NUM (stochastic methods for the analysis of numerical codes),
- MEPHY (multiphase flows),
- NBODY (electronic structure),
- REST (theoretical spectroscopy),
- CHOCOLAS (experimental and numerical study of shock waves).

The project-team is involved in two Labex: the Labex Bezout (2011-) and the Labex MMCD (2012-).

We have invited the following national researchers to visit our team:

- A. Lozinski (University of Besançon): repeated visits during the year 2019.

8.2. European Initiatives

The ERC consolidator Grant MSMATH (ERC Grant Agreement number 614492, PI T. Lelièvre) ended in June 2019.

The ERC Synergy Grant EMC2 (ERC Grant Agreement number 810367 , PI E. Cancès, L. Grigori, Y. Maday, J-P. Piquemal) has started in September 2019.

8.3. International Initiatives

T. Lelièvre, G. Stoltz and F. Legoll participate in the Laboratoire International Associé (LIA) CNRS / University of Illinois at Urbana-Champaign on complex biological systems and their simulation by high performance computers. This LIA involves French research teams from Université de Nancy, Institut de Biologie Structurale (Grenoble) and Institut de Biologie Physico-Chimique (Paris). The LIA has been renewed for 4 years, starting January 1st, 2018.

MEMPHIS Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

We are part of the GDR AMORE on ROMs.

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects: ARIA RISE project

The overarching objective of ARIA (Accurate Roms for Industrial Applications) project is to form an international and intersectoral network of organizations working on a joint research program in numerical modelling, specifically in the fields of model reduction and convergence between data and models. Memphis team is ccordinating this 926KEuro project. 7 industrial partners are involved (VW, Valorem, Optimad, IEFluids, VirtualMech, Nurea, Esteco), 5 EU academic partners (Inria, Université de Seville, Poitecnico di Milano, Politecnico di Torino, SISSA) and 3 universities in the USA: Stanford University, Virginia Tech and University of South Carolina.

9.3. International Initiatives

9.3.1. Inria International Labs

Inria@SiliconValley
Associate Team involved in the International Lab:

9.3.1.1. MARE

Title: Multiscale Accurate Reduced-order model Enablers

International Partner (Institution - Laboratory - Researcher):

Stanford (United States) - VNU University of Engineering and Technology - Charbel Farhat

Start year: 2019

See also: https://team.inria.fr/memphis/mare-associate-team/

Reduced-order models (ROMs) are simplified mathematical models derived from the full set of partial differential equations governing the physics of the phenomenon of interest. We focus on ROMs that are data-driven as they are based on relevant solution data previously obtained. In particular we will focus on multiscale adaptive models where the large scales are governed by a PDE and the small scales are described by data driven models. To do that we will leverage on tools from data geometry, numerical PDEs and machine learning.

MEPHYSTO Team

6. Partnerships and Cooperations

6.1. National Initiatives

6.1.1. ANR

A. de Laire is a member of the ANR ODA project.

Title: Dispersive and random waves

ANR reference: ANR-18-CE40-0020-01

Coordinator: Nikolay Tzvetkov, Université de Cergy-Pontoise

A. Hardy is a member of the ANR BoB project.

Title: Inférence bayésienne à ressources limitées - données massives et modèles coûteux

Programme ANR: (DS0705) 2016

ANR reference: ANR-16-CE23-0003

Coordinator: R. Bardenet, CNRS & Université de Lille

Duration: October 2016 - October 2020

M. Simon has been a member of the ANR EDNHS project.

Title: Diffusion de l'énergie dans des système hamiltoniens bruités

Type: Défi de tous les savoirs (DS10) 2014

ANR reference: ANR-14-CE25-0011

Coordinator: C. Bernardin, Université de Nice

Duration: October 2014 - October 2019

6.2. European Initiatives

6.2.1. FP7 & H2020 Projects

M. Simon is a collaborator of the ERC Starting Grant HyLEF project.

Title: Hydrodynamic Limits and Equilibrium Fluctuations: universality from stochastic systems

Duration: May 2017 - April 2022

Coordinator: P. Gonçalves, Instituto Superior Técnico, Lisbon, Portugal

MINGUS Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

- M. Lemou and N. Crouseilles are head of the project "MUNIQ" of ENS Rennes. This two-years project (2018-2019) intends to gather multiscale numerical methods and uncertainty quantification techniques. The MINGuS members are P. Chartier, N. Crouseilles, M. Lemou and F. Méhats and colleagues from university of Madison-Wisconsin also belong to this project.

8.2. National Initiatives

8.2.1. ANR

8.2.1.1. MOONRISE: 2015-2019

Participants: François Castella, Philippe Chartier, Nicolas Crouseilles, Mohammed Lemou, Florian Méhats.

The project *Moonrise* submitted by Florian Méhats has been funded by the ANR for 4 years, for the period 2015-2019. This project aims at exploring modeling, mathematical and numerical issues originating from the presence of high-oscillations in nonlinear PDEs from the physics of nanotechnologies (quantum transport) and from the physics of plasmas (magnetized transport in tokamaks). The partners of the project are the IRMAR (Rennes), the IMT (Toulouse) and the CEA Cadarache. In the MINGuS team, François Castella, Philippe Chartier, Nicolas Crouseilles and Mohammed Lemou are members of the project Moonrise.

Postdocs

- Loïc Le Treust has been hired as a Postdoc, under the supervision of Philippe Chartier and Florian Méhats. His contract started in september 2015 and ended in august 2016. Loïc Le Treust is now assistant professor at the university of Marseille.
- Yong Zhang has been hired as a Postdoc, under the supervision of Philippe Chartier and Florian Méhats. His contract started in september 2015 and ended in august 2016. Yong Zhang is now professor at the Tianjin university (China).
- Xiaofei Zhao has been hired as a Postdoc from september 2015 to september 2016 under the supervision of Florian Méhats. Xiaofei Zhao is now postdoc assistant professor in the Wuhan University (China).

8.2.1.2. MFG: 2016-2020

Participant: Arnaud Debussche.

Mean Field Games (MFG) theory is a new and challenging mathematical topic which analyzes the dynamics of a very large number of interacting rational agents. Introduced ten years ago, the MFG models have been used in many areas such as, e.g., economics (heterogeneous agent models, growth modeling,...), finance (formation of volatility, models of bank runs,...), social sciences (crowd models, models of segregation) and engineering (data networks, energy systems...). Their importance comes from the fact that they are the simplest (“stochastic control"-type) models taking into account interactions between rational agents (thus getting beyond optimization), yet without entering into the issues of strategic interactions. MFG theory lies at the intersection of mean field theories (it studies systems with a very large number of agents), game theory, optimal control and stochastic analysis (the agents optimize a payoff in a possibly noisy setting), calculus of variations (MFG equilibria may arise as minima of suitable functionals) and partial differential equations (PDE): In the simplest cases, the value of each agent is found by solving a backward Hamilton-Jacobi equation whereas the distribution of the agents’ states evolves according to a forward Fokker-Planck equation. The “Master" equation (stated in the space of probability measures) subsumes the individual and collective

behaviors. Finally, modeling, numerical analysis and scientific computing are crucial for the applications. French mathematicians play a world-leading role in the research on MFG: The terminology itself comes from a series of pioneering works by J.-M. Lasry and P.-L. Lions who introduced most of the key ideas for the mathematical analysis of MFG; the last conference on MFG was held last June in Paris and organized by Y. Achdou, P. Cardaliaguet and J.-M. Lasry. As testifies the proposal, the number of researchers working on MFG in France (and also abroad) is extremely fast-growing, not only because the theoretical aspects are exciting and challenging, but also because MFG models find more and more applications. The aim of the project is to better coordinate the French mathematical research on MFG and to achieve significant progress in the theory and its applications.

The partners of the project are the CEREMADE laboratory (Paris Dauphine), the IRMAR laboratory (Rennes I), the university of Nice and of Tours.

8.2.1.3. ADA: 2019-2023

Participant: Arnaud Debussche.

The aim of this project is to treat multiscale models which are both infinite-dimensional and stochastic with a theoretic and computational approach. Multiscale analysis and multiscale numerical approximation for infinite-dimensional problems (partial differential equations) is an extensive part of contemporary mathematics, with such wide topics as hydrodynamic limits, homogenization, design of asymptotic-preserving scheme. Multiscale models in a random or stochastic context have been analysed and computed essentially in finite dimension (ordinary/stochastic differential equations), or in very specific areas, mainly the propagation of waves, of partial differential equations. The technical difficulties of our project are due to the stochastic aspect of the problems (this brings singular terms in the equations, which are difficult to understand with a pure PDE's analysis approach) and to their infinite-dimensional character, which typically raises compactness and computational issues. Our main fields of investigation are: stochastic hydrodynamic limit (for example for fluids), diffusion-approximation for dispersive equations, numerical approximation of stochastic multiscale equations in infinite dimension. Our aim is to create the new tools - analytical, probabilistic and numerical - which are required to understand a large class of stochastic multiscale partial differential equations. Various modelling issues require this indeed, and are pointing at a new class of mathematical problems that we wish to solve. We also intend to promote the kind of problems we are interested in, particularly among young researchers, but also to recognized experts, via schools, conference, and books.

The partners are ENS Lyon (coordinator J. Vovelle) and ENS Rennes (Coordinator A. Debussche).

8.2.2. Fédération de Recherche : Fusion par Confinement Magnétique

We are involved in the national research multidisciplinary group around magnetic fusion activities. As such, we answer to annual calls.

8.2.3. IPL SURF

A. Debussche and E. Faou are members of the IPL (Inria Project Lab) SURF: Sea Uncertainty Representation and Forecast. Head: Patrick Vidard.

8.2.4. AdT J-Plaff

This AdT started in october 2019 and will be finished in september 2021. An engineer has been hired (Y. Mocquard) to develop several packages in the Julia langage. The J-Plaff is shared with the Fluminance team.

8.3. European Initiatives

8.3.1. Collaborations in European Programs, Except FP7 & H2020

Program: Eurofusion

Project acronym: MAGYK

Project title:

Duration: january 2019-december 2020

Coordinator: E. Sonnendrücker

Other partners: Switzerland, Germany, France, Austria, Finland.

Abstract: This proposal is aimed at developing new models and algorithms that will be instrumental in enabling the efficient and reliable simulation of the full tokamak including the edge and scrape-off layer up to the wall with gyrokinetic or full kinetic models. It is based on a collaboration between applied mathematicians and fusion physicists that has already been very successful in a previous enabling research project and brings new ideas and techniques into the magnetic fusion community. New modelling and theoretical studies to extend the modern gyrokinetic theory up to the wall including boundary conditions will be addressed, and the limits of gyrokinetics will be assessed. New multiscale methods will enable to efficiently and robustly separate time scales, which will on the one hand make gyrokinetic codes more efficient and on the other hand enable full implicit kinetic simulations. Difficult algorithmic issues for handling the core to edge transition, the singularities at the O- and X-points will be addressed. And finally, pioneering work based on recent (deep) machine learning techniques will be performed, on the one hand to automatically identify a Partial Differential Equation (PDE) from the data, which can be used for verification and sensitivity analysis purposes, and on the other hand to develop reduced order models that will define a low- cost low-fidelity model based on the original high-fidelity gyrokinetic or kinetic model that can be used for parameter scans and uncertainty quantification.

8.4. International Initiatives

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

8.4.1.1. ANTIpODE

Title: Asymptotic Numerical meThods for Oscillatory partial Differential Equations with uncertainties

International Partner (Institution - Laboratory - Researcher):

University of Wisconsin-Madison, USA (United States)

Start year: 2018

See also: https://team.inria.fr/antipode/

The proposed associate team assembles the Inria team IPSO and the research group led by Prof. Shi Jin from the Department of Mathematics at the University of Wisconsin, Madison. The main scientific objective of ANTIpODE consists in marrying uniformly accurate and uncertainty quantification techniques for multi-scale PDEs with uncertain data. Multi-scale models, as those originating e.g. from the simulation of plasma fusion or from quantum models, indeed often come with uncertainties. The main scope of this proposal is thus (i) the development of uniformly accurate schemes for PDEs where space and time high oscillations co-exist and (ii) their extension to models with uncertainties. Applications to plasmas (Vlasov equations) and graphene (quantum models) are of paramount importance to the project.

8.4.2. Inria International Partners

8.4.2.1. Informal International Partners

The members of MINGuS have several interactions with the following partners

- Europe: University of Geneva (Switzerland), University of Jaume I (Spain), University of Basque Country (Spain), University of Innsbruck (Austria), University of Ferrare (Italy), Max Planck Institute (Germany), SNS Pisa (Italy)
- USA: Georgia Tech, University of Maryland, University of Wisconsin, NYU
- Asia: Chinese Academy of Science (China), University of Wuhan (China), shanghai jiao tong university (China), National University of Singapore (Singapore)

8.4.3. Participation in Other International Programs

- SIMONS project. Erwan Faou is one of the Principal investigators of the Simons Collaboration program *Wave Turbulence*. Head: Jalal Shatah (NYU).

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Fernando Casas (University of Jaume I, Spain) was invited in the MINGuS team during 6 months (september 2018 to february 2019), funded by the Labex (CHL) Center Henri Lebesgue.
- Yingzhe Li (University of Chinese Academy of Sciences, China) is visiting the IRMAR laboratory during one year (March 2019-February 2020) thanks to a chinese grant. He is currently a PhD student advised by Yajuan Sun, professor at CAS.
- Xiaofei Zhao (University of Wuhan, China) was invited in the MINGuS team during 2 weeks (july 2019).
- Yoshio Tsutsumi (Kyoto University, Japan) was invited in the IRMAR laboratory during 2 months (october-november 2019).

8.5.1.1. Internships

- G. Barrué: Master 2 internship, A. Debussche.
- Q. Chauleur: Master 2 internship, R. Carles (CNRS, Rennes) and E. Faou.
- U. Léauté: Master 1 internship, B. Boutin (University Rennes I and N. Crouseilles).
- A. V. Tuan: Master 2 internship, M. Lemou and F. Méhats.

8.5.2. Visits to International Teams

8.5.2.1. Sabbatical programme

P. Chartier was on a sabbatical visit from the 1st of February to the 30th of September 2019 at the University of the Basque Country, Spain.

8.5.2.2. Research Stays Abroad

- P. Chartier was invited by G. Vilmart, University of Geneva, Geneva, Switzerland, January 2019.
- P. Chartier was invited by F. Casas at the university of Jaume I, Castellon, Spain, July 2019.
- P. Chartier was Invited by Q. Li at the university of Wisconsin, Madison, USA, September 2019.
- P. Chartier was Invited by M. Tao at Georgia Tech, Atlanta, USA, August 2019.
- A. Debussche was invited by G. Da Prato at Scuola Normale Superiore, Pise, Italy, April 2019.
- E. Faou was a participant of the Semester *Geometry, compatibility and structure preservation in computational differential equations*, Isaac Newton Institute, Cambridge, UK (3 months stay, September-December 2019).
- M. Lemou was invited by J. Joudioux and L. Anderson, at the Albert Einstein Institute, Golm, Germany, February 2019.
- M. Lemou was invited by A. M. M. Luz at the Universidade Federal Fluminense, Rio de Janeiro, Brazil, April 2019.
- M. Lemou was invited by S. Jin at Shanghai Jiao Tong University, Shanghai, China, April 2019.
- M. Lemou was invited by J. Ben-Artzi at the university of Cardiff, Cardiff, UK, May 2019.
- M. Lemou was invited by G. Vilmart, University of Geneva, Geneva, Switzerland, January 2019.
- M. Lemou was Invited by Q. Li at the university of Wisconsin, Madison, USA, September 2019.
- M. Lemou was Invited by M. Tao at Georgia Tech, Atlanta, USA, August 2019.
- F. Méhats was invited by A. de la Luz at the Universidade Federal Fluminense, Rio de Janeiro, Brazil, April 2019.
- F. Méhats was invited by G. Vilmart, University of Geneva, Geneva, Switzerland, January 2019.

MOKAPLAN Project-Team

6. Partnerships and Cooperations

6.1. National Initiatives

6.1.1. ANR

V. Duval is the PI of the CIPRESSI (ANR JCJC) project. Its aim is to develop novel numerical schemes which respect the continuous nature of the variational problems in image or signal processing.
J-D. Benamou and G. Carlier are members of the ANR MFG (ANR-16-CE40-0015-01). Scientific topics of the project: Mean field analysis Analysis of the MFG systems and of the Master equation Numerical analysis Models and applications
J-D. Benamou G. Carlier F-X. Vialard and T. O. Gallouët are members of ANR MAGA (ANR-13-JS01-0007-01). The Monge-Ampère equation is a fully nonlinear elliptic equation, which plays a central role in geometry and in the theory of optimal transport. However, the singular and non-linear nature of the equation is a serious obstruction to its efficient numerical resolution. The first aim of the MAGA project is to study and to implement discretizations of optimal transport and Monge-Ampère equations which rely on tools from computational geometry (Laguerre diagrams). In a second step, these solvers will be applied to concrete problems from various fields involving optimal transport or Monge-Ampère equations such as computational physics: early universe reconstruction problem, congestion/incompressibility constraints economics: principal agent problems, geometry: variational problems over convex bodies, reflector and refractor design for non-imaging optics
T. O. Gallouët is member of the ANR GEOPOR (JCJC of C. Cancès) Scientific topic: geometrical approach, based on Wasserstein gradient flow, for multiphase flows in porous media. Theory and Numerics.
T. O. Gallouët is member of the ANR MESA (JCJC of M. Fathi) Scientific topic: Stein methods.

6.2. European Initiatives

6.2.1. FP7 & H2020 Projects

J-D. Benamou and Giorgi Rukhaia are members of ROMSOC ITN-EID.

6.3. International Initiatives

6.3.1. Inria International Partners

6.3.1.1. Informal International Partners

The team has strong ties with Technische Universität München, dept. of Math. (Profs. Daniel Matthes, Gero Friesecke, Bernhardt Schmitzer)

6.4. International Research Visitors

6.4.1. Visits of International Scientists

15-28/02 Visit of Prof. Yanir Rubinstein (University of Maryland).

6.4.2. Visits to International Teams

6.4.2.1. Research Stays Abroad

P. Pegon has been invited by Maria Colombo (Chair of Mathematical Analysis, Calculus of Variations and PDEs) at EPFL, Lausanne for 4 months (Feb-June 2019) to work on optimal and branched transport problems.

NACHOS Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR project

8.1.1.1. OPERA (Adpative planar optics)

Participants: Emmanuel Agullo [HIEPACS project-team, Inria Bordeaux - Sud-Ouest], Régis Duvigneau [ACUMES project-team], Mahmoud Elsawy, Patrice Genevet [CRHEA laboratory, Sophia Antipolis], Luc Giraud [HIEPACS project-team, Inria Bordeaux - Sud-Ouest], Stéphane Lanteri.

Type: ANR ASTRID Maturation

See also: http://www-sop.inria.fr/nachos/opera/

Duration: Avril 2019 - March 2022

Coordinator: Inria

Partner: CRHEA laboratory in Sophia Antipolis and NAPA Technologies in Archamps

Inria contact: Stéphane Lanteri

Abstract: In the OPERA project, we are investigating and optimizing the properties of planar photonic devices based on metasurfaces using numerical modelling. The scientific and technical activities that constitute the project work programme are organized around 4 main workpackages. The numerical characterization of the optical properties of planar devices based on metasurfaces, as well as their optimization are at the heart of the activities and objectives of two horizontal (transversal) workpackages. These numerical methodologies will be integrated into the DIOGENeS software framework that will eventually integrates (1) discontinuous Galerkin-type methods that have been tested over the past 10 years for the discretization of Maxwell equations in time and frequency regimes, mainly for applications in the microwave band, (2) parallel resolution algorithms for sparse linear systems based on the latest developments in numerical linear algebra, (3) modern optimization techniques based on learning and metamodeling methods and (4) software components adapted to modern high performance computing architectures. Two vertical workpackages complete this program. One of them aims to demonstrate the contributions of methodological developments and numerical tools resulting from transversal workpackages through their application to diffusion/radiation control by passive planar devices. The other, more prospective, concerns the study of basic building blocks for the realization of adaptive planar devices.

8.2. European Initiatives

8.2.1. H2020 Projects

8.2.1.1. PRACE 6IP

Title: PRACE Sixth Implementation Phase (PRACE-6IP) project

See also: https://cordis.europa.eu/project/id/823767

Duration: May 2019 - December 2021

Partners: see https://cordis.europa.eu/project/id/823767

Inria contact: Luc Giraud

PRACE, the Partnership for Advanced Computing is the permanent pan-European High Performance Computing service providing world-class systems for world-class science. Systems at the highest performance level (Tier-0) are deployed by Germany, France, Italy, Spain and Switzerland, providing researchers with more than 17 billion core hours of compute time. HPC experts from 25 member states enabled users from academia and industry to ascertain leadership and remain competitive in the Global Race. Currently PRACE is finalizing the transition to PRACE 2, the successor of the initial five year period. The objectives of PRACE-6IP 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 development of PRACE 2; strengthening the internationally recognised PRACE brand; continuing and extend advanced training which so far provided more than 36 400 person·training days; preparing strategies and best practices towards Exascale computing, work on forward-looking SW solutions; coordinating and enhancing the operation of the multi-tier HPC systems and services; and 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 7 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; assistance to PRACE 2 development; 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. This will be monitored through a set of KPIs.

8.2.1.2. EPEEC

Title: European joint effort toward a highly productive programming environment for heterogeneous exascale computing

Program: H2020

See also: https://epeec-project.eu

Duration: October 2018 - September 2021

Coordinator: Barcelona Supercomputing Center

Partner: Barcelona Supercomputing Center (Spain)

Coordinator: CEA

Partners:

Fraunhofer–Gesellschaft (Germany)

CINECA (Italy)

IMEC (Blegium)

INESC ID (Portugal)

Appentra Solutions (Spain)

Eta Scale (Sweden)

Uppsala University (Sweden)

Inria (France)

Cerfacs (France)

Inria contact: Stéphane Lanteri

EPEEC's main goal is to develop and deploy a production-ready parallel programming environment that turns upcoming overwhelmingly-heterogeneous exascale supercomputers into manageable platforms for domain application developers. The consortium will significantly advance and integrate existing state-of-the-art components based on European technology (programming models, runtime systems, and tools) with key features enabling 3 overarching objectives: high coding productivity,

high performance, and energy awareness. An automatic generator of compiler directives will provide outstanding coding productivity from the very beginning of the application developing/porting process. Developers will be able to leverage either shared memory or distributed-shared memory programming flavours, and code in their preferred language: C, Fortran, or C++. EPEEC will ensure the composability and interoperability of its programming models and runtimes, which will incorporate specific features to handle data-intensive and extreme-data applications. Enhanced leading-edge performance tools will offer integral profiling, performance prediction, and visualisation of traces. Five applications representative of different relevant scientific domains will serve as part of a strong inter-disciplinary co-design approach and as technology demonstrators. EPEEC exploits results from past FET projects that led to the cutting-edge software components it builds upon, and pursues influencing the most relevant parallel programming standardisation bodies.

8.3. International Initiatives

8.3.1. Participation in Other International Programs

8.3.1.1. International Initiatives

PHOTOM

Title: PHOTOvoltaic solar devices in Multiscale computational simulations

International Partners:

Center for Research in Mathematical Engineering, Universidad de Concepcion (Chile), Rodolfo Araya

Laboratório Nacional de Computação Científica (Brazil), Frédéric Valentin

Instito de Matemáticas, PUCV (Chile), Diego Paredes

Duration: 2018 - 2020

Start year: 2018

See also: http:////www.photom.lncc.br

The work consists of devising, analyzing and implementing new multiscale finite element methods, called Multiscale Hybrid-Mixed (MHM) method, for the Helmholtz and the Maxwell equations in the frequency domain. The physical coefficients involved in the models contain highly heterogeneous and/or high contrast features. The goal is to propose numerical algorithms to simulate wave propagation in complex geometries as found in photovoltaic devices, which are naturally prompt to be used in massively parallel computers. We demonstrate the well-posedness and establish the optimal convergence of the MHM methods. Also, the MHM methods are shown to induce a new face-based a posteriori error estimator to drive space adaptivity. An efficient parallel implementation of the new multiscale algorithm assesses theoretical results and is shown to scale on a petaflop parallel computer through academic and realistic two and three-dimensional solar cells problems.

8.3.1.2. Informal International Partners

Prof. Kurt Busch, Humboldt-Universität zu Berlin, Institut für Physik, Theoretical Optics & Photonics

8.3.1.3. Inria International Chairs

IIC VALENTIN Frédéric

Title: Innovative multiscale numerical algorithms for wave-matter interaction models at the nanoscale

International Partner (Institution - Laboratory - Researcher):

Laboratório Nacional de Computação Científica (Brazil), Frédéric Valentin

Duration: 2018 - 2022

Start year: 2018

See also: https://www.lncc.br/~valentin/

The project addresses complex three-dimensional nanoscale wave-matter interaction models, which are relevant to the nanophotonics and nanophononics fields, and aims at devising innovative multi-scale numerical methods, named Multiscale Hybrid-Mixed methods (MHM for short), to solve them with high accuracy and high performance.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

- David Pardo (Basque Center for Applied Mathematics, Spain) at Inria, France, April 2-5, 2019.
- Christophe Geuzaine (University of Liège, Belgium) at Inria, France, April 29-30, 2019.
- Jean-Francois Remacle (Ecole Polytechnique de Louvain, Belgium) at Inria, France, April 29-30, 2019.
- Jay Gopalakrishnan (University of Portland, USA) at Inria, France, June 4-5, 2019.

NANO-D Team

7. Partnerships and Cooperations

7.1. Regional Initiatives

- An IDEX UGA grant is covering post-doc of Didier Devaurs, starting from December.
- Inria CORDI-S post-doctoral fellowship was obtained for Agnieszka Karczynska.

7.2. National Initiatives

7.2.1. ANR

In 2019, NANO-D had funding from one ANR program:

- **ANR PRCI**: covered the end of the PhD thesis of Guillaume Pages.

7.3. European Initiatives

7.3.1. Collaborations with Major European Organizations

The European Bioinformatics Institute (EMBL-EBI), Protein Data Bank in Europe (PDBe) team, Hinxton (UK)

We are collaborating on the integration of methods developed in the team into the PDBe web resource.

The Institute Laue-Langevin (ILL), the bioSANS team, Grenoble (France)

We are collaborating on the development of neutron small-angle scattering software

7.4. International Initiatives

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

7.4.1.1. FlexMol

Title: Algorithms for Multiscale Macromolecular Flexibility

International Partner (Institution - Laboratory - Researcher):

Rocasolano Institute of Physical Chemistry (IQFR-CSIC), Madrid, Spain (Spain) - Pablo Chacon

Start year: 2019

See also: https://team.inria.fr/nano-d/research/flexmol/

Molecular flexibility is essential to link structure and function of many biological macromolecules. Changes in protein conformation play a vital role in biochemical processes, from biopolymer synthesis to membrane transport. Many proteins can drastically alter their architecture and display considerable interdomain flexibility, as found in their 3D structures. For example, proteins rely on flexibility to respond to environmental changes, ligand binding and chemical modifications. Also, protein flexibility is tightly bound to their stability and is fundamental for drugs to exert biological effects.

Thus, one of the main challenges in the field of computational structural biology is to predict and explain molecular flexibility and corresponding conformational changes. For example, currently there are no methods that can reliably predict structural changes in proteins upon their binding. However, these are crucial to predict the structure of protein complexes with large conformational changes upon binding. To give another example, flexibility of the protein binding pocket is the

major hurdle in reliable prediction of protein-ligand interactions for computer-aided drug design. Finally, intrinsic flexibility of macromolecules is nowadays the limiting factor for high-resolution experimental structure determination.

The partners of this associate team proposal comprise world-leading teams working with sound mathematical representations and techniques in the field of structural bioinformatics. These include spherical harmonics, normal modes analysis, high-order fast Fourier transforms, and more. The partners have very similar interests, but complimentary expertise. The goal of this collaboration is to mutually explore novel computational techniques for emerging problems in structural biology and bioinformatics related to molecular flexibility. This problem can be tackled at different scales. Large-scale flexibility of macromolecules can be efficiently described using collective coordinates. We will try to represent these in polynomial spaces, such that a practical flexible docking method can be based on this representation. Other applications include 3D shape reconstruction and scattering problems. Local molecular flexibility can be modelled using various techniques, including robotics-inspired methods, fragment libraries, etc. Here, our goal will be to rapidly sample the conformational space, and to construct a potential energy function applicable to flexible molecules. The ultimate goal of the project is to combine multiple levels of representation of molecular flexibility together. The project outcome will be built around innovative computer-aided drug-design algorithm with applications to prediction and computational design of important pharmaceutical targets such as antibodies.

7.4.2. Inria International Partners

7.4.2.1. Declared Inria International Partners : BIOTOOLS

Title: Novel Computational Tools for Structural Bioinformatics

International Partner (Institution - Laboratory - Researcher):

MIPT (Russia (Russian Federation)) - Department of Control and Applied Mathematics - Vadim Strijov

Duration: 2016 - 2020

Start year: 2016

Abstract : The general scientific objectives of the forthcoming collaboration are the new developments of computational tools for structural bioinformatics. In particular, we plan to collaborate on several subjects: 1. Development of tractable approximations for intractable combinatorial problems in structural biology. 2. Development of new computational tools for scattering experiments. 3. Machine learning for structural bioinformatics.

7.4.2.2. Informal International Partners

- University of Stony Brook, lab of Dima Kozakov (USA). We have been collaborating on the development of novel protein docking methods.
- University of Vilnius, department of Bioinformatics (Lithuania). We have been collaborating on the development of novel protein docking methods.
- KU Copenhagen (Denmark), department of Chemistry. We collaborated on the integrative structural biology approaches.
- Francis Crick Institute, London (UK), Biomolecular Modelling Laboratory. We collaborate on the development of flexible protein docking methods.
- University of Oslo. Ongoing collaboration on modeling protein systems guided by small-angle Xray and neutron small-angle scattering.
- University of Bergen, Norway. Ongoing collaboration on novel methods for normal mode analysis of protein structures.
- Nagoya University and RIKEN Center for Computational Science, Kobe, Japan. We collaborated on novel algorithms for scattering methods.

- University of Kansas, bioinformatics unit, USA. We have been collaborating on modeling protein-protein interactions.

7.4.3. Participation in Other International Programs

Our team has obtained the PHC Gilibert grant for a 2-year collaboration with the Vilnius University (Lithuania). Our partner is the Department of Bioinformatics, http://www.bti.vu.lt/en/departments/department-of-bioinformatics.

7.5. International Research Visitors

7.5.1. Visits of International Scientists

- Karina Dos Santos Machado, lecturer at the Federal University of Rio Grande (FURG, Brazil), Oct 2018 - Oct 2019.
- Vadim Strijov, professor at the department of Intelligent Systems, MIPT Moscow MIPT Moscow, July-August 2019.

7.5.1.1. Internships

- Khalid Mustafin (MIPT Moscow, Russia), Sep 2018 - Feb 2019.
- Ilia Igashov (MIPT Moscow, Russia), Nov 2018 - Apr 2020.
- Dmitrii Zhemchuzhnikov (UGA Grenoble), May 2019 - Sep 2019.

7.5.2. Visits to International Teams

- Sergei Grudinin visited the team of Ilia Vakser at Kansas University, Oct 15-31, 2019.

7.5.2.1. Explorer programme

- Sergei Grudinin visited Florence Tama and Osamu Miyashita, Nagoya University and RIKEN Center for Computational Science, Kobe, Japan. This was supported by the Exploration Japon 2019 program.
- Sergei Grudinin visited the team of Reidar Lund at University of Oslo, and the team of Nathalie Reuter at University of Bergen, Norway. Supported by the ÅSGARD 2019 program.

POEMS Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

- ANR project NonlocalDD *(Non-local domain decomposition methods in electromagnetics)*
  Partners: Inria Alpines, Inria POEMS, Inria Magique 3D
  Start: 10/2015. End: 09/2020. Administrator: Inria
  Participants of POEMS: S. Chaillat, P. Joly
  Coordinator: X. Claeys (LJLL, EPI ALPINES)
- ANR project MODULATE *(Modeling lOng-perioD groUnd motions, and assessment of their effects on Large-scale infrAsTructurEs)*
  Partners: ENSTA (UME), Inria POEMS, CentraleSupelec, BRGM, GDS
  Start: 11/2018. End: 10/2021. Administrator: ENSTA
  Participant of POEMS: S. Chaillat
  Coordinator: K. Meza Fajardo (BRGM)

8.1.2. DGA

- Contracts between DGA and POEMS:
  - Contract on *boundary element methods and high-frequency problems*
    Participants: E. Lunéville, M. Lenoir, N. Kielbasiewicz.
    Start: 10/2018. End: 09/2021. Administrator: ENSTA
    In partnership with F. Alouges and M. Aussal (CMAP, Ecole Polytechnique).
- DGA provides partial funding for several PhD students:
  - C. Bénéteau on the *asymptotic analysis of time harmonic Maxwell equations in presence of metamaterials* (Start: 10/2017)
  - D. Chicaud on *domain decomposition methods for time-harmonic electromagnetic wave problems with complex media* (Start: 10/2018)

8.2. International Initiatives

8.2.1. Inria International Partners

8.2.1.1. Informal International Partners

Juan Pablo Borthagaray (Universidad de la República, Uruguay)

Shravan Veerapaneni (Univ. of Michigan at Ann Arbor, USA)

Bojan Guzina (University of Minnesota, USA)

Jean-François Molinari (EPFL, Lausanne, Switzerland)

Fioralba Cakoni (University of Rutgers, USA)

Wilkins Aquino (Duke University, USA)

Bojan Guzina (University of Minnesota, USA)

Jorge Albella (University of Santiago de Compostela, Spain)

Carlos Perez Arancibia (Pontificia Universidad Católica, Chile)

Camille Carvalho (UC Merced, Merced, USA)

Simon Chandler Wilde (University of Reading, UK)

Mahadevan Ganesh (Colorado School of Mines, USA)
Christophe Geuzaine (Université de Liège, Belgium)
Marcus Grote (Universitaet Basel, Switzerland)
Moez Khenissi (Univesité de Sousse, Tunisia)
Sergei Nazarov (Saint-Petersburg University, Russia)
Karl-Mikael Perfekt (University of Reading, UK)
Jerónimo Rodríguez (University of Santiago de Compostela, Spain)
Ruben Rosales (MIT, USA)
Adrien Semin (TU Darmstadt, Germany)
Knut Sølna (University of California, Irvine, USA)
Catalin C. Turc (NJIT, NJ, USA)
Jun Zou (Chinese University of Hong Kong, HK)

8.3. International Research Visitors

8.3.1. Visits of International Scientists

- Mahadevan Ganesh (Colorado School of Mines, USA) — March 2019
- Carlos Jerez-Hanckes (Universidad Adolfo Ibanez, Chile) — Septembre 2019
- Shravan Veerapaneni (Univ. of Michigan at Ann Arbor, USA) — November 2019

RAPSODI Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. ERC Generator

T. Rey has been awarded an ERC Generator grant (116 545 euros) from I-SITE Université Lille - Nord Europe for his project MANAKINEQO (R-ERCGEN-19-007-REY). In the next two years, T. Rey aims at investigating mathematical properties, as well as developing efficient numerical schemes, for multiscale collisional kinetic equations of the Boltzmann type. A 20-months post-doc will be funded using this grant, as well as an international conference. Following this ERC Generator grant, T. Rey will apply for an ERC Consolidator grant.

9.1.2. Actions of Technological Development (ADT)

S. Lemaire is the PI of the ADT project ParaSkel++, which is one of the funded ADT of the Inria Lille - Nord Europe 2019 campaign. The aim of the project is to develop an optimized C++ platform for the arbitrary-order numerical approximation of PDEs by skeletal methods on general 2D/3D meshes, with a particular emphasis on the implementation of HPC facilities. L. Beaude has been hired as a development engineer for this project. She will start in February 2020.

In the same vein, T. Rey is part of the ADT project SIMPAPH led by the MEPHYSTO-POST team, that has as well been funded as a result of the Inria Lille - Nord Europe 2019 campaign. The aim is to develop robust numerical methods to solve large systems of stochastic differential equations describing (among others) particles in an optic fiber, schools of fish, or microscopic particles. The expected code will attempt to solve these multiscale problems using different approaches, and to be versatile enough to act as an industrial benchmark. A. Roget has been hired as a development engineer for this project.

9.2. National Initiatives

9.2.1. ANR

C. Chainais-Hillairet has been a member of the ANR MOONRISE project. The MOONRISE project aimed at exploring modeling, mathematical, and numerical issues originating from the presence of high oscillations in nonlinear PDEs mainly from the physics of nanotechnologies and from the physics of plasmas.

Title: MOdels, Oscillations, and NumeRIcal SchEmes

Type: Fondements du numérique (DS0705) - 2014

ANR reference: ANR-14-CE23-0007

Coordinator: F. Méhats (Université de Rennes 1)

Duration: October 2014 - June 2019

C. Chainais-Hillairet and T. Rey are members of the ANR MOHYCON project. The MOHYCON project is related to the analysis and simulation of multiscale models of semiconductors. As almost all current electronic technology involves the use of semiconductors, there is a strong interest for modeling and simulating the behavior of such devices, which was recently reinforced by the development of organic semiconductors used for example in solar panels or in mobile phones and television screens (among others).

Title: Multiscale MOdels and HYbrid numerical methods for semiCONductors

Type: Société de l'information et de la communication (DS07) - 2017

ANR reference: ANR-17-CE40-0027

Coordinator: M. Bessemoulin-Chatard (CNRS and Université de Nantes)

Duration: January 2018 - December 2020

C. Cancès is a member of the ANR COMODO project. The COMODO project focuses on the mathematical and numerical study of cross-diffusion systems in moving domains. The targeted application is the simulation of the building of solar plants by the vapour deposition process.

Title: CrOss-diffusion equations in MOving DOmains

Type: Modèles numériques, simulation, applications (CE46) - 2019

ANR reference: ANR-19-CE46-0002

Coordinator: V. Ehrlacher (École des Ponts ParisTech and Inria Paris)

Duration: January 2020 - December 2023

M. Herda is a member of the ANR JCJC MICMOV project. The MICMOV project aims at gathering PDE analysts, probability theorists, and theoretical physicists to work on the derivation of macroscopic properties of physical systems from their microscopic description. The rigorous microscopic description of moving interfaces, the understanding of macroscopic nonlocal effects, and the mathematical apprehension of the underlying atomic mechanisms, are particularly important matters of this project.

Title: MICroscopic description of MOVing interfaces

Type: Mathématiques (CE40) - 2019

Coordinator: M. Simon (Inria Lille - Nord Europe)

9.2.2. LabEx CEMPI

Title: Centre Européen pour les Mathématiques, la Physique et leurs Interactions

Coordinator: S. De Bièvre (LPP, Université de Lille)

Duration: January 2012 - December 2019, extended in 2019

Partners: Laboratoire Paul Painlevé (LPP) and Laser Physics department (PhLAM), Université de Lille

The "Laboratoire d'Excellence" Centre Européen pour les Mathématiques, la Physique et leurs Interactions (CEMPI), a project of the Laboratoire de mathématiques Paul Painlevé (LPP) and the laboratoire de Physique des Lasers, Atomes et Molécules (PhLAM), was created in the context of the "Programme d'Investissements d'Avenir" in February 2012.

The association Painlevé-PhLAM creates in Lille a research unit for fundamental and applied research and for training and technological development that covers a wide spectrum of knowledge stretching from pure and applied mathematics to experimental and applied physics.

One of the three focus areas of CEMPI research is the interface between mathematics and physics. This focus area encompasses three themes. The first is concerned with key problems of a mathematical, physical and technological nature coming from the study of complex behavior in cold atoms physics and nonlinear optics, in particular fiber optics. The two other themes deal with fields of mathematics such as algebraic geometry, modular forms, operator algebras, harmonic analysis and quantum groups that have promising interactions with several branches of theoretical physics.

9.2.3. PEPS

T. Rey has been the laureate in 2019 of a Young Researcher PEPS grant from CNRS's INSMI (3 500 euros, from March to November 2019). The granted project aimed at investigating high-order (in time and velocity) numerical methods for approximating the solutions to the granular gases equation.

9.3. European Initiatives

C. Cancès, C. Chainais-Hillairet and B. Merlet are involved in the H2020 project EURAD (EUropean Joint Programme on RADioactive Waste Management). The aim of their project inside EURAD is to establish an energetic formulation of the Diffusion Poisson Coupled Model leading to new large-time robust numerical methods for the simulation of the corrosion processes in an underground repository.

C. Cancès is the leader of the task "Numerical methods for high-performance computing of coupled processes" within the EURAD project.

9.4. International Initiatives

C. Cancès is a member of the Indo-French Center for Applied Mathematics (IFCAM) project "Conservation laws: BV^s, control, interfaces" (PIs: S. Ghoshal, TIFR Centre For Applicable Mathematics, India and S. Junca, Université de Nice).

9.5. International Research Visitors

9.5.1. Visits of International Scientists

In January-February, E. Daus (TU Vienna, Austria) visited C. Cancès and C. Chainais-Hillairet during two weeks.

In 2019, RAPSODI members also invited several researchers for short visits (a week or less) in Lille.

- R. Bailo (Imperial College London, UK) came in November to work with T. Rey (funded by his Young Researcher PEPS grant).
- R. V. Sabariego (KU Leuven, Electrical Engineering ESAT/Electa, EnergyVille, Belgium) came in May to work with E. Creusé.
- E. Bretin and S. Masnou (Institut Camille Jordan, Lyon) and M. Goldman (CNRS and LJLL/Université Paris Diderot) came in June and December to work with B. Merlet.
- A. Trescases (CNRS and Institut de Mathématiques de Toulouse) came in September to work with M. Herda.
- C. Bataillon (CEA), V. Ehrlacher (École des Ponts ParisTech and Inria Paris) and C. Perrin (CNRS and Université d'Aix-Marseille) came to work with C. Cancès.
- M. Cassier (CNRS and Institut Fresnel, Marseille) came in February-March to work with S. Lemaire.

On a slightly different note, from March to October, G. Robillard has been an AIRLab resident (Artiste en Immersion Recherche dans un Laboratoire) in order to work with C. Calgaro and E. Creusé (with a support from the Communauté d'Universités et d'Établissements Lille Nord-de-France).

9.5.2. Visits to International Teams

B. Gaudeul spent two weeks in WIAS Berlin, Germany in November in order to work with J. Fuhrmann on the extension of the results obtained in [48] to Nernst–Planck–Poisson systems with ion size and solvation effects.

M. Herda spent one week at Imperial College London, UK in February to work with P. Degond on a Fokker–Planck approach to the study of robustness in gene expression.

T. Rey visited 3 times J. A. Carrillo and J. Hu at Imperial College London, UK between February and March, for 3 days long stays funded by his Young Researcher PEPS grant, to work (in particular) on the development of a new high-order numerical method for solving the granular gases equation.

C. Cancès and B. Merlet spent one week at the University of Lisbon, Portugal in December to work with L. Monsaingeon.

C. Cancès spent one week at Université de Tours to work with B. Andreianov.

B. Merlet visited E. Bretin and S. Masnou at Institut Camille Jordan in Lyon in February, and visited several times M. Goldman at LJLL/Université Paris Diderot in March, May, October, and November.

F. Chave and S. Lemaire spent 3 days at Université de Montpellier in September to work with D. A. Di Pietro on arbitrary-order polytopal methods for electromagnetism.

9.5.3. Research Stays Abroad

M. Herda was in residence at the Hausdorff Research Institute for Mathematics (University of Bonn, Germany) from May 19 to July 7 in the framework of the Junior Trimester Program in Kinetic Theory, that gave young mathematicians the opportunity to carry out collaborative research in kinetic theory. M. Herda was part of a project in collaboration with N. Ayi (Sorbonne Université), M. Breden (École Polytechnique), J. Guerand (University of Cambridge, UK), H. Hivert (Centrale Lyon), and I. Tristani (ENS Paris) on the study of a fractional kinetic Fokker–Planck equation. This collaboration has already led to the article [44], and a second article is in preparation. A collaboration was also initiated with M. Breden and A. Trescases (CNRS and Institut de Mathématiques de Toulouse) on the derivation of cross-diffusion systems from kinetic models.

CAGE Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

- ANR SRGI, for *Sub-Riemannian Geometry and Interactions*, coordinated by **Emmanuel Trélat**, started in 2015 and runs until 2020. Other partners: Toulon University and Grenoble University. SRGI deals with sub-Riemannian geometry, hypoelliptic diffusion and geometric control.
- ANR Finite4SoS, for *Commande et estimation en temps fini pour les Systèmes de Systèmes*, coordinated by Wilfrid Perruquetti, started in 2015 and run up to this year. Other partners: Inria Lille, CAOR - ARMINES. Finite4SoS aims at developing a new promising framework to address control and estimation issues of Systems of Systems subject to model diversity, while achieving robustness as well as severe time response constraints.
- ANR QUACO, for *QUAntum COntrol: PDE systems and MRI applications*, coordinated by Thomas Chambrion, started in 2017 and runs until 2021. Other partners: Lorraine University. QUACO aims at contributing to quantum control theory in two directions: improving the comprehension of the dynamical properties of controlled quantum systems in infinite-dimensional state spaces, and improve the efficiency of control algorithms for MRI.

8.2. European Initiatives

8.2.1. FP7 & H2020 Projects

Program: H2020-EU.1.3.1. - Fostering new skills by means of excellent initial training of researchers

Call for proposal: MSCA-ITN-2017 - Innovative Training Networks

Project acronym: QUSCO

Project title: Quantum-enhanced Sensing via Quantum Control

Duration: From November 2017 to October 2021.

Coordinator: Christiane Koch

Coordinator for the participant Inria: Ugo Boscain

Abstract: Quantum technologies aim to exploit quantum coherence and entanglement, the two essential elements of quantum physics. Successful implementation of quantum technologies faces the challenge to preserve the relevant nonclassical features at the level of device operation. It is thus deeply linked to the ability to control open quantum systems. The currently closest to market quantum technologies are quantum communication and quantum sensing. The latter holds the promise of reaching unprecedented sensitivity, with the potential to revolutionize medical imaging or structure determination in biology or the controlled construction of novel quantum materials. Quantum control manipulates dynamical processes at the atomic or molecular scale by means of specially tailored external electromagnetic fields. The purpose of QuSCo is to demonstrate the enabling capability of quantum control for quantum sensing and quantum measurement, advancing this field by systematic use of quantum control methods. QuSCo will establish quantum control as a vital part for progress in quantum technologies. QuSCo will expose its students, at the same time, to fundamental questions of quantum mechanics and practical issues of specific applications. Albeit challenging, this reflects our view of the best possible training that the field of quantum technologies can offer. Training in scientific skills is based on the demonstrated tradition of excellence in research of the consortium. It will be complemented by training in communication and commercialization. The latter builds on strong industry participation whereas the former existing expertise on visualization and gamification and combines it with more traditional means of outreach to realize target audience specific public engagement strategies.

8.3. International Research Visitors

8.3.1. Internships

Rosa Kowalewski made an internship under the supervision of Barbara Gris from January to May 2019.

COMMANDS Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. IPL

8.1.1.1. Algae in Silico

Inria Project Lab ALGAE IN SILICO (2014-2018) was dedicated to provide an integrated platform for numerical simulation of microalgae “from genes to industrial process“. Commands joined the project in 2017 to tackle the optimization aspects. Our previous collaborations with teams Modemic and Biocore on bioreactors [27], [15] have been renewed in this framework.

8.1.1.2. Cosy

Inria Project Lab COSY (started in 2017) aims at exploiting the potential of state-of-art biological modelling, control techniques, synthetic biology and experimental equipment to achieve a paradigm shift in control of microbial communities. More precisely, we plan to determine and implement control strategies to make heterogeneous communities diversify and interact in the most profitable manner. Study of yeast cells has started in collaboration with team Lifeware (G. Batt) in the framework of the PhD of V. Andreani, and is pursued in the Postdoc of D. Lunz (started Nov. 2019).

DISCO Project-Team

6. Partnerships and Cooperations

6.1. Regional Initiatives

Islam Boussaada is a deputy director of the IRS iCODE Institute, the institute for control and decision of the Idex Paris Saclay (http://icode-institute.fr).

- The project *Distributed Algorithms for Microbiological Systems* was funded by iCODE.
- The project *Symbolic/Numerical Methods and Implementations in Delayed-Control design* was funded by iCODE.
- The project *From modeling to control of microalgae growth in photo-bioreactor* was funded by iCODE.
- The project *Distributed Algorithms for Microbiological systems* was funded by iCODE.

6.2. National Initiatives

Islam Boussaada is a member of the administration council of the Association SAGIP (https://www.sagip.org), which structures and promotes the disciplines of automatic control and industrial engineering at the national level.

6.2.1. ANR

Giorgio Valmorbida is a member of the ANR HANDY - Hybrid And Networked Dynamical sYstems (http://projects.laas.fr/handy). Project Summary: Networked dynamical systems are ubiquitous in current and emerging technologies. From energy grids, fleets of connected autonomous vehicles to online social networks, the same scenario arises in each case: dynamical units interact locally to achieve a global behavior. When considering a networked system as a whole, very often continuous-time dynamics are affected by instantaneous changes, called jumps, leading to so-called hybrid dynamical systems. The jumps may originate from (i) the intrinsic dynamics of the nodes, like in multimedia delivery with fixed rate encoding, (ii) intrinsic limitations of the control actions, possibly constrained to a finite set of possible selections, like in power converters within energy grids, (iii) the creation/loss of links or the addition/removal of nodes like in renewable energy systems and social networks. Hybrid phenomena thus play an essential role in these control applications, and call upon the development of novel adapted tools for stability and performance analysis and control design. In this context, the aim of HANDY project is to provide methodological control-oriented tools for realistic networked models, which account for hybrid phenomena.

6.3. European Initiatives

6.3.1. Collaborations in European Programs, Except FP7 & H2020

Program: **COST Action**

Project acronym: FRACTAL

Project title: Fractional-order systems; analysis, synthesis and their importance for future design

Duration: November 2016 - October 2020

Coordinator: Jaroslav Koton Czech Republic

Abstract: Fractional-order systems have lately been attracting significant attention and gaining more acceptance as generalization to classical integer-order systems. Mathematical basics of fractional-order calculus were laid nearly 300 years ago and since that it has gained deeply rooted mathematical concepts. Today, it is known that many real dynamic systems cannot be described by a system of simple differential equation or of integer-order system. In practice we can encounter such systems in electronics, signal processing, thermodynamics, biology, medicine, control theory, etc. The Action will favor scientific advancement in above mentioned areas by coordinating activities of academic research groups towards an efficient deployment of fractal theory to industry applications.

Program: **PHC AURORA**

Project acronym: -

Project title: Control and Observation of Nonlinear Systems

Duration: 01/2019-12/2019

Coordinator: Giorgio VALMORBIDA

Other partners: NTNU, Norvège

Abstract: Control theory and controller design for linear dynamical systems is well developed. The same cannot be said for nonlinear systems and searching for a general set of design tools applicable to any nonlinear system may be futile. Restricting the class of system dynamics with the aim of developing a more complete set of controller design tools for such a restricted model class therefore appears to be a reasonable approach. One such restricted class of system dynamics is the class of polynomial dynamical systems, for which stability analysis and controller design tools based on Convex Optimization has recently flourished, using so-called Sum of Squares (SOS) programming. Three topics were studied: - Time discretization techniques. SOS programming for discrete time system is less developed than for continuous time systems. This research task will then study discretization techniques leading to polynomial or rational models. In particular we will develop methods to compare the continuous time system and the discretized one by, for instance, comparing estimates of the region of attraction of stable equilibria. - Observer design. In many applications, not all states are measured, and therefore they have to be inferred using a state observer. Note that the so-called Certainty Equivalence Principle does not in general hold for nonlinear systems. This research task will therefore address observer design using SOS programming, and study the effects of interactions between controller design and observer design on the stability of the overall system. - Benchmark application. CentraleSupelec has a cart and pendulum experimental setup. The complexity of SOS-based controller design for this system is near the limit of what can be accommodated by current optimization packages and computational resources. This research task will test the limits of available numerical solution tools and provide a convincing demonstration of the capabilities of SOS-based controller design.

Program: **PHC BALATON**

Project acronym: SadHuB

Project title: Analysis of stabilizability of delayed dynamical system as function of the systems parameters and the time delays with applications to human balancing

Duration: 01/2018-12/2019

Coordinator: Islam Boussaada

Other partners: Budapest University of Technology and Economics, Hungary

Abstract: Motivated by a class of Time-delay systems occurring in modeling of many mechanical engineering applications, this project aims to associate researchers from control theory, applied mathematics and mechanical engineering to build together a general methodology for the analysis and control of mechanical/bio-mechanical structures. In particular, the human balance is often considered as a control system which operates in the presence of delays, primarily due to the time it takes to acquire the information needed for decision-making, to create control decisions, and to execute these decisions. A particular interest will be devoted to the delayed human balance, where a depthful study of the delay effect on the stability is expected.

6.4. International Initiatives

6.4.1. Inria International Partners

6.4.1.1. Informal International Partners

- Louisiana State University, Baton Rouge, USA
- Rutgers University, USA
- CINVESTAV, IPN, Mexico-City, Mexico
- Southern Illinois University, USA
- The University of Texas at Austin, Dept. of Aerospace Engineering & Engineering Mechanics, USA
- City University of Hong Kong, China
- Czech technical university in Prague, Czech Republic
- Budapest University of Technology and Economics, Hungary
- Katholieke Universiteit Leuven, Belgium
- Blikent University, Turkey
- Northeastern University, China
- Northeastern University, Boston, USA
- Universidad de Chile, Chile
- School of Mathematics, University of Leeds, U.K.
- UNICAMP, Brazil
- Kyoto University, Japan
- University Badji Mokhtar-Annaba, Algeria
- University Mouloud-Mammeri Tizi Ouzou, Algeria
- Universitat Politècnica de Catalunya, Spain
- University of Melbourne, Australia

6.4.2. Participation in Other International Programs

The team is member of the GDRI (International Research Group funded by CNRS) SpaDisco (following the GDRI Delsys) since 2017.

6.5. International Research Visitors

6.5.1. Visits of International Scientists

Jie Chen, CityU Hong Kong, 16-20 Dec 2019.

André Fioravanti, UNICAMP, Brazil, 1-7 Dec 2019.

Dan Ma, Northeastern University, 16-20 Dec 2019.

Hitay Özbay, Bilkent University, 4-8 Dec 2019.

Matheus Souza, UNICAMP, Brazil, 1-7 Dec 2019.

Joao Manoel Gomes da Silva Jr, UFRGS, Brazil, 15 Jul -15 Ago 2019.

Ross Drummond, University of Oxford, U.K., 1-7 Dec 2019.

Yutaka Yamamoto, Kyoto University, Japan, 30 oct - 8 Dec 2019.

6.5.1.1. Internships

Master internship: Lotfi Baour, Qualitative behaviour of two models of bacteria communication, Université de Cergy-Pontoise. Supervisors: Catherine Bonnet, Walid Djema, Matthias Fuegger and Thomas Nowak.

Master internship: Khaoula El Farhani, Modeling, estimation and control of microalgae growth for energy production and synthesis of molecules of high added values, CentraleSupelec, 05-09/2019. Supervisors: Sette Diop and Islam Boussaada.

Master internship: Jawher Kahouli, estimation and modelling of microalgae growth in photobioreactor, IPSA/Sup'Biotech,02-08/2019. Supervisors: Islam Boussaada, Ali El Ati and Jean-Yves Trosset.

Master internship: Robin Lacombe, qualification and start-up of Synoxis nano 2l photobioreactor, IPSA/Sup'Biotech,02-08/2019. Supervisors: Islam Boussaada, Ali El Ati and Jean-Yves Trosset.

Master internship: Lucas Leclerc, Modelling of bacteria communication through EDO/EDP, CentraleSupélec. Supervisor: Catherine Bonnet, Matthias Fuegger and Thomas Nowak.

Master internship: Javier Eduardo Pereyra Zamundio, New backstepping design using satificial delays for systems with pointwise delays, CINVESTAV, Instituto Politecnico Nacional. Supervisors: Sabine Mondié, Frédéric Mazenc.

6.5.2. Visits to International Teams

Islam Boussaada visited Budapest University of Technology and Economics during 1-7 Dec 2019.

Giorgio Valmorbida visited the University of Oxford 15-17 Jul 2019.

Giorgio Valmorbida visited the UFRGS, CEFET-Divinopolis, and the UNICAMP, Brazil 26 Jul - 6 Ago 2019.

FACTAS Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

- The team co-advises a PhD (G. Bose) with the CMA team of LEAT (http://leat.unice.fr/pages/activites/cma.html) funded by the Labex UCN@Sophia on the co-conception of Antennas and Filters.
- The team participates in the project ToMaT, "Multiscale Tomography: imaging and modeling ancient materials, technical traditions and transfers", funded by the Idex UCA^{Jedi} ("programme structurant Matière, Lumière, Interactions"). This project brings together researchers in archaeological, physical, and mathematical sciences, with the purpose of modeling and detecting low level signals in 3-D images of ancient potteries. The other concerned scientists are from CEPAM-CNRS-UCA (project coordinator: Didier Binder), Nice http://www.cepam.cnrs.fr, the team Morpheme, CNRS-I3S-Inria http://www.inria.fr/equipes/morpheme, and IPANEMA, CNRS, Ministère de la Culture et de la Communication, Université Versailles Saint Quentin http://ipanema.cnrs.fr/. Since March 2018, they co-advise together the post-doctoral research of Vanna Lisa Coli, see Section 6.6 , and this year the internship training of Pat Vatiwutipong.

8.2. National Initiatives

8.2.1. ANR MagLune

The ANR project MagLune (Magnétisme de la Lune) was active from July 2014 to August 2019. It involved the Cerege (Centre de Recherche et d'Enseignement de Géosciences de l'Environnement, joint laboratory between Université Aix-Marseille, CNRS and IRD), the IPGP (Institut de Physique du Globe de Paris) and ISTerre (Institut des Sciences de la Terre). Associated with Cerege were Inria (Apics, then Factas team) and Irphe (Institut de Recherche sur les Phénomènes Hors Équilibre, joint laboratory between Université Aix-Marseille, CNRS and École Centrale de Marseille). The goal of this project (led by geologists) was to understand the past magnetic activity of the Moon, especially to answer the question whether it had a dynamo in the past and which mechanisms were at work to generate it. Factas participated in the project by providing mathematical tools and algorithms to recover the remanent magnetization of rock samples from the moon on the basis of measurements of the magnetic field it generates. The techniques described in Section 6.1 were instrumental for this purpose.

8.2.2. ANR Repka

ANR-18-CE40-0035, "REProducing Kernels in Analysis and beyond", starting April 2019 (for 48 months).

Led by Aix-Marseille Univ. (IMM), involving Factas team, together with Bordeaux (IMB), Paris-Est, Toulouse Universities.

The project consists of several interrelated tasks dealing with topical problems in modern complex analysis, operator theory and their important applications to other fields of mathematics including approximation theory, probability, and control theory. The project is centered around the notion of the so-called reproducing kernel of a Hilbert space of holomorphic functions. Reproducing kernels are very powerful objects playing an important role in numerous domains such as determinantal point processes, signal theory, Sturm-Liouville and Schrödinger equations.

This project supports the PhD of M. Nemaire within Factas, co-advised by IMB partners.

8.3. European Initiatives

8.3.1. Collaborations with Major European Organizations

Factas is part of the European Research Network on System Identification (ERNSI) since 1992.

System identification deals with the derivation, estimation and validation of mathematical models of dynamical phenomena from experimental data.

8.4. International Initiatives

8.4.1. Inria International Partners

8.4.1.1. Informal International Partners

Following two Inria Associate teams (2013-2018) and a MIT-France seed funding (2014-2018), the team has a strong and regular collaboration with the Earth and Planetary Sciences department at Massachusetts Institute of Technology (Cambridge, MA, USA) and with the Mathematics department of Vanderbilt University (Nashville, TN, USA) on inverse problems for magnetic microscopy applied to the analysis of ancient rock magnetism.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

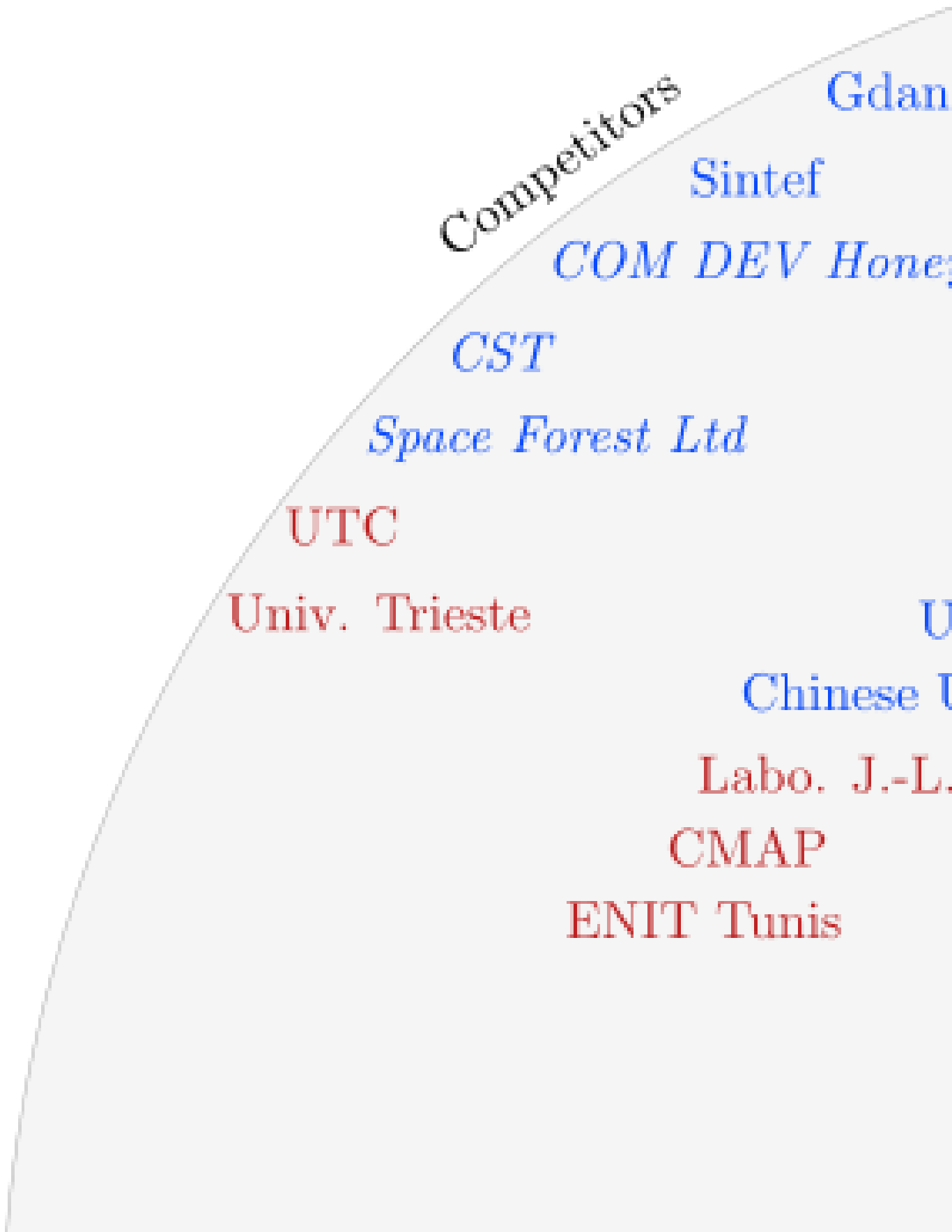
- Smain Amari (Royal Military College of Canada, Kingston, Canada), February 4-9.
- Jonathan Partington (Univ. of Leeds, England), February 4-7.
- Dmitry Ponomarev (T.U. Vienna, Vienna, Austria), June 24.
- Élodie Pozzi (St Louis Univ., St Louis, Missouri, USA), Brett Wick (Washington Univ., St Louis, Missouri, USA), January 9-10.
- Yves Rolain (Vrije Universiteit Brussel, VUB, Brussels, Belgium), February 5-7.
- Maxim Yattselev (University of Indianapolis, Purdue University at Indianapolis, USA), June 29-July 1.

8.5.1.1. Internships

- Paul Asensio, École Centrale Lyon, *Study of silent current sources in electroencephalography (EEG) and magnetoencephalography (MEG)*; advisors: L. Baratchart, J. Leblond.
- Masimba Nemaire, MathMods Master, *Study of silent current sources in EEG and MEG*; advisors: L. Baratchart, J. Leblond.
- Tuong Vy Nguyen Hoang, *Mathematical Circuit Modeling for Antennas*; advisors: F. Seyfert, M. Olivi.
- Pat Vatiwutipong, MathMods Master, *Properties of the d-Radon transform and applications to imaging issues in archaeology*; advisors: V. L. Coli, J. Leblond.

8.6. List of international and industrial partners

Figure 10 sums up who are our main collaborators, users and competitors.


Competitors
Gdan
Sintef
COM DEV Hone
CST
Space Forest Ltd
UTC
Univ. Trieste
U
Chinese U
Labo. J.-L.
CMAP
ENIT Tunis

I4S Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. SYSIFE

Participant: Ivan Guéguen.

Type: CPER + REVES project funding

Objectif: Development of a test bench for railways testing

Duration: 2019 - 2020

Coordinator : IFSTTAR

Partners: Cerema, ColasRail, Edilon, SNCF Réseau, Railenium, Vossloh

Inria contact: Ivan Guéguen

8.1.2. SHM-TGROUT

Participant: Xavier Chapeleau.

Type: Weamec regional cluster

Objectif: to assess the suitability of several non-destructive methods to detect and track the damage for metal pipes.

Duration: 2019 - 2020

Coordinator : IFSTTAR

Partners: University of Nantes, STX

Inria contact: Xavier Chapeleau

Abstract:

The cement bond between metal pipes is a very common technique in the offshore environment, particularly in the "oil and gas" sector. This technique has been used in the offshore wind sector installed to connect the structure (jacket or monopile) to its foundation. A small-scale sample of this type of cement connection was sized, and instrumented it with several technologies. sensors (including fiber optic sensors) and subjected it to axial fatigue stresses. Although the results of the instrumentation are still in operation, the damage could be detected by the various methods tested. A new trial is planned in the first half of 2020 to confirm the results obtained.

8.1.3. MUSIWIND

Participants: Xavier Chapeleau, Laurent Mevel, Frederic Gillot.

Type: RFI WIZE

Objectif: Qualify a very high precision sensor for vibratory monitoring of wind turbines, develop monitoring algorithms using SSI methods and validation indicators

Duration: 12 months in 2020

Coordinator : IFSTTAR

Partners: Inria, SERCELL, VALOREM

Inria contact: Xavier Chapeleau

Abstract: Structural health monitoring of wind turbines is becoming a real economic issue for the managers of these structures. Indeed, they are more and more demanding of new structural health control techniques that enable the implementation of an automated and planned monitoring strategy to ensure the structural integrity of their wind turbines throughout their lifetime, particularly in the case of exceptional events such as storm or earthquake. In this business sector where innovation is crucial to stay competitive, the project MusiWind aims at the hardware, software and scientific development of a new device for monitoring the structural integrity of wind turbines and their qualification in real conditions. Through a multi-sensor approach, the project integrates in particular the newQuietSeisTM low-noise accelerometer (developed by SERCEL) with a generic data acquisition card Pegase 3 (developed by IFSTTAR) on which is embedded innovative signal processing (data analysis) developed by the Ifsttar / Inria I4S joint research team. Statistical inference algorithms meant to extract structural information under ambient excitation. The originality of the project will be to develop identification methods as well as multi-varied damage indicators that merge data froms ensors of different types and qualities, as well as the fusion of complementary physical characteristics.

8.1.4. SURFEOL: SURveillance et Fiabilité des Fondations d'EOLiennes

Participants: Xavier Chapeleau, Michael Doehler, Laurent Mevel, Flavien Bouché.

The regional project SURFEOL was in collaboration with les Chantiers de l'Atlantique and ended in 2017. Many months of data were collected. Three main axes were investigated.

- Study of monitoring of off shore wind turbines
- Laboratory experiments for fatigue monitoring using fiber optic sensors
- Development of a monitoring system based on optical gages and test in real conditions on a marine buoy

A Master 2 internship was dedicated on the analysis of multiple months of data by means of data analysis and subspace identification techniques.

8.1.5. Collaboration with IETR

Participants: Vincent Le Cam, David Pallier.

The thesis is directed by Sébastien Pillement at IETR. It is funded by RFI WISE Electronique Professionnelle within the SENTAUR project. The objective is to correct the time drift of the quartz in wireless sensor networks. Quartz modelizations, test platforms under real GPS conditions have been built. First results are based on Kalman algorithms to correct drift[34].

8.1.6. Collaboration with GeM

Participants: Laurent Mevel, Michael Doehler.

I4S' PhD student Md Delwar Hossain Bhuyan has done his PhD on damage localization on civil structures in collaboration with GeM (Institute of Civil and Mechanical Engineering), Université de Nantes, and successfully defended in November 2017. In the follow-up, a mockup of the Saint Nazaire bridge has been funded by GeM in 2018 for damage localization, and tests on it are ongoing [25].

8.1.7. Vibration analysis by video image processing for civil engineering structure monitoring

Participants: Bian Xiong, Qinghua Zhang.

- Type: ARED (Allocations de Recherche Doctorale)
- Objective: to develop video-based methods for civil engineering structure monitoring.
- Duration: 2018 - 2021
- Coordinator : Inria
- Partners: IFSTTAR
- Inria contact: Qinghua Zhang
- Abstract:

The I4S team develops real-time vibration analysis methods for the monitoring of civil engineering structures (bridges, buildings, etc.), usually based on mechanical sensors integrated into the monitored structures. In parallel, the team works also on image processing techniques for non-destructive testing of civil engineering construction materials. This PhD project, co-supervised with Vincent Baltazart (IFSTTAR researcher), aims to combine the two approaches in order to develop a method of vibration analysis based on image processing. Given a sequence of images of the structure to be monitored, the motion signal of the structure is derived from video image analysis, then methods of vibration analysis are applied to this motion signal. Such a solution will have the advantage of avoiding the integration of mechanical sensors into monitored structures and simplifying the maintenance of the monitoring system

8.2. National Initiatives

8.2.1. CEA List : Acoustic High Frequency synchronous and wireless

Participants: Vincent Le Cam, Arthur Bouché.

In the area of infrastructure, strengthening links with CEA-LIST and Alstom-Rail will focus on non-destructive ultrasonic testing methods for rails. We will focus in particular on the opening of cracks in the passage of the trains, which requires a very precise synchronization of the various sensors. In 2019 the first tests of validation on the site of Bar le Duc with the help of the prototype were conclusive: capacities to emit and receive ultrasonic waves in 1.4 km of rail by perfectly synchronized materials (until the microsecond UT). In 2020 the objectives of the future contract will be:

- make several boxes to carry out more complete tests
- conducting qualification test campaigns (according to CDC Alstom)
- upgrade the high frequency daughter card (with PEGASE 3 more globally)

8.2.2. ANR Resbati

Participants: Ludovic Gaverina, Jean Dumoulin.

Type: ANR

Objectif: In-situ measurements of thermal wall resistance

Duration: 10/2016 to 10/2019

Coordinator: Laurent Ibos

Partners : IFSTTAR, CERTES, CEREMA, CSTB, LNE, THEMACS, AFNOR

Inria contact: Jean Dumoulin

Abstract: RESBATI is an applied research project whose objective is to develop a field measurement device that meets precise specifications to systematically measure the level of thermal insulation of building walls. The preferred metrological tool is infrared thermography. A smart logger and a protype have been developed and presented. A full autonomous system has been studied and developed for in-situ measurement on existing building envelope. In parallel, thermal resistance estimation method was studied. First experiments were carried out with a first generation prototype in 2019. For this purpose different instrumented building walls were built and qualified at CSTB before carrying out in-situ evaluations of the prototype.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

8.3.1.1. INFRASTAR(Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk)

Participants: Xavier Chapeleau, Antoine Bassil.

Call: H2020-MSCA-ITN-2015 (Horizon 2020 Marie-Sklodowska Curie Actions Innovative Training Networks)

Type of Action: MSCA-ITN-ETN

Objective: Improve energy performance of building design

Duration: 48 months since 2016 May 1st

Coordinator: Odile Abraham (IFSTTAR)

Academic and industrial Partners: IFSTTAR, UNIVERSITY OF AALBORG, BAM, EPFL, GuD Consult Gmbh, COWI A/S, NeoStrain, PHIMECA

Inria contact: X. Chapeleau

Website: http://infrastar.eu/

Abstract: This thesis work aims to develop and validate a method for monitoring crack openings using distributed fiber optics strain measurements. First, the various existing theories on strain transfer from the host material to the optical fiber are presented, with their validity domain. The problem of perfect interfacial bonding is then studied and a three-layer analytical model capable of handling imperfect bonding case is proposed. This model is then generalized to multi-layer systems. Experimental studies validating this new model are presented. They show that it is possible to monitor crack openings up to 1 mm with an error of less than 10% for a fiber optic cable glued on the surface. Cables embedded in concrete show less accurate results. The type of cable, the bonding length and the hardening of the concrete material also influence the accuracy of the estimated crack openings. Finally, the results of case studies on laboratory-size reinforced concrete samples are presented. They show the optical fibers capacity to detect cracks as early as ultrasonic sensors and to monitor the opening of multiple micro cracks.

8.3.1.2. DESDEMONA(DEtection of Steel Defects by Enhanced MONitoring and Automated procedure for self-inspection and maintenance)

Participants: Jean Dumoulin, Laurent Mevel, Michael Doehler, Xavier Chapeleau.

Call: H2020 -Call: RFCS-2017 (Call of the research programme of the Research Fund for Coal and Steel - 2017)

Type of Action: RFCS-RPJ (Research project)

Objective: DESDEMONA objective is the development of novel design methods, systems, procedure and technical solution, to integrate sensing and automation technologies for the purpose of self-inspection and self-monitoring of steel structures.

Duration: 36 months since 2018 June 1st

Coordinator: Pr. Vincenzo Gatulli (La Sapienza University of Rome)

Academic and industrial Partners: Sapienza Università di Roma (Italy), Universidad de Castilla – La Mancha, (Spain), Universidade do Porto (Portugal), Università di Pisa (Italy), IFSTTAR (France), Aiviewgroup srl (Italy), Sixense systems (France), Ecisa compania general de construcciones sa (Spain), Università di Cassino e del Lazio Meridionale (Italy), Universidad de Alicante (Spain), Inria (France).

Inria contact: J. Dumoulin and L. Mevel

Website: http://www.desdemonaproject.eu

Abstract: DESDEMONA objective is the development of novel design methods, systems, procedure and technical solution, to integrate sensing and automation technologies for the purpose of self-inspection and self-monitoring of steel structures. The approach will lead to an increment of the service life of existing and new steel civil and industrial infrastructure and to a decrease in the cost associated to inspections, improving human activities performed in difficult conditions, safety and workers' potential by the use of advanced tools. The research aims to expand beyond the current state-of-the-art new high-quality standard and practices for steel structure inspection and maintenance through the interrelated development of the following actions: i) steel structure geometry and condition virtualization through data fusion of image processing, thermography and vibration measurements; ii) developing a procedure for steel defect detection by robotic and automatic systems such as Unmanned Aerial Vehicles (UAV) and ground mobile robots iii) embedding sensor systems to revalorize and transform steel elements and structures into self-diagnostic (smart) elements and materials even through nanotechnologies, iv) realizing an experimental lab-based apparatus and a series of case studies inspected by intelligent and robotic systems. The project outcome will have an impact on the reduction of the cost of steel structures inspection and maintenance and on the increase of user safety and comfort in industrial and civil environment. The proposal with a multidisciplinary approach fulfils the objectives of the Strategic Research Agenda of the European Steel Technology Platform.

8.3.2. Collaborations in European Programs, Except FP7 & H2020

8.3.2.1. COST Action TU 1402

Participants: Michael Doehler, Laurent Mevel.

L. Mevel is member of the management committee of the COST Action.

M. Doehler is co-leader of working group 2 "SHM strategies and structural performance" and member of the steering committee.

Type: COST

Objective: Quantifying the value of structural health monitoring

Duration: 11/2014 - 4/2019

Coordinator: S. Thoens (DTU Denmark)

Partner: 29 countries, see https://www.cost.eu/actions/TU1402

Inria contact: Laurent Mevel

Abstract: Since 2014, until 2018, the COST Action has altogether around 120 participants from over 25 countries. This Action aims to develop and describe a theoretical framework, together with methods, tools, guidelines, examples and educational activities, for the quantification of the value of SHM.

8.4. International Initiatives

8.4.1. Collaboration with University of British Columbia, Canada

Participants: Laurent Mevel, Michael Doehler, Alexander Mendler.

Alexander Mendler's PhD thesis started in September 2018 co-supervised by M. Doehler and C. Ventura. A. Mendler spent 6 months in Rennes in 2019 thanks to a MITACS grant.

8.4.2. Collaboration with BAM, Germany

Participants: Laurent Mevel, Michael Doehler, Eva Viefhues.

Eva Viefhues is currently PhD student of Laurent Mevel and Michel Doehler in Berlin, financed by BAM. M. Doehler is also associate researcher at BAM since 2016. Besides the supervision of the PhD, collaboration on temperature robustness is ongoing with BAM [18], [24].

8.4.3. Collaboration with Technical University of Denmark (DTU)

Participants: Michael Doehler, Laurent Mevel.

During COST Action TU 1402 and previously at BAM, collaboration with Sebastian Thöns from DTU in Denmark started on risk analysis and SHM based reliability updating. Also, Aalborg University's PhD student Lijia Long is involved.

8.4.4. Collaboration with Aalborg University, Denmark

Participant: Michael Doehler.

Together with Structural Vibration Solutions, collaboration with Aalborg University (professor Lars Damkilde, Department of Civil Engineering) happened during the PhD of Szymon Gres on damage detection methods, with current conference publications [29], [30]. The PhD has been defended on November 19, 2019.

8.4.5. Collaboration with Laval University, Canada

Participant: Jean Dumoulin.

In the Framework of On Duty Project (http://www.ondutycanada.ca) we are working on Non Destructive Testing techniques and automation of inspection process. Jean Dumoulin spent 10 days in Canada in 2019 devoted to corrosion detection by active infrared thermography NDT approach.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

Szymon Gres visited us for 2 months from January to February 2019 during his thesis.

A. Mendler got a 6 month MITACS grant to visit us from May to October 2019.

8.5.1.1. Research Stays Abroad

J. Dumoulin was with University Laval and with CNR IREA in Fall 2019.

MCTAO Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

Sub-Riemannian Geometry and Interactions (SRGI). Started 2015 (decision ANR-15-CE40-0018), duration: 4 years. L. Rifford is a member.

Intéractions Systèmes Dynamiques Équations d'Évolution et Contrôle (ISDEEC). Started 2016 (decision ANR-16-CE40-0013), duration: 4 years. L. Rifford is a member.

Maximic: optimal control of microbial cells by natural and synthetic strategies. Started 2017, duration: 4 years. J.-B. Caillau, L. Giraldi, J.-B. Pomet are members.

9.1.2. Others

Défi InfIniti CNRS project, Control and Optimality of Magnetic Microrobots, (PI L. Giraldi). Started 2017, duration: 2 years. This project involves colleagues from Paris Sorbonne Université S. Régnier and from University of Strasbourg C. Prud'Homme's.

PGMO grant (2017-2019) on "Algebro-geometric techniques with applications to global optimal control for Magnetic Resonance Imaging (MRI)". B. Bonnard, A. Nolot and J. Rouot participate in this project, the PI is O. Cots, from ENSEIHHT, Toulouse.

PGMO grant (2019-2021) on "Sampled-Data Control Systems and Applications" (PI B. Bonnard).

The McTAO team participates in the GdR MOA, a CNRS network on Mathematics of Optimization and Applications.

J.-B. Caillau is associate researcher of the CNRS team Parallel Algorithms & Optimization at ENSEEIHT, Univ. Toulouse.

9.2. International Research Visitors

9.2.1. Visits of International Scientists

Prof. Sorin Sabau (Tokai University) visited Inria during two weeks in May 2019. He gave a talk on "The calculus of variations on Finsler manifolds".

9.2.1.1. Research Stays Abroad

- Bernard Bonnard visited the University of Hawaii at Manoa, Mars 2019 (1 month, host: M. Chyba).

NECS Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

DATASAFE (Understanding data accidents for traffic safety). PI: M.L. Delle Monache (2018-2019)
DATASAFE is a two years project funded by Grenoble Data Institute, with the aim to understand from real traffic data the behavior of traffic in the moments preceding an accident. The general approach is to use novel statistical techniques in order to learn traffic characteristics that can be used to develop new traffic models. Bayesian approaches are used to (supervised) classification and (unsupervised) clustering in order to respectively predict collision occurrences and discover traffic patterns.

MAVIT (Modeling autonomous vehicles in traffic flow). PI: M.L. Delle Monache (2018-2019)
MAVIT is a two year project funded by the University Grenoble Alpes, MSTIC department. The goal of this project is to develop a unified micro-macro approach for traffic management, involving human and autonomous vehicles drivers by providing analytical and numerical tools for traffic modeling, estimation and control. We will work towards field operational tests, by using instrumented cars to collect data on AVs trajectory and their interaction with the traffic flow with human drivers. The proposed research provides new mathematical models, computational/software tools, and engineering solutions for the control of human controlled vehicles via intelligently controlled AVs in the traffic stream. Moreover, the control of traffic via moving actuators provides a new alternative to contemporary control technologies, such as ramp metering and variable speed limits; even when AVs comprise a tiny fraction of the total fleet, these techniques may be viable, and rapidly configurable. This research considers new types of traffic models, new control algorithms for traffic flow regulation, and new sensing and control paradigms that are enabled by a small number of controllable systems anticipated in a flow. Specifically, the research focuses on new (1) micro-macro models to model few AVs in a flow; (2) estimation techniques for AV interactions with the traffic flow; (3) developing and assessing dynamical controllers to mitigate traffic events

SPACE (NanoSatellite Project: Advanced modelling and Control of attitude dynamics for quantum communication). PI: H. Fourati (2018-2019)
SPACE is a two-year project funded by the IDEX University Grenoble Alpes. It aims to launch an exploratory study to find the required minimal data we need to collect and combine for software design of Nanosatellite Attitude Determination and Control System (ADCS).

CAPTIMOVE (CAPture et analyse d'acTivités humaInes par MOdules inertiels : vers une solution adaptée à la naVigation multimodalE urbaine intelligente). PI: H. Fourati (2018-2019)
Mobility is currently evolving in urban scenarios and multimodality today is the key tomore efficient transportation. It is important to analyze the ecological impact of the varioustransportation modes, to be able to detect the mode used by the commuter and the rule usedto switch from one mode to another. The ultimate goal is to suggest smarter itineraries tocommuters. To this purpose, detection and classification of activities in human mobility fromhis principal residence to his destination (for example, place of work, place of entertainment,etc.) is an important study to carry out. We aim to identify, with high precision, the natureof the transportation modes used during the day (walking, cycling, public transportation, car,etc.) as well as transitions from one mode to another. To reach this goal, we will use inertial and attitude modules, embedded in most inertial units, connected watches and smartphones.These technological tools constitute truly innovative and promising instrumentation for bothnon-invasive automatic capture information in situ, over extended periods, only for accurateand reliable analysis of activities of a person during his/her trip. In terms of research, we willexploit techniques from Machine Learning and state estimation to address this issue. A studyshall be conducted to determine the type, number and location of sensors to be used., Issuesrelated to the quality of data to be provided to algorithms and how to detect and discarderroneous ones from our computation process, will be also addressed. This research finds itsmajor future interest later in the development of a multimodal

intelligent navigation systemfor indoor and outdoor environments. These results, once obtained, can also be used to studyand analyze the behavior (choice) of users regarding pedestrian navigation (walking) or theuse of modes of transport (convenience, cost, speed, safety and more and more frequentlyeffects on the environment) or respect for the privacy of individuals (dynamic anonymizationof data while retaining their usefulness).

9.2. National Initiatives

DOOM (Systems-theory for the Disorders Of Online Media). 80 PRIME from CNRS MITI (2019–2022). PI: P. Frasca
Online social media have a key role in contemporary society and the debates that take place on them are known to shape political and societal trends. For this reason, pathological phenomena like the formation of "filter bubbles" and the viral propagation of "fake news" are observed with concern. The scientific assumption of this proposal is that these information disorders are direct consequences of the inherent nature of these communication media, and more specifically of the collective dynamics of attention thereby. In order to capture these dynamics, this proposal advocates the mathematical modelling of the interplay between the medium (algorithmic component) and the users (human component). The resulting dynamics shall be explored by a system-theoretic approach, using notions such as feedback and stability. This quantitative and rigorous approach will not only unlock fundamental insights but also deliver suggestions on suitable policies to manage the media.

HANDY (Hybrid and Networked Dynamical Systems). ANR PRC (2019-2022). Co-PI: P. Frasca
Networked dynamical systems are ubiquitous in current and emerging technologies. From energy grids, fleets of connected autonomous vehicles to online social networks, the same scenario arises in each case: dynamical units interact locally to achieve a global behavior. When considering a networked system as a whole, very often continuous-time dynamics are affected by instantaneous changes, called jumps, leading to so-called hybrid dynamical systems. Hybrid phenomena thus play an essential role in these control applications, and call upon the development of novel adapted tools for stability and performance analysis and control design. In this context, the aim of HANDY project is to provide methodological control-oriented tools for realistic networked models, which account for hybrid phenomena. The project brings together researchers from LAAS in Toulouse, CRAN in Nancy, GIPSA in Grenoble and LSS in Gif-sur-Yvette, with expertise in various domains of automatic control, ranging from geometric control and optimization, switched systems, hybrid dynamics, nonlinear control, and multi-agent systems. See also: http://projects.laas.fr/handy

AgileWorld-MRSEI. PI: A. Kibangou AgileWorld is an ANR-MRSEI project (2018-2020), which aims at building an European network for an innovative training on road transportation systems in a connected world. The funding will help to prepare and then submit a proposal for the MSCA-ITN 2019 call. For this purpose a workshop was organized in November 2019 with the partners of the project in Grenoble.

9.3. European Initiatives

9.3.1. Collaborations in European Programs, Except FP7 & H2020

COST (Mathematical models for interacting dynamics on networks). Action no. 18232, 2019-2023, Management committee substitute member. PI: M.L. Delle Monache
Many physical, biological, chemical, financial or even social phenomena can be described by dynamical systems. It is quite common that the dynamics arises as a compound effect of the interaction between sub-systems in which case we speak about coupled systems. This Action shall study such interactions in particular cases from three points of view: 1. the abstract approach to the theory behind these systems, 2. applications of the abstract theory to coupled structures like networks, neighbouring domains divided by permeable membranes, possibly non-homogeneous simplicial complexes, etc., 3. modelling real-life situations within this framework. The purpose of this Action is to bring together leading groups in Europe working on a range of issues connected with modelling and analysing mathematical models for dynamical systems on networks. It aims to develop a semigroup approach to various (non-)linear dynamical systems on networks as well as numerical methods based on modern variational methods and applying them to road traffic, biological systems,

and further real-life models. The Action also explores the possibility of estimating solutions and long time behaviour of these systems by collecting basic combinatorial information about underlying networks

9.4. International Initiatives

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

MEMENTO (ModEling autonoMous vEhicles iN Traffic flOw). International Partner: Vanderbilt University, Nashville (United States) - Dan Work, Start year: 2018. See also: http://necs.inrialpes.fr/memento/index.html
PI: M.L. Delle Monache
In recent years, the strategic priorities of automotive and transportation systems focus on research, development and adoption of automation-related technologies as they emerge. As these technology developments are introduced in the traffic stream, an open question is how the mathematical models that are at the heart of transportation planning and operations will need to be advanced to accommodate these changes. The goal of the NeCS-Vanderbilt, MEMENTO, associate team is to create a multidisciplinary environment to model autonomous vehicles (AV) in human traffic flow. Specifically, our goal is to develop a unified micro-macro approach for traffic management, involving human drivers and autonomous vehicles by providing analytical and numerical tools for traffic modeling, estimation and control. We will work towards field operational tests, by using instrumented cars to collect data on AVs trajectories and their interaction with the traffic flow with human drivers.

9.4.2. Participation in Other International Programs

(Mean field game models for traffic application). Rutgers Global Grant - International collaborative research grant: International partner : Rutgers University - Camden (USA). PI: M.L. Delle Monache
This project focuses on the theoretical tools for traffic systems to mitigate traffic events that adversely affect. Specifically, the project will build algorithms to mitigate "phantom" traffic jams, which are instabilities caused by human driving behavior, lane changes, and other disturbances. This project is premised on the concept that connected and autonomous vehicles (CAVs) can act as instability pacifiers and enable a new era of freeway traffic management in which CAVs themselves are part of the traffic control system. The stabilizing Lagrangian (i.e., mobile) control signal will be fed directly to the vehicles, which will adjust their speed and lanes to match the requirements of the control.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Raphael Stern (University of Minnesota (USA)) visited the team in March 2019 to work with Maria Laura Delle Monache and Thibault Liard, in the framework of the associated team MEMENTO.

9.5.2. Visits to International Teams

- P. Frasca is a Visiting Scientist at the IEIIT-CNR Institute, National Research Council CNR, Turin, Italy. By this collaboration, he performs research on distributed estimation in sensor networks and distributed control of social networks. He visited Turin three times in 2019. He is also a Visiting Faculty at the Department of Applied Mathematics, University of Twente, Enschede, The Netherlands. By this collaboration, he performs research on vehicle platooning and on the dynamics of social media.
- Maria Laura Delle Monache visited Rutgers University – Camden in March and in November 2019 to work with Prof. Piccoli in the framework of the Rutgers collaborative grant.
- Maria Laura Delle Monache visited Vanderbilt University in November 2019 in the framework of the of the associated team MEMENTO.
- Stephane Mollier visited Temple University in January 2019 to discuss with Prof. Seibold concerning 2D traffic models.

- A. Kibangou visited the University of Johannesburg (South Africa) in March and November 2019. During his stay, he gave a lecture to students of Department of Town and Regional Planning of Univ. of Johannesburg on Mobility and traffic management. He also attended the first French-South African Science and Innovation days (December 2-3, 2019).

QUANTIC Project-Team

7. Partnerships and Cooperations

7.1. Regional Initiatives

- **Paris EMERGENCE project ENDURANCE**: In the framework of the Paris Ile de France program “EMERGENCE”, Zaki Leghtas has received a funding for his research program "Multi-photon processes in superconducting circuits for quantum error correction". This grant of 230k euros has allowed us to purchase the experimental equipment to complement the experiment based at ENS.
- **DIM SIRTEQ PhD fellowship**: We have received funding from DIM SIRTEQ to cover half of the PhD of Jérémie Guillaud under supervision of Mazyar Mirrahimi.
- **DIM SIRTEQ project SCOOP**:Half a PhD grant for Marius Villiers, supervised by Zaki Leghtas and Audrey Cottet (ENS Paris). The project is to use quantum circuits to detect the entanglement of a single Cooper pair. University.
- **EDPIF PhD fellowship**: Ecole Doctorale de Physique en Ile de France has funded half a PhD grant for Marius Villiers.
- **DGA PhD fellowship**: Direction Générale de l’Armement has funded half a PhD grant for Camille Berdou supervised by Zaki Leghtas. The project is to build a repetition code of cat-qubits.
- **Mines Paristech PhD Fellowship**: Ecole des Mines Paristech has funded half a PhD grant for Camille Berdou.
- **PSL working group on “structural stability and chaos in open quantum systems”**: This is a Groupe de Travail with researchers from CEREMADE (Paris Dauphine) and Observatoire de Paris under the direction of Jacques Fejoz. In the framework of the PhD thesis of Michiel Burgelman, we study the dynamics of superconducting Josephson circuits driven by strong microwave drives.

7.2. National Initiatives

- **ANR project ENDURANCE**: In the framework of the ANR program “Accueil de chercheur de haut niveau”, Zaki Leghtas has received a funding for his research program "Multi-photon processes in superconducting circuits for quantum error correction". This grant of 400k euros has allowed us to purchase the experimental equipment to build a new experiment based at ENS. The project started in March 2016 for 42 months.
- **ANR project HAMROQS**: In the framework of the ANR program JCJC, Alain Sarlette has received a funding for his research program "High-accuracy model reduction for open quantum systems". This grant of 212k euros started on april 2019 and will run for 4 years.

7.3. European Initiatives

7.3.1. FP7 & H2020 Projects

Program: H2020

Type: ERC

Project acronym: ECLIPSE

Project title: Exotic superconducting CIrcuits to Probe and protect quantum States of light and mattEr

Duration: 2019-

Coordinator: Zaki Leghtas, Mines Paristech

Program: H2020

Type: Quantera

Project acronym: QuCos

Project title: Quantum Computation with Schrödinger cat states

Duration: 2019-

Coordinator: Gerhard Kirchmair, University of Innsbruck, Austria.

Inria contacts: Zaki Leghtas and Mazyar Mirrahimi

Other partners: ENS Lyon (France), Karlsruhe Institut of Technology (Germany), Quantum Machines (Israel), National Institute for Research and Development of Isotopic and Molecular Technologies, Romania.

Abstract: This project seeks to establish a radically new, alternative approach to realizing the fundamental building blocks of quantum computers with superconducting qubits. In the next 3 years, we plan to employ only a handful of realistic components to realize robust error-corrected logical quantum bits. We aim to demonstrate the same level of protection provided by a few hundreds of qubits (with properties beyond the state of the art) in today's mainstream approach of the so-called surface code architecture. Our alternative approach is known as cat codes, because it employs multiple interconnected high coherence cavity modes with non-linear dissipation, to encode a qubit in superpositions of Schrödinger cat states. Our project combines realizing the quantum processor architecture as well as the control system and the protocols that drive it, building towards a full-stack error-corrected quantum computer. The partners in our collaboration form a strong synergetic group that has the full range of expertise needed to design and realize these systems, and to obtain these challenging goals. Furthermore, all partners of our project, including both industry and academia, have worked together and published works in the fields of quantum computing and quantum information processing. We aim to implement error protected qubits, fault tolerant operations, and demonstrate the scalability of this approach by realizing a repetition code. Our project will enable quantum experiments towards the ambitious and well-defined goal of constructing a logical qubit, on which we can perform gates, and most importantly, quantum error-correction (QEC).

7.3.2. Collaborations with Major European Organizations

Partner 1: ENS Lyon

We are pursuing our interdisciplinary work about quantum control from theoretical aspects in direct collaboration with existing experiments (ENS Lyon) with the group of Benjamin Huard, former member of the QUANTIC team. Joint papers are published and underway. The ANR-JCJC project HAMROQS by Alain Sarlette has Benjamin Huard as external supporting collaborator.

Partner 2: Laboratoire Kastler Brossel

We have been continuing collaborations with the teams of Samuel Deleglise and Igor Dotsenko from Laboratoire Kastler Brossel on the theoretical analysis of their experiments.

Partner 3: Ghent University.

Alain Sarlette has been collaborating with applied mathematicians interested in quantum control at UGent in the framework of thesis co-supervisions. One PhD student has successfully defended his thesis this year (Zhifei Zhang).

7.4. International Initiatives

7.4.1. Inria International Labs

Inria@EastCoast
Associate Team involved in the International Lab:

7.4.1.1. TAQUILLA

Title: TAilored QUantum Information protocoLs for quAntum superconducting circuits

International Partner (Institution - Laboratory - Researcher):

Université Yale (United States) -Department of Applied Physics - Michel Devoret

Start year: 2019

See also: https://team.inria.fr/quantic/Taquilla.html

We seek to establish an alternative approach to quantum error correction (QEC) for superconducting qubits. This approach, developed through the Inria-Yale collaboration, is known under the name of cat codes, because it employs multiple interconnected high coherence cavity modes with non-linear dissipation to encode a qubit in superpositions of Schrödinger cat states. We aim to implement error protected qubits, fault tolerant operations, and demonstrate the scalability of this approach. Our project will enable quantum experiments towards the ambitious and well-defined goal of constructing a logical qubit, on which we can perform gates, and most importantly, QEC.

7.4.2. Participation in Other International Programs

- **Yale-ARO subaward:** In the framework of the collaborations with Yale university, Quantic team has received a sub-award of 500k dollars over 4 years starting in 2018 from Yale university. This sub-award is part of an ARO (Army Research Office) grant received by our collaborators at Yale and covers the expenses related to our collaborations (hiring of new PhD students and postdocs at Inria and travels between Inria and Yale).
- **DARPA:** Alain Sarlette is international key personnel on the DARPA project "The Quantum Computing Revolution and Optimization: Challenges and Opportunities" led by optimization researchers at Lehigh Universty. This project of about 2M dollars can fund some exchanges during the coming years.
- **Berkeley exchange initiative:** P. Rouchon and A. Sarlette have set up an exchange initiative with Birgitta Whaley about quantum control and error correction based on continuous measurements. This initiative has funded a research visit of Gerardo Cardona at Berkeley; a student from Berkeley is bound to visit us soon in return.

7.5. International Research Visitors

7.5.1. Visits of International Scientists

P.S. Pereira da Silva (Escola Politecnica, PTC, University of Sao Paulo, Brazil) made two visits (September 16 to 27 and December 2 to 6) to investigate with Pierre Rouchon motion planning issues based on Lyapunov tracking for quantum gate generations for open quantum systems governed by Lindblad master equations.

7.5.2. Visits to International Teams

7.5.2.1. Research Stays Abroad

- In the framework of our collaborations with Yale (Taquilla associated team), Mazyar Mirrahimi and Michiel Burgelman have spent 3 months at Yale. In the same framework Philippe Campagne-Ibarcq and Christian Siegele also made a visit of 5 days during the same period.
- In the framework of the Berkeley exchange initiative, Gerardo Cardona has spent a month (October 2019) in the research group of Birgitta Whaley at Berkeley University.

SPHINX Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

- **Project Acronym :** IFSMACS
  Project Title : Fluid-Structure Interaction: Modeling, Analysis, Control and Simulation
  Coordinator: Takéo Takahashi
  Participants: Julien Lequeurre, Alexandre Munnier, Jean-François Scheid, Takéo Takahashi
  Duration : 48 months (starting on October 1st, 2016)
  Other partners: Institut de Mathématiques de Bordeaux, Inria Paris, Institut de Mathématiques de Toulouse
  Abstract: The aim of this project is to analyze systems composed by structures immersed in a fluid. Studies of such systems can be motivated by many applications (motion of the blood in veins, fish locomotion, design of submarines, etc.) but also by the corresponding challenging mathematical problems. Among the important difficulties inherent to these systems, one can quote nonlinearity, coupling, free-boundaries. Our objectives include asymptotic analyses of FSIS, the study of controllability and stabilizability of FSIS, the understanding of locomotion of self-propelled structures and the analyze and development of numerical tools to simulate fluid-structure system.
  URL: http://ifsmacs.iecl.univ-lorraine.fr/
- **Project Acronym:** QUACO
  Project title: QUAntum COntrol: PDE systems and MRI
  Coordinator: Thomas Chambrion
  Duration: 48 months (starting January 1st 2018).
  URL: http://www.iecl.univ-lorraine.fr/~Thomas.Chambrion/QUACO/index.html
  Abstract The aim of the project is the use of geometrical tools for the study and the control of quantum system with application to MRI.
- **Project acronym:** ISDEEC
  Project title: Interaction entre Systèmes Dynamiques, Equations d'Evolution et Contrôle
  Coordinator: Romain Joly
  Participant: Julie Valein
  Other partners: Institut Fourier, Grenoble; Département de Mathématiques d'Orsay
  Duration: 36 months (2017-2020)
  URL: http://isdeec.math.cnrs.fr/
  Abstract The aim of the project is to study the qualitative dynamics of various classes of PDEs and classes of ODEs with special structure. This work program requires expertise in different mathematical domains such as dynamical systems theory, PDE techniques, control theory, geometry, functional analysis... while the current trend in mathematics is for high specialisation. The purpose of this project is to create and extend interactions between experts of these various domains, in order to deepen our understanding of the dynamics of evolution equations and to explore the new challenging questions, which will emerge.

- **Project Acronym:** ODISSE
  Project title: Observer Design for Infinite-dimensional Systems
  Coordinator: Vincent Andrieu
  Local coordinator: Karim Ramdani
  Duration: 48 months (starting on October 1st 2019)
  Participants: Ludovick Gagnon, Karim Ramdani, Julie Valein and Jean-Claude Vivalda.
  Other partners: Laas, Lagepp, Inria-Saclay
  Abstract: This ANR project includes 3 work-packages
  1. Theoretical aspects of observability and identifiability.
  2. From finite dimensional systems to infinite dimensional systems : Infinite-dimensional Luenberger observers, Parametric identification and adaptive estimation algorithm, Infinite-dimensional observers for finite-dimensional systems.
  3. From infinite dimensional systems to finite dimensional systems : discretization, hierarchical reduction.

9.2. International Initiatives

9.2.1. Inria International Labs

9.2.1.1. BEC2HPC

Title: Bose-Einstein Condensates : Computation and HPC simulation

Head: Xavier Antoine

International Partner: Sichuan University, Chengdu (China) - Department of mathematics - Qinglin TANG

Start year: 2019

See also: https://team.inria.fr/bec2hpc/

All members of the associate team are experts in the mathematical modeling and numerical simulation of PDEs related to engineering and physics applications. The first objective of the associate team is to develop efficient high-order numerical methods for computing the stationary states and dynamics of Bose-Einstein Condensates (BEC) modeled by Gross-Pitaevskii Equations (GPEs). A second objective is to implement and validate these new methods in a HPC environment to simulate large scale 2D and 3D problems in quantum physics. Finally, a third objective is to provide a flexible and efficient HPC software to the quantum physics community for simulating realistic problems.

9.2.2. Participation in Other International Programs

9.2.2.1. Réseau Franco-Brésilien de mathématiques

Ludovick Gagnon collaborates with the Universidade Federal da Paraiba and Universidade Federal do Rio de Janeiro funded by the Réseau Franco-Brésilien de mathématiques.

9.2.2.2. Indo-French Center of Applied Mathematics

Title : **Analysis, Control and Homogenization of Complex Systems**

International Partner: TIFR CAM, Bangalore

Heads: Takéo Takahashi (France) and Mythily Ramaswamy (India).

Duration: 2018 - 2021

Scientific Objectives

- Study the well-posedness of models arising from either structure in the fluid or structure on the boundary of the domain containing the fluid.
- Explore Controllability, Optimal Control and Stabilization of such fluid-structure interaction problems.
- Study systems describing fluid flows in a time dependent domain with a rapidly oscillating boundary using Homogenization Theory. The rapid oscillations of the boundary takes into account, the rough character of the boundary and its movements may take into account the displacement of a deformable body into a fluid flow.
- Carry out Finite Element Analysis for such models, including elastic structures as well as rigid ones.

9.3. International Research Visitors

9.3.1. Visits to International Teams

Jean-François Scheid was invited to the "École Supérieure des Sciences et Technologie d'Hammam-Sousse", Tunisia, 30 September–5 October 2019.

9.3.1.1. Research Stays Abroad

Xavier Antoine was invited to the Department of Mathematics, Sichuan University, Chengdu, January 2019 (2 weeks) + August 2019 (4.5 weeks) + November 2019 (3 weeks).

TRIPOP Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

The SMART PROTECT project (2019–2022) is a R&D booster project granted by the Région Auvergne Rhône–Alpes. The project is coordinated by Géolithe Innov, a French company specialized in the innovation in Geotechnics. The partners are Géolithe, Irstea and Myotis. The aim of the project is to design and validate a new type of protection structures against rockfall and avalanches. The role of the TRIPOP team is to propose a numerical modeling of the structure and to improve the link between simulations and wireless sensors, which will equip the structure.

8.2. National Initiatives

8.2.1. ANR project Digitslid

B. Brogliato coordinates the ANR project Digitslid (PRC, ANR-18-CE40-0008-01), Differentiateurs et commandes homogenes par modes glissants en temps discret: l'approche implicite. Partners: LS2N (Ecole Centrale de Nantes), Inria Lille Nord Europe (team Non-A-Post), and Tripop. October 2018-September 2021. 12 participants overall (3 post-doc students recruited by the project, 3 Ph.D. students supported by other means). Total financial support by the ANR: 338 362 euros (100 762 for Tripop, 18 months of post-doc to be recruited in 2019).

8.2.2. FUI Modeliscale.

https://team.inria.fr/modeliscale/

The ModeliScale FUI focuses on the modeling, simulation and analysis of large cyber-physical systems. It federates the research activities of several teams, covering a broad spectrum of topics, namely hybrid systems modeling & verification, numerical analysis, programming language design and automatic control. Our research agenda includes the following tracks:

- New compilation techniques for Modelica modelers: structural analysis of multimode DAE (Differential Algebraic Equations) systems, modular compilation, combining state-machines and non-smooth dynamical systems (complementarity dynamical systems and Filippov differential inclusions), contract-based specification of cyber-physical systems requirements, requirements capture using under-/over-determined DAE systems.
- Simulation of large cyber-physical systems: distributed simulation, discretization methods for non-smooth dynamical systems, space-/time-adaptive discretization methods for multimode DAE systems, quantized state solvers (QSS).
- Guaranteed numerics: guaranteed simulation of non-smooth and hybrid dynamical systems, numerical methods preserving invariant properties of hybrid systems, contract-based reasoning methods.

8.2.3. Inria Project Lab (IPL): ModeliScale, Languages and Compilation for Cyber-Physical System Design

https://team.inria.fr/modeliscale/

The project gathers researchers from three Inria teams, and from three other research labs in Grenoble and Paris area.

Table 1. Member of IPL Modeliscale

Name	Team	Inria Center or Laboratory
Vincent Acary	Bipop	Inria Grenoble Rhône Alpes
Bernard Brogliato		
Albert Benveniste	Hycomes Inria Rennes	
Benoît Caillaud		Bretagne Atlantique
Khalil Ghorbal		
Marc Pouzet	Parkas	ENS
Tim Bourke		Inria Paris
Goran Frehse	Tempo	Verimag-univ. Grenoble Alpes
Antoine Girard		L2S-CNRS, Saclay
Eric Goubault	Cosynus	LIX, École Polytechnique,
Sylvie Putot		Saclay

The main objective of ModeliScale is to advance modeling technologies (languages, compile-time analyses, simulation techniques) for CPS combining physical interactions, communication layers and software components. We believe that mastering CPS comprising thousands to millions of components requires radical changes of paradigms. For instance, modeling techniques must be revised, especially when physics is involved. Modeling languages must be enhanced to cope with larger models. This can only be done by combining new compilation techniques (to master the structural complexity of models) with new mathematical tools (new numerical methods, in particular).

ModeliScale gathers a broad scope of experts in programming language design and compilation (reactive synchronous programming), numerical solvers (nonsmooth dynamical systems) and hybrid systems modeling and analysis (guaranteed simulation, verification). The research program is carried out in close cooperation with the Modelica community as well as industrial partners, namely, Dassault Systèmes as a Modelica/FMI tool vendor, and EDF and Engie as end users.

TROPICAL Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

- Projet ANR JCJC CAPPS ("Combinatorial Analysis of Polytopes and Polyhedral Subdivisions"), responsable Arnau Padrol (IMJ-PRG, Sorbonne Université). Partenaires : IMJ-PRG (Sorbonne Université), Inria Saclay (Tropical), LIGM (Université Paris-Est Marne-la-Vallée), LIF (Université Aix-Marseille), CERMICS (École Nationale des Ponts et Chaussées), LIX (École Polytechnique).

9.1.2. Labex Hadamard

- Projet du Labex Hadamard, intitulé "ALgebraic Methods in gAmes and optimization ALMA", conjoint avec le PGMO, coordonné par E. Tisgaridas (Inria Paris) et X. Allamigeon, faisant intervenir M. Akian et S. Gaubert.

9.1.3. IRS iCODE (Institut pour le Contrôle et la Décision de l'Idex Paris-Saclay)

- White project "New perspectives in the numerical solution of Hamilton-Jacobi-Bellman partial differential equations", coordinated by M. Akian, including S. Gaubert and members of the EPC Commands (Inria Saclay and École polytechnique), UMA (ENSTA), and LMO (Paris-Sud).

9.1.4. Centre des Hautes Études du Ministère de l'Intérieur

- Project "Optimisation de la performance de centres de traitement d'appels d'urgence en cas d'événements planifiés ou imprévus", coordinated by X. Allamigeon, involving M. Boyet, B. Colin and S. Gaubert.

9.2. International Initiatives

9.2.1. Participation in Other International Programs

- Bilateral projects FACCTS, between the University of Chicago (Statistics) – Lek-Heng Lim– and Ecole polytechnique – Stéphane Gaubert– "Tropical geometry of deep learning".
- Math AmSud Project ARGO, "Algebraic Real Geometry and Optimization", accepted, with CMM (Chile), Univ. Buenos Aires (Argentina), Univ. Fed. Rio and Univ. Fed. Ceara (Brasil), Univ Savoie and CMAP, Ecole polytechnique (France).

9.3. International Research Visitors

9.3.1. Visits of International Scientists

- Oliver Lorscheid, IMPA, Rio (on sabattical at MPI, Bonn), one week in June and 3 days in October, joint invitation with CMLS, Ecole polytechnique.
- Louis Rowen, Bar Ilan University, 3 days in March.
- Sergei Sergeev, Birmingham, 1 week in April.
- Grigorio Malajovich, Univ. Federal, Rio, 1 week in August.
- Armando Gutiérrez, Aalto University, 2 days in February.

9.3.1.1. Internships

- Sarah Vannucci, PhD student, University of Salerno, has been invited for 3 months in the team.

9.3.2. Visits to International Teams

- S. Gaubert
  - Univ. Birmingham, Math and Stats Dep, Jan. 2019 (visiting S. Sergeev)
  - Univ. Bar Ilan, Math Dep, June 2019 (visiting L. Rowen)
  - Univ. Baltimore, Math Dep, Oct. 2019 (visiting A. Sagnier)
- B. Tran
  - U. de Hong Kong, March-April 2019 (2 months, visiting Zheng Qu)
- C. Walsh
  - Univ. Kent, School of Mathematics, Statistics and Actuarial Science, 1 week in November (visiting B. Lemmens and M. Roelands).

VALSE Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

The team participates in CPER Data programs and projects:

- ControlHub, coordinator A. Polyakov, see the dedicated platform description above
- "ContrATech" subprogram of CPER ELSAT, coordinator J.-M. Foucaut (LMFL)

8.2. National Initiatives

8.2.1. ANR

- Digitslid, coordinator B. Brogliato (Inria, Grenoble)
- Finite4SoS, coordinator W. Perruquetti (École Centrale de Lille)
- WaQMoS, coordinator D. Efimov (Inria, Lille)
- TurboTouch, coordinator G. Casiez (Inria, Lille)

8.2.2. Inria project labs

The team participates in IPL COSY, coordinator E. Cinquemani (Inria, Grenoble).

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

The team is involved in 1 EU project UCoCoS, coordinator W. Michiels (KUL, Belgium).

8.4. International Initiatives

8.4.1. Inria North European associate teams

- WeCare with Uppsala University (Sweden), coordinator R. Ushirobira
- RECoT with IBM Research (Ireland), coordinator A. Polyakov

8.4.2. Inria International Partners

- UNAM (Mexico), L. Fridman and J. Moreno
- ITMO University (Russia), A. Bobtsov and I. Furtat

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- A. Aleksandrov, SPbSU (Russia), from Mar 2019 until Apr 2019
- S. Aranovskiy, École supérieure d'électricité, Jun 2019
- J. Epperlein, IBM Research (Ireland), from Dec 2019
- E. Fridman, Tel Aviv University (Israel), from Jul 2019 until Sep 2019, **Inria invited professor**
- A. Medvedev, Upsalla University (Sweden), from Nov 2019 until Dec 2019
- J. Moreno, UNAM (Mexico), from Dec 2019
- Y. Orlov, CICESE (Mexico), from Dec 2019
- M. Ruderman, University of Agder (Norway), from Dec 2019
- L. Tupak Aguilar Bustos, CICESE (Mexico), from Dec 2019
- J. Zhang, HDU (China), from Aug 2019
- K. Zimenko, ITMO University (Russia), from Sep 2019 until Nov 2019
- S. Zhuk, IBM Research (Ireland), from Dec 2019

8.5.1.1. Internships

- M. Ballesteros Escamilla, Cinvestav (Mexico), until Apr 2019
- D. Cruz Ortiz, Cinvestav (Mexico), until Apr 2019
- J. Franco Jaramillo, Technological Institute of La Laguna (Mexico), from Oct 2019 until Nov 2019
- J. Mendoza Avila, UNAM (Mexico), from Sep 2019 until Dec 2019

BONUS Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

- *CPER Data (2015-2020)*: in this project, that promotes research and software development related to advanced data science, the BONUS team is the scientific leader (N. Melab) of one of the three research lines of the project "Optimization and High-Performance Computing". In this context, a two-year (2018-2019) engineer (J-Y. Ji) is supported to develop a software demonstrator on decomposition-based big optimization. In addition, the team is co-leader of the workpackage/lever "Research infrastructures" related to the Grid'5000 nation-wide experimental testbed. This allowed to extend the testbed at Lille with a GPU-powered cluster highly important for the BONUS project. In addition, two engineers have been hired for the system & network administration of the testbed, user support and development.
- *CPER ELSAT (2015-2020)*: in this project, focused on ecomobility, security and adaptability in transport, the BONUS team is involved in the transversal research line: planning and scheduling of maintenance logistics in transportation. The team got support for a one-year (2017-2018) post-doc position (M. Rahimi) and a one-year (2019-2020) engineer position (N. Aslimani).

9.2. National Initiatives

9.2.1. ANR

- *Bilateral ANR/RGC France/Hong Kong PRCI* (2016-2021), "Big Multi-objective Optimization" in collaboration with City University of Hong Kong

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

Program: H2020

Project acronym: SYNERGY

Project title: Synergy for Smart Multi-Objective Optimisation

Duration: 02 2016 - 03 2019

Coordinator: Jožef Stefan Institute (JSI), Ljubljana, Slovenia

Other partners: University of Lille (France), Cologne University of Applied Sciences (Germany)

Abstract: Many real-world application areas, such as advanced manufacturing, involve optimization of several, often time-consuming and conflicting objectives. For example, they require the maximization of the product quality while minimizing the production cost, and rely on demanding numerical simulations in order to assess the objectives. These, so-called multi-objective optimization problems can be solved more efficiently if parallelization is used to execute the simulations simultaneously and if the simulations are partly replaced by accurate surrogate models.

9.3.2. Collaborations in European Programs, Except FP7 & H2020

Program: COST CA15140

Project acronym: ImAppNIO

Project title: Improving applicability of nature-inspired optimization by joining theory and practice

Duration: 2016-2019

Coordinator: Thomas Jansen

Abstract: The main objective of the COST Action is to bridge this gap and improve the applicability of all kinds of nature-inspired optimisation methods. It aims at making theoretical insights more accessible and practical by creating a platform where theoreticians and practitioners can meet and exchange insights, ideas and needs; by developing robust guidelines and practical support for application development based on theoretical insights; by developing theoretical frameworks driven by actual needs arising from practical applications; by training Early Career Investigators in a theory of nature-inspired optimisation methods that clearly aims at practical applications; by broadening participation in the ongoing research of how to develop and apply robust nature-inspired optimisation methods in different application areas.

9.3.3. Collaborations with Major European Organizations

University of Mons, Belgium, Parallel surrogate-assisted optimization, large-scale exact optimization, two joint PhDs (M. Gobert and G. Briffoteaux).

University of Luxembourg, Q-Learning-based Hyper-Heuristic for Generating UAV Swarming Behaviours.

University of Coimbra and University of Lisbon, Portugal, Exact and heuristic multi-objective search.

University of Manchester, United Kingdom, Local optimality in multi-objective optimization.

University of Elche and University of Murcia, Spain, Matheuristics for DEA.

University of Mohamed V, Morocco, Large scale (multi-objective) optimization.

9.4. International Initiatives

9.4.1. Inria International Labs

9.4.1.1. Other IIL projects

Title: Frontiers in Massive Optimization and Computational Intelligence (MODO)

International Partner (Institution - Laboratory - Researcher): Shinshu University, Japan

Start year: 2017

See also: https://sites.google.com/view/lia-modo/

Abstract: The aim of MODO is to federate French and Japanese researchers interested in the dimensionality, heterogeneity and expensive nature of massive optimization problems. The team receives a yearly support for international exchanges and shared manpower (joint PhD students).

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

Title: Three-fold decomposition in multi-objective optimization (D^3MO)

International Partner (Institution - Laboratory - Researcher): University of Exeter, UK

Start year: 2018

9.4.3. Inria International Partners

9.4.3.1. Informal International Partners

- School of Public Health and Preventive Medicine, Monash University, Australia (ranked 73^{th} over 1000 in the Shangai international ranking).
- Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Maracanaú, Brazil.

9.4.4. Participation in Other International Programs

Title: **Evolutionary many-objective optimization: application to smart cities and engineering design**

International Partner (Institution - Laboratory - Researcher): CINVESTAV-IPN, Mexico

Start year: 2016

Abstract: The project is co-funded by ECOS Nord, France and ANUIES, Mexico. It is focused on evolutionary many-objective optimization and its application to smart cities and engineering design.

Title: **Bridging the gap between exact methods and heuristics for multi-objective search (MOCO-Search)**

International Partner (Institution - Laboratory - Researcher): University of Coimbra and University of Lisbon, Portugal

Start year: 2018

Website: http://sites.google.com/view/moco-search/

Abstract: This international project for scientific cooperation (PICS), funded by CNRS and FCT, aims to fill the gap between exact and heuristic methods for multi-objective optimization. The goal is to establish the link between the design principles of exact and heuristic methods, to identify features that make a problem more difficult to be solved by each method, and to improve their performance by hybridizing search strategies. Special emphasis is given to rigorous performance assessment, benchmarking, and general-purpose guidelines for the design of exact and heuristic multi-objective search.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Luís Paquete, University of Coimbra, Portugal, April 2019
- Darrell Whitley, Colorado State University, USA, Invited Professor, July 2019
- Minami Miyakawa, Shinshu University, Japan, October 2019
- Renzo Massobrio, Republica University, Uruguay, January to March 2019
- Bernabe Dorronsoro, University of Cadiz, Spain, March 2019
- Rachid Ellaia, University of Mohamed V, Morocco, April 2019

9.5.1.1. Internships

- Kazuki Maeda, Shinshu University, Japan, November-December 2019
- Kyo Migishima, Shinshu University, Japan, November-December 2019

9.5.2. Visits to International Teams

9.5.2.1. Explorer programme

- T. Carneiro, Cray Inc., Seattle, WA, USA, December 2019
- E-G. Talbi, University of Elche, Spain, November 2019
- E-G. Talbi, University of Luxembourg, Luxembourg, June 2019
- E-G. Talbi, University of Bangkok, Thailand, January 2019
- E-G. Talbi, University of Colorado, USA, November 2019
- E-G. Talbi, University of Mohamed V, Morocco, April 2019
- A. Liefooghe, Shinshu University, Japan, May 2019
- B. Derbel, University of Coimbra, Portugal, October 2019
- A. Liefooghe, University of Coimbra, Portugal, October 2019
- N. Melab, University of Mons, Belgium, working meetings throughout the year

CELESTE Project-Team

7. Partnerships and Cooperations

7.1. National Initiatives

7.1.1. ANR

Sylvain Arlot and Matthieu Lerasle are part of the ANR grant FAST-BIG (Efficient Statistical Testing for high-dimensional Models: application to Brain Imaging and Genetics), which is lead by Bertrand Thirion (Inria Saclay, Parietal).

GEOSTAT Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

Geostat is a member of the GPR ("Grand Projet de Recherche") **ORIGINS** ("Origine, évolution, matière primordiale, nucléosynthèse, complexification, étoiles, planètes, Terre, habitabilité, climat, biodiversité, hominés, big data, sociologie, médiation scientifique) carried by Laboratoire d'Astrophysique de Bordeaux (LAB) (M. Gargaud). Geostat is involved in the axis "Data Science pour les Sciences de Origins".

9.2. 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).
- Prolongation for A. El Aouni in 2019 (4 months) through the program "BOOSTE TON DOC" of the Toubkal PHC project PHC-Toubkal project "Caractérisation multi-capteurs et suivi spatio-temporel de l'Upwelling sur la côte atlantique marocaine par imagerie satellitaire", which finished December 2018.
- GEOSTAT is a member of ISIS (Information, Image & Vision), 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.

9.3. European Initiatives

9.3.1. 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.

9.4. International Initiatives

9.4.1. Inria exploratory action

TRACME This project focuses on modelling a physical system from measurements on that system. How, starting from observations, to build a reliable model of the system dynamics? When multiple processes interact at different scales, how to obtain a significant model at each of these scales? The goal is to provide a model simple enough to bring some understanding of the system studied, but also a model elaborated enough to allow precise predictions. In order to do so, this project proposes to identify causally equivalent classes of system states, then model their evolution with a stochastic process. Renormalizing these equations is necessary in order to relate the scale of the continuum to that, arbitrary, at which data are acquired. Applications primarily concern natural sciences. PI: N. Brodu.

9.4.2. Participation in Other International Programs

9.4.2.1. 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 for emergency, 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. 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.

9.5. Introduction

9.5.1. Visits of International Scientists

- D. Singh [IIT Rookee, June 2019]

9.5.1.1. Internships

- D. Nash, level L3, intern in June 2019. Supervisor: N. Brodu.

9.5.2. Visits to International Teams

- PhD student A. Rashidi met with Dr Francis Bach of Inria Paris on optimization methods. first meeting was on November 2019.
- A. Rashidi registered for "Inversion et imagerie haute resolution" lectures of Dr. Francois Giovannelli, starting from January 2020.
- A. Rashidi participated in PRAIRE artificial intelligence summer school in October 2019 at Paris.

INOCS Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

ANR project AGIRE "Aide à la Gestion Intelligente des Ressources dans les Entrepôts - Decision system for smart management of resources in warehouses" in collaboration with Ecole des Mines de Saint-Etienne (Gardanne), IFSTTAR (Champs-sur-Marne), HappyChic (Tourcoing). This project addresses human resources management in warehouses which supply either sale points (B2B) or final consumers (B2C). Nowadays, such warehouses are under pressure. This is mainly due to the no inventory policy at the sale points and to the constant growth of e-commerce sales in France and Europe. In terms of logistics, this translates into an increasing number of parcels to prepare and to ship to satisfy an order, which is known typically a few hours before. Moreover, the total number of products to be packed varies very significantly from day-to-day by a factor of at least 3 (https://fr.wikipedia.org/wiki/Happychic).

The novelty of the project is twofold: (1) The human factor is explicitly be taken into account. It is integrated in the mathematical models and algorithms that are developed for the project. The aim is to improve the quality of employees' work ensuring the efficiency of the logistic system; (2) Problems at different decision levels are integrated and tackled jointly. At the tactical level, the main problematics are workload smoothing and the management of the storage zone. At operational level, the major issues concern the rearrangement of the picking zone, the picking tours, and the dynamic reorganization of activities to manage uncertainties.

ANR project PI-Commodality "Co-modal freight transportation chains: an approach based on physical internet" in collaboration with CGS-ARMINES (Paris), LAAS (Toulouse), DHL (2016 - 2019). The PI-co-modality project aims to design new sustainable logistic services between preset origins and destinations. It is based on innovative approaches both in terms of: (1) Logistics and transportation services: by considering the PI-internet approach, specifically: mesh logistics and transportation networks based on available capacities, by designing consistent integrated co-modal chains; (2) Methodology: by addressing the underlying problems according to two approaches: centralized and decentralized, by proposing news realistic models relevant for practitioner taking into account the consistency, by developing state-of-the-art decision making algorithms.

9.1.2. F.R.S.-FNRS (Belgium)

Bilevel optimization is a branch of mathematical optimization that deals with problems whose constraints embed an auxiliary optimization problem. The F.R.S.-FNRS research project "bilevel optimization" (2018-2019) will study such bilevel problems with bilinear objectives and simple second level problems. Each follower chooses one strategy in a given fixed set of limited size. Two classes of such problems will be studied: Pricing Problems and Stackelberg Security Games.

In pricing problems, prices for products must be determined to maximize the revenue of a leader given specific behaviors of customers (followers). More precisely, we will consider the single minded pricing problem and the rank pricing problem.

In Stackelberg games, mixed strategies to cover targets,must be determined in order to maximize the defender expected payoff given that attackers (followers) attack targets that maximize their own payoffs.

9.2. Regional Initiatives

9.2.1. Lille

The ELSAT research program addresses the issues involved in sustainable transportation and mobility. Within ELSAT, INOCS is involved on two projects devoted to hybrid optimization methods in logistics and to city logistics in collaboration with LAMIH (Université de Valenciennes), LGI2A (Université d'Artois) and LEOST (IFSTTAR). ELSAT is supported by the CPER 2015-2020 (State-Region Contract).

9.2.2. Brussels

ValueBugs is a citizen participatory research project, funded by INNOVIRIS (2018-2020). The objective of ValueBugs is to collectively develop a method for decentralized insect production in cities while enhancing the value of food waste on a small scale. In practical terms, peelings are consumed by insect larvae that have reached the end of their development and offer many promising outlets: feed for hens, farmed fish, pets... and much more! This new, totally innovative sector will be a new tool to be put in the hands of every citizen: we must therefore imagine it collectively.

9.3. International Initiatives

9.3.1. Inria International Labs

Inria Chile

Associate Team involved in the International Lab:

9.3.1.1. BIPLOS

Title: BIlevel Problems in LOgistics and Security

International Partner (Institution - Laboratory - Researcher):

University of Chile - Complex Engineering Systems Institute (ISCI) - Ordonez Fernando

Start year: 2017

See also: https://team.inria.fr/inocs/

This projet is devoted to bilevel optimisation problems with application in the security and logistics domains. Stackelberg games, including one defender and several followers, and competitive location problems will be considered. Mixed integer linear optimisation models and efficient algorithms to solve them will be developed.

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

9.3.2.1. LOBI

Title: Learning within Bilevel Optimization

International Partner (Institution - Laboratory - Researcher):

Polytechnique Montréal (Canada) - Research Group in Decision Analysis (GERAD) - Gilles Savard

Start year: 2018

See also: https://team.inria.fr/lobi/

The interplay between optimization and machine learning is one of the most important developments in modern computational science. Simultaneously there is a tremendous increase in the availability of large quantities of data in a multitude of applications, and a growing interest in exploiting the information that this data can provide to improve decision-making. Given the importance of big data in business analytics, its explicit integration into an optimization process is a challenge with high potential impact. The innovative project is concerned with the interconnection between machine learning approaches and a particular branch of optimization called bilevel optimization in this “big data” context. More precisely, we will focus on the development of new approaches integrating machine learning within bilevel optimization (LOBI: “learning au sein de l’Optimisation BIniveau”) for two important practical applications, the pricing problem in revenue management and the energy ressource aggregation problem in smart grids. The applications arise from current industry collaborations of the teams involved, and will serve as testbeds to demonstrate the potential impact of the proposed approach.

9.3.2.2. North-European associated team

Title: Physical-internet services for city logistics

International Partner (Institution - Laboratory - Researcher):

Norwegian School of Economics - Stein Wallace

Start year: 2017

In this project, we consider an urban logistic terminal and new logistics services which could be developed according to a Physical Internet approach. The main objective is to evaluate the services using optimization models created within the project. We are developing optimization models to identify win-win cooperation between carriers based on supply and demand. We aim to explore how to include stochasticity in the description of the supplies and demands, as well as travel times, and to what extent the plans within a day can improve by such knowledge. The second task is to develop solution algorithms for these models. These are real scientific challenges as we are facing stochastic mixed integer problems.

9.3.3. Inria International Partners

9.3.3.1. Informal International Partners

Department of Statistics and Operations Research, University of Vienna, Austria

Centre for Quantitative Methods and Operations Management, HEC-Liège, Belgium

Interuniversity Centre on Entreprise Networks, Transportation and Logistics (CIRRELT), Montreal, Canada

Department of Industrial Engineering, University of Talca, Curicó, Chile

Complex Engineering Systems Institute (ISCI), University of Chile, Santiago, Chile

Department of Mathematics, Trier University, Germany

The Centre for Business Analytics, University College Dublin, Ireland

Department of Electrical, Electronic, and Information Engineering, University of Bologna, Italy

Department of Mathematics, University of Padova, Italy

Department of Electrical and Information Engineering, University of Padova, Italy

Department of Mathematics, University of Salerno, Italy

Department of Control and Computer Engineering, Politecnico di Torino, Italy

Department of Mathematics, University of Aveiro, Portugal

Department of Statistics and Operations Research, Universidade de Lisboa, Portugal

Department of Statistics and Operational Research, University of Murcia, Spain

Institute of Mathematics, University of Seville, Spain

Stewart School of Industrial and Systems Engineering, Georgia Tech Institute of Technology, USA

9.3.4. Participation in Other International Programs

9.3.4.1. Inria International Chairs

IIC ANJOS Miguel

Title: Power Peak Minimization for the Smart Gird

International Partner (Institution - Laboratory - Researcher):

Polytechnique Montréal (Canada) - Miguel Anjos

Duration: 2016 - 2020

Start year: 2016

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Yasemin Arda Da Silveira, HEC-Liège, University of Liège, Belgium, Mar 2019
- Maria Del Carmen Gale Pola, University of Zaragoza, Spain, Feb 2019
- Anton Kleywegt, Georgia Institute of Technology, USA, from Apr 2019 until May 2019
- Daniel Pereda Herrera, University of Chile, Chile, from Nov 2019
- Sebastián Dávila, University of Chile, Chile, from June 2019 until Dec 2019
- Natividad Gonzalez Blanco, University of Sevilla, Spain, from May 2019 until July 2019
- Federica Laureanam, University of Salerno, Italy, from Feb 2019 until May 2019

9.4.1.1. Internships

Sebastián Dávila, Ph.D. student at University of Chile, June to December 2019

MISTIS Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

MISTIS is involved in the 4-year ANR project ExtremReg (2019-2023) hosted by Toulouse University. This research project aims to provide new adapted tools for nonparametric and semiparametric modeling from the perspective of extreme values. Our research program concentrates around three central themes. First, we contribute to the expanding literature on non-regular boundary regression where smoothness and shape constraints are imposed on the regression function and the regression errors are not assumed to be centred, but one-sided. Our second aim is to further investigate the study of the modern extreme value theory built on the use of asymmetric least squares instead of traditional quantiles and order statistics. Finally, we explore the less-discussed problem of estimating high-dimensional, conditional and joint extremes

The financial support for MISTIS is about 15.000 euros.

9.1.2. Grenoble Idex projects

MISTIS is involved in a transdisciplinary project **NeuroCoG** and in a newly accepted cross-disciplinary project (CDP) **Risk@UGA**. F. Forbes is also a member of the executive committee and responsible for the *Data Science for life sciences* work package in another project entitled **Grenoble Alpes Data Institute**.

- The main objective of the RISK@UGA project is to provide some innovative tools both for the management of risk and crises in areas that are made vulnerable because of strong interdependencies between human, natural or technological hazards, in synergy with the conclusions of Sendai conference. The project federates a hundred researchers from Human and Social Sciences, Information & System Sciences, Geosciences and Engineering Sciences, already strongly involved in the problems of risk assessment and management, in particular natural risks. The PhD thesis of Meryem Bousebata is one of the eleven PhDs funded by this project.
- The NeuroCoG project aims at understanding the biological, neurophysiological and functional bases of behavioral and cognitive processes in normal and pathological conditions, from cells to networks and from individual to social cognition. No decisive progress can be achieved in this area without an aspiring interdisciplinary approach. The interdisciplinary ambition of NeuroCoG is particularly strong, bringing together the best scientists, engineers and clinicians at the crossroads of experimental and life sciences, human and social sciences and information and communication sciences, to answer major questions on the workings of the brain and of cognition. One of the work package entitled InnobioPark is dedicated to Parkinson's Disease. The PhD thesis of Veronica Munoz Ramirez is one of the three PhDs in this work package.
- The Grenoble Alpes Data Institute aims at undertaking groundbreaking interdisciplinary research focusing on how data change science and society. It combines three fields of data-related research in a unique way: data science applied to spatial and environmental sciences, biology, and health sciences; data-driven research as a major tool in Social Sciences and Humanities; and studies about data governance, security and the protection of data and privacy. In this context, a 2-year multi-disciplinary projects has been granted in November 2018 to Mistis in collaboration with the Grenoble Institute of Neuroscience. The objective of this project is to develop a statistical learning technique that is able to solve a problem of tracking and analyzing a large population of single molecules. The main difficulties are: 1) the large number of observations to analyse, 2) the noisy nature of the signals, 3) the definition of a quality index to allow the elimination of poor-quality data and false positive signals. We also aim at providing a powerful, well-documented and open-source software, that will be user-friendly for non-specialists.

Also in the context of the Idex associated with the Université Grenoble Alpes, Alexandre Constantin was awarded half a PhD funding from IRS (Initiatives de Recherche Stratégique), 50 keuros.

9.1.3. Competitivity Clusters

The MINALOGIC VISION 4.0 project: MISTIS is involved in a three-year (2016-19) project. The project is led by VI-Technology, a world leader in Automated Optical Inspection (AOI) of a broad range of electronic components. The other partners are the G-Scop Lab in Grenoble and ACTIA company based in Toulouse. Vision 4.0 (in short Vi4.2) is one of the 8 projects labeled by Minalogic, the digital technology competitiveness cluster in Auvergne-Rhône-Alpes, that has been selected for the Industry 4.0 topic in 2016, as part of the 22nd call for projects of the FUI-Régions, for a total budget of the project of 3,4 Meuros.

Today, in the printed circuits boards (PCB) assembly industry, the assembly of electronic cards is a succession of ultra automated steps. Manufacturers, in constant quest for productivity, face sensitive and complex adjustments to reach ever higher levels of quality. Project VI4.2 proposes to build an innovative software solution to facilitate these adjustments, from images and measures obtained in automatic optical inspection (AOI). The idea is - from a centralized station for all the assembly line devices - to analyze and model the defects finely, to adjust each automatic machine, and to configure the interconnection logic between them to improve the quality. Transmitted information is essentially of statistical nature and the role of sc mistis is to identify which statistical methods might be useful to exploit at best the large amount of data registered by AOI machines. Preliminary experiments and results on the Solder Paste Inspection (SPI) step, at the beginning of the assembly line, helped determining candidate variables and measurements to identify future defects and to discriminate between them. More generally, the idea is to analyze two databases at both ends (SPI and Component Inspection) of the assembly process so as to improve our understanding of interactions in the assembly process, find out correlations between defects and physical measures and generate accordingly proactive alarms so as to detect as early as possible departures from normality.

9.1.4. Networks

MSTGA and AIGM INRA (French National Institute for Agricultural Research) networks: F. Forbes and J.B Durand are members of the INRA network called AIGM (ex MSTGA) network since 2006, http://carlit.toulouse.inra.fr/AIGM, on Algorithmic issues for Inference in Graphical Models. It is funded by INRA MIA and RNSC/ISC Paris. This network gathers researchers from different disciplines. MISTIS co-organized and hosted 2 of the network meetings in 2008 and 2015 in Grenoble.

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

VHIA ERC project (2015-19).

MISTIS is involved in R. Horaud's ERC advanced Grant entitled Vision and Hearing In Action. VHIA studies the fundamentals of audio-visual perception for human-robot interaction.

9.3. International Initiatives

9.3.1. Inria International Labs

International Laboratory for Research in Computer Science and Applied Mathematics
Associate Team involved in the International Lab:

9.3.1.1. SIMERG2E

Title: Statistical Inference for the Management of Extreme Risks, Genetics and Global Epidemiology

International Partner (Institution - Laboratory - Researcher):

UGB (Senegal) Abdou Kâ Diongue

Start year: 2018

See also: http://mistis.inrialpes.fr/simerge

SIMERG2E is built on the same two research themes as SIMERGE, with some adaptations to new applications: 1) Spatial extremes, application to management of extreme risks. We address the definition of new risk measures, the study of their properties in case of extreme events and their estimation from data and covariate information. Our goal is to obtain estimators accounting for possible variability, both in terms of space and time, which is of prime importance in many hydrological, agricultural and energy contexts. 2) Classification, application to genetics and global epidemiology. We address the challenge to build statistical models in order to test association between diseases and human host genetics in a context of genome-wide screening. Adequate models should allow to handle complexity in genomic data (correlation between genetic markers, high dimensionality) and additional statistical issues present in data collected from a family-based longitudinal survey (non-independence between individuals due to familial relationship and non-independence within individuals due to repeated measurements on a same person over time).

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

9.3.2.1. LANDER

Title: Latent Analysis, Adversarial Networks, and DimEnsionality Reduction

International Partner (Institution - Laboratory - Researcher):

La Trobe university, Melbourne (Australia) - Department of Mathematics - Hien Nguyen

Start year: 2019

See also: https://team.inria.fr/mistis/projects/lander/

The collaboration is based on three main points, in statistics, machine learning and applications: 1) clustering and classification (mixture models), 2) regression and dimensionality reduction (mixture of regression models and non parametric techniques) and 3) high impact applications (neuroimaging and MRI). Our overall goal is to collectively combine our resources and data in order to develop tools that are more ubiquitous and universal than we could have previously produced, each on our own. A wide class of problems from medical imaging can be formulated as inverse problems. Solving an inverse problem means recovering an object from indirect noisy observations. Inverse problems are therefore often compounded by the presence of errors (noise) in the data but also by other complexity sources such as the high dimensionality of the observations and objects to recover, their complex dependence structure and the issue of possibly missing data. Another challenge is to design numerical implementations that are computationally efficient. Among probabilistic models, generative models have appealing properties to meet all the above constraints. They have been studied in various forms and rather independently both in the statistical and machine learning literature with different depths and insights, from the well established probabilistic graphical models to the more recent (deep) generative adversarial networks (GAN). The advantages of the latter being primarily computational and their disadvantages being the lack of theoretical statements, in contrast to the former. The overall goal of the collaboration is to build connections between statistical and machine learning tools used to construct and estimate generative models with the resolution of real life inverse problems as a target. This induces in particular the need to help the models scale to high dimensional data while maintaining our ability to assess their correctness, typically the uncertainty associated to the provided solutions.

9.3.3. Inria International Partners

9.3.3.1. Informal International Partners

The context of our research is also the collaboration between MISTIS and a number of international partners such as the statistics department of University of Michigan, in Ann Arbor, USA, the statistics department of McGill University in Montreal, Canada, Université Gaston Berger in Senegal and Universities of Melbourne and Brisbane in Australia.

The main other active international collaborations in 2019 are with:

- E. Deme and A. Diop from Gaston Berger University in Senegal.
- N. Wang and C-C. Tu from University of Michigan, Ann Arbor, USA.
- Guillaume Kon Kam King, Stefano Favaro, Pierpaolo De Blasi, Collegio Carlo Alberto, Turin, Italy.
- Igor Prünster, Antonio Lijoi, and Riccardo Corradin Bocconi University, Milan, Italy.
- Bernardo Nipoti, Trinity College Dublin, Ireland.
- Yeh Whye Teh, Oxford University and DeepMind, UK.
- Stephen Walker, University of Texas at Austin, USA.
- Alex Petersen, University of California Santa Barbara, USA.
- Dimitri van de Ville, EPFL, University of Geneva, Switzerland.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Bernardo Nipoti, assistant professor at Milano Bicocca University, Italy, visited for a month in 2019 (three visits in February, April and September).
- Natalie Karavarsamis, assistant professor at La Trobe University in Melbourne, Australia, visited for a week in November 2019.
- Hien Nguyen, researcher at La Trobe University in Melbourne, Australia, visited for a month in November 2019.
- Darren Wraith, assistant professor at QUT, Brisbane, Australia, visited for 2 weeks in December 2019 and January 2020.
- Aboubacrène Ag Ahmad, PhD student at Univ. Gaston Berger, Senegal visited from September 2019 until November 2019.

9.4.1.1. Internships

Sharan Yalburgi did an internship of three months with Julyan Arbel on *Bayesian deep learning for model selection and approximate inference*.

9.4.1.2. Research Stays Abroad

Mariia Vladimirova visited David Dunson at Duke University for three months (Nov 2019 - Jan 2020).

MODAL Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. ONCOLille partnership

Participants: Sophie Dabo-Niang, Cristian Preda.

ONCOLille is a regional scientific interest group whose purpose is to develop fundamental, translational (pre-clinical) and clinical interdisciplinary cancer research, particularly in the field of resistance to therapies. Sophie Dabo-Niang is member of the executive group.

9.2. National Initiatives

9.2.1. Programme of Investments for the Future (PIA)

Bilille is a member of the PIA "Infrastructures en biologie-santé" IFB, French Institute of Bioinformatics (https://www.france-bioinformatique.fr/en). As the co-head of the platform, Guillemette Marot is thus involved in this network.

9.2.2. RHU PreciNASH

Participant: Guillemette Marot.

RHU PreciNASH

Acronym: PreciNASH

Project title: Non-alcoholic steato-hepatitis (NASH) from disease stratification to novel therapeutic approaches

Coordinator: F. Pattou

Duration: 5 years

Partners: FHU Integra and Sanofi

Abstract: PreciNASH, project coordinated by Pr. F. Pattou (UMR 859, EGID), aims at better understanding non alcoholic stratohepatitis (NASH) and improving its diagnosis and care. In this RHU, Guillemette Marot supervises a 2 years post-doc, as her team EA 2694 is a member of the FHU Integra. EA 2694 is involved in the WP1 for the development of a clinical-biological model for the prediction of NASH. Other partners of the FHU are UMR 859, UMR 1011 and UMR 8199, these last three teams being part of the labex EGID (European Genomic Institute for Diabetes). Sanofi is the main industrial partner of the RHU PreciNASH. The whole project will last 5 years (2016-2021).

9.2.3. CNRS PEPS Blanc – BayesRealForRNN project

Participants: Pascal Germain, Vera Shalaeva.

BayesRealForRNN project: PAC-Bayesian theory for recurrent neural networks: a control theoretic approach

Coordinator: Mihaly Petreczky, CNRS, UMR 9189 CRIStAL, Université de Lille

Year: 2019

Abstract: The project proposes to analyze the mathematical correctness of deep learning algorithms by combining techniques from control theory and PAC-Bayesian statistical theory. More precisely, the project proposes to concentrate on recurrent neural networks (RNNs), develop their structure theory using techniques from contol theory, and then apply this structure theory to derive PAC-Bayesian error bounds for RNNs.

9.2.4. CNRS AMIES PEPS 2 - DiagChange project

Participants: Cristian Preda, Quentin Grimonprez.

DiagChange

Coordinator: Cristian Preda, Inria MODAL

Year: 2019

Abstract: The project proposes to study the topic of change detection distribution for multivariate signal in a industrial context.The project is in collaboration with the Diagrams start-up.

9.2.5. AMIES PEPS 1 - CADIS2

Participants: Serge Iovleff, Sophie Dabo-Niang, Cristian Preda.

Partners: Société SIRS https://www.sirs-fr.com/sirs/fr/

Acronym: CADIS2

Project title: Classification Automatique D'Images Sentinel-2

Coordinator: Serge Iovleff

Year: 2019

Duration: 1 year

Abstract: In the context of several European projects, SIRS is in charge of exploring the improvements to be made to the "High Resolution Layers" as well as future prototypes such as "CORINE Land Cover +", on a European scale using the Sentinel-2 images, through the project H2020 "ECoLaSS". The CADIS2 project aims to develop, study and implement supervised classification methods to classify trees in predefined forest areas by SIRS.

9.2.6. AMIES PEPS 2 - MadiPa

Participants: Stéphane Girard, Serge Iovleff.

Partners: Société Phimeca http://phimeca.com/, Mistis team Inria Grenoble Rhône-Alpes

Acronym: MadiPa

Project title: Modèles Auto-associatifs pour la Dispersion de Polluants dans l'Atmosphère

Coordinator: Stéphane Iovleff

Duration: 18 month (start in december 2019)

Abstract: Our goal is to develop a method for predicting the dispersion of pollutants in the atmosphere from an initial emission map and meteorological data. A map of the probabilities of exceeding a critical threshold of pollutants will be estimated thanks to the construction of a metamodel: the large dimension of the problem is reduced by the use of auto-associative models, a nonlinear extension of the Principal Components Analysis.

9.2.7. ANR

9.2.7.1. ANR APRIORI

Participants: Benjamin Guedj, Pascal Germain, Hemant Tyagi, Vera Shalaeva.

APRIORI 2019–2023, ANR PRC

PAC-Bayesian theory and algorithms for deep learning and representation learning.

Main coordinator of the project: Emilie Morvant, Université Jean Monnet.

Funding: 300k EUR.

2 partners - MODAL (Inria LNE), Hubert Curien Lab. (UMR CNRS 5516).

9.2.7.2. ANR BEAGLE

Participants: Benjamin Guedj, Pascal Germain.

BEAGLE 2019–2023, ANR JCJC

PAC-Bayesian theory and algorithms for agnostic learning

Main coordinator of the project: Benjamin Guedj

Funding: 180k EUR

The consortium also includes Pierre Alquier (RIKEN AIP, Japan), Peter Grünwald (CWI, The Netherlands), Rémi Bardenet (UMR CRIStAL 9189).

9.2.7.3. ANR SMILE

Participants: Christophe Biernacki, Vincent Vandewalle.

SMILE Project-2018-2022

ANR project (ANR SMILE - Statistical Modeling and Inference for unsupervised Learning at LargE-Scale)

Main coordinator of the project: Faicel Chamroukhi, LMNO, Université de Caen

4 partners - MODAL (Inria LNE), LMNO UMR CNRS 6139 (Caen), LMRS UMR CNRS 6085 (Rouen), LIS UMR CNRS 7020 (Toulon).

9.2.7.4. ANR TheraSCUD2022

Participant: Guillemette Marot.

Acronym: TheraSCUD2022

Project title: Targeting the IL-20/IL-22 balance to restore pulmonary, intestinal and metabolic homeostasis after cigarette smoking and unhealthy diet

Coordinator: P. Gosset

Duration: 3 years (2017-2020)

Partners: CIIL Institut Pasteur de Lille and UMR 1019 INRA Clermont-Ferrand

Abstract: TheraSCUD2022, project coordinated by P. Gosset (Institut Pasteur de Lille), studies inflammatory disorders associated with cigarette smoking and unhealthy diet (SCUD). Guillemette Marot is involved in this ANR project as head of bilille platform, and will supervise 1 year engineer on integration of omic data. The duration of this project is 3 years (2017-2020).

9.2.8. Working groups

Sophie Dabo-Niang belongs to the following working groups:

- STAFAV (STatistiques pour l'Afrique Francophone et Applications au Vivant)
- ERCIM Working Group on computational and Methodological Statistics, Nonparametric Statistics Team

Benjamin Guedj belongs to the following working groups (GdR) of CNRS:

- ISIS (local referee for Inria Lille - Nord Europe)
- MaDICS
- MASCOT-NUM (local referee for Inria Lille - Nord Europe).

Guillemette Marot belongs to the StatOmique working group.

9.2.9. Other initiatives

Participants: Serge Iovleff, Cristian Preda, Vincent Vandewalle.

Serge Iovleff is the head of the project CloHe granted in 2016 by the Mastodons CNRS challenge "Big data and data quality". The project is axed on the design of classification and clustering algorithms for mixed data with missing values with applications to high spatial resolution multispectral satellite image time-series. Website. Cristian Preda and Vincent Vandewalle are also members of the CloHe project.

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

PERF-AI project (Nov 2018 - Nov 2020, involving Benjamin Guedj, Vincent Vandewalle - hired Florent Dewez, Arthur Taelpert). Two partners: Inria LNE and the company Safety Line (Paris, France).

Commercial aviation is already responsible for 3% of the total CO2 emissions, and with a constant growth rate of 5% per year, traffic will double within the next decade. With the support of new technologies such as Big Data, Artificial Intelligence, in-flight connectivity, major improvements can be introduced to optimize flight trajectories. PERF-AI focuses on the challenge of minimizing fuel consumption throughout the flight. The aim of PERF-AI is to provide a flight trajectory optimization prototype that implements new machine learning performance models.

The first step of the project that was carried out in the first year was to define, implement and test narrow system identification techniques. Several Machine Learning methods have been tried and have provided very encouraging initial results.

PERF-AI main objective is to provide a computation engine that can be used in two ways:

- support update of FMS that integrate individual aircraft performance models, that allow to perform accurate trajectory prediction;
- perform trajectory optimization on the ground using most accurate aircraft performance models.

9.3.2. Collaborations with Major European Organizations

Sophie Dabo-Niang is chair of EMS-CDC (European Mathematical society-Committe of Developing Countries).

Sophie Dabo-Niang is a member of the executive committee of CIMPA (International Centre of Pure and Applied Mathematics)

9.4. International Initiatives

9.4.1. Inria International Labs

9.4.1.1. 6PAC (IIL CWI-Inria)

Scientific leaders: Benjamin Guedj, Peter Grünwald.

Other members: Emilie Kaufmann (Inria LNE, EPI SequeL), Wouter Koolen (CWI).

Title: Making Probably Approximately Correct Learning Active, Sequential, Structure-aware, Efficient, Ideal and Safe

International Partner (Institution - Laboratory - Researcher):

CWI (Netherlands) - Machine Learning Group - Peter Grünwald (head)

Start year: 2018, renewed for 2019 and 2020

Webpage: https://bguedj.github.io/6pac/index.html

This project roots in statistical learning theory, which can be viewed as the theoretical foundations of machine learning. The most common framework is a setup in which one is given n training examples, and the goal is to build a predictor that would be efficient on new (similar) data. This efficiency should be supported by PAC (Probably Approximately Correct) guarantees, e.g. upper bounds on the excess risk of a predictor that hold with high probability. Such guarantees however often hold under stringent assumptions which are typically never met in real-life application, e.g., independent, identically distributed data. More realistic modelling of data has triggered many research efforts in several directions: first, accommodating possible data (e.g., dependent, heavy-tailed), and second, in the direction of sequential learning, in which the predictor can be built on the fly, while new data is gathered. We believe that an ever more realistic paradigm is active learning, a setup in which the learner actively requests data (possibly facing constraints, such as storage, velocity, cost, etc.)

and adapts its queries to optimize its performance. The 3-years objective of 6PAC (where 6 stands for Sequential, Active, Efficient, Structured, Ideal, Safe - the six research directions we intend to contribute to) is to pave the way to new PAC generalization and sample-complexity upper and lower bounds beyond batch learning. Our ambition is to contribute to several learning setups, ranging from sequential learning (where data streams are collected) to adaptive and active learning (where data streams are requested by the learning algorithm).

9.4.2. Inria International Partners

9.4.2.1. Declared Inria International Partners

A byproduct of Benjamin Guedj's sabbatical position at University College London (UCL) since Dec 2018 is a strengthened link between UCL and Inria. DGDS has established contact with UCL President in April 2019 and a MoU has been signed between UCL and Inria in December 2019. A research group (known as Inria@UCL) has been established by Benjamin Guedj within UCL, Department for Computer Science, Centre for Artificial Intelligence. Inria@UCL initiative is expected to grow in 2020 and possibly evolve into a joint team or more. A strategic partnership between Inria and UCL will be explored in 2020.

SIMERGE

Title: Statistical Inference for the Management of Extreme Risks and Global Epidemiology

International Partner (Institution - Laboratory - Researcher):

UGB (Senegal) - LERSTAD - Abdou Ka Diongue

Serge Iovleff and Sophie Dabo-Niang are associated members of SIMERGE.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Mihai Cucuringu (University of Oxford) visited Hemant Tyagi in January 2019 for a research visit of 1 week.
- Martin Wahl (Humboldt Universität from Berlin) visited Alain Celisse in March 2019 for a research visit of 1 week and November 2019 for a research visit of 1 week.
- Apoorv Vikram Singh is currently visiting Hemant Tyagi to work on a research project which is jointly supervised by Hemant Tyagi and Mihai Cucuringu (University of Oxford). The duration of the visit is 4 months (October 1, 2019 - January 31, 2020) and is partly funded by the Alan Turing Institute, London.
- Abdou Kâ Diongue visited Serge Iovleff in June 2019 for one month.

9.5.2. Visits to International Teams

9.5.2.1. Sabbatical programme

Since Dec 2018, Benjamin Guedj is on sabbatical at University College London (UCL). He is a PI of the UCL Centre for Artificial Intelligence (UCL AI) and a visiting researcher at the Alan Turing Institute. This has led to the Inria@UCL initiative, see supra.

9.5.2.2. Research Stays Abroad

- Sophie Dabo-Niang has visited University of Kuala Lumpur, Malaysia in August 2019 and University of Mohamed V, Morroco in December 2019.
- Serge Iovleff has visited University Gaston Berger, Senegal in February 2019 and gave a course entitled “Introduction to Statistical Learning”.
- Hemant Tyagi visited Mihai Cucuringu and Benjamin Guedj at the Alan Turing Institute, UK from in October 2019.
- Alain Celisse visited Markus Reißand Martin Wahl at the Humboldt Universität, Germany in March and December 2019.
- Alain Celisse visited Benjamin Guedj at the University College London, UK in February-March and July-August 2019.
- Pascal Germain visited Benjamin Guedj at University College London, UK on several occasions totalling about 1.5 month in 2019.
- Cristian Preda visited Amarioarei Alexandru at University of Bucharest on several occasions totalling about 1 week in 2019.

RANDOPT Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

- PGMO/FMJH project "AESOP: Algorithms for Expensive Simulation-Based Optimization", 7kEUR, 2017–2019

9.2. National Initiatives

9.2.1. ANR

- ANR project "Big Multiobjective Optimization (BigMO)", Dimo Brockhoff participates in this project through the Inria team BONUS in Lille (2017–2020)

9.3. International Initiatives

9.3.1. Inria International Partners

9.3.1.1. Informal International Partners

- Youhei Akimoto, Tsukuba University, Japan
- Tobias Glasmachers, Ruhr University, Bochum, Germany
- Tea Tušar, Jozef Stefan Institute, Ljubljana, Slovenia

9.4. International Research Visitors

9.4.1. Visits to International Teams

9.4.1.1. Research Stays Abroad

Anne Auger and Dimo Brockhoff visited Tea Tušar (Jozef Stefan Institute, Slovenia) for two weeks in April 2019

REALOPT Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

- **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.

9.2. International Initiatives

9.2.1. Inria International Partners

9.2.1.1. Informal International Partners

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

We continue close collaboration with the LOGIS laboratory (Universidade Federal Fluminense, Niteroi, Brazil) after the end of the Inria Associate Team SAMBA.

9.3. International Research Visitors

9.3.1. Visits of International Scientists

Eduardo Uchoa visited the team in April 2019 for one week.

Emir Démirovic (University of Melbourne, Australia) visited the team in July for one week

Isaac Cleland (University of Auckland, New-Zealand) visited the team in July for one week

9.3.2. Visits to International Teams

9.3.2.1. Research Stays Abroad

Guillaume Marques spent 3 months in Universidade Federal Fluminense, Niteroi, Brazil (August-November 2019), financed by mobility grant of IdEx Bordeaux

SEQUEL Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. With U. INSERM 1190, CHU Lille

Participants: Odalric-Ambrym Maillard, Philippe Preux, Philippe Preux.

Title: Bandits for Health (B4H)

Type: I-SITE Lille

Coordinator: Philippe Preux

Duration: 2019–2023

Abstract: B4H is a fundamental research project on a certain type of bandit algorithms, tailored to be applied to post-surgical patient follow-up. Bandit in a non-stationary environment will be studied. This work is performed in collaboration with Pr. F. Pattou and his group.

Title: No title

Type: Informal

Coordinator: Philippe Preux

Duration: 2019–2020

Abstract: This is mostly a data analysis work in order to study whether a certain disease may be predicted based on a certain dataset collected by U. INSERM 1190. Estelle Chatelain, a BiLille engineer, is involved in this project. This work is performed in collaboration with Pr. F. Pattou and his group.

9.1.2. With Service de Radiologie et Imagerie Musculosquelettique, CHU Lille

Participants: Philippe Preux, Franck Valentini.

Title: Radiology AI Demonstrator (RAID)

Type: CPER, Région Hauts-de-France

Coordinator: Philippe Preux

Duration: 2019–2020

Abstract: The goal of the RAID project is to assess the potential of deep learning for radio analysis and patient triage. Various applications are investigated.

9.2. National Initiatives

9.2.1. ANR BOLD

Participants: Émilie Kaufmann, Michal Valko, Pierre Ménard, Xuedong Shang, Omar Darwiche Domingues.

Title: Beyond Online Learning for better Decision making

Type: National Research Agency

Coordinator: Vianney Perchet (ENS Paris-Saclay / ENSAE)

Duration: 2019–2023

Abstract: Reactive machine learning algorithms adapt to data generating processes, typically do not require large computational power and, moreover, can be translated into offline (as opposed to online) algorithms if needed. Introduced in the 30s in the context of clinical trials, online ML algorithms have been gaining a lot of theoretical interest for the last 15 years because of their applications to the optimization of recommender systems, click through rates, planning in congested networks, to name just a few. However, in practice, such algorithms are not used as much as they should, because the traditional low-level modelling assumptions they are based upon are not appropriate, as it appears.

Instead of trying to complicate and generalise arbitrarily a framework unfit for potential applications, we will tackle this problem from another perspective. We will seek a better understanding of the simple original problem and extend it in the appropriate directions. There are currently three main barriers to a broader development of online learning, that this project aim at overcoming. 1) The classical "one step, one decision, one reward" paradigm is unfit. 2) Optimality is defined with respect to worst-case generic lower bounds and mechanics behind online learning are not fully understood. 3) Algorithms were designed in a non strategic or interactive environment.

The project gathers four parnters: ENS Paris-Saclay, University of Toulouse, Inria Lille and Université Paris Descartes.

9.2.2. ANR BoB

Participant: Michal Valko.

Title: Bayesian statistics for expensive models and tall data

Type: National Research Agency

Coordinator: CNRS (Rémi Bardenet)

Duration: 2016–2020

Abstract: Bayesian methods are a popular class of statistical algorithms for updating scientific beliefs. They turn data into decisions and models, taking into account uncertainty about models and their parameters. This makes Bayesian methods popular among applied scientists such as biologists, physicists, or engineers. However, at the heart of Bayesian analysis lie 1) repeated sweeps over the full dataset considered, and 2) repeated evaluations of the model that describes the observed physical process. The current trends to large-scale data collection and complex models thus raises two main issues. Experiments, observations, and numerical simulations in many areas of science nowadays generate terabytes of data, as does the LHC in particle physics for instance. Simultaneously, knowledge creation is becoming more and more data-driven, which requires new paradigms addressing how data are captured, processed, discovered, exchanged, distributed, and analyzed. For statistical algorithms to scale up, reaching a given performance must require as few iterations and as little access to data as possible. It is not only experimental measurements that are growing at a rapid pace. Cell biologists tend to have scarce data but large-scale models of tens of nonlinear differential equations to describe complex dynamics. In such settings, evaluating the model once requires numerically solving a large system of differential equations, which may take minutes for some tens of differential equations on today's hardware. Iterative statistical processing that requires a million sequential runs of the model is thus out of the question. In this project, we tackle the fundamental cost-accuracy trade-off for Bayesian methods, in order to produce generic inference algorithms that scale favorably with the number of measurements in an experiment and the number of runs of a statistical model. We propose a collection of objectives with different risk-reward trade-offs to tackle these two goals. In particular, for experiments with large numbers of measurements, we further develop existing subsampling-based Monte Carlo methods, while developing a novel decision theory framework that includes data constraints. For expensive models, we build an ambitious programme around Monte Carlo methods that leverage determinantal processes, a rich class of probabilistic tools that lead to accurate inference with limited model evaluations. In short, using innovative techniques such as subsampling-based Monte Carlo and determinantal point processes, we propose in this project to push the boundaries of the applicability of Bayesian inference.

9.2.3. ANR Badass

Participants: Odalric-Ambrym Maillard, Émilie Kaufmann.

Title: BAnDits for non-Stationarity and Structure

Type: National Research Agency

Coordinator: Inria Lille (O. Maillard)

Duration: 2016–2020

Abstract: Motivated by the fact that a number of modern applications of sequential decision making require developing strategies that are especially robust to change in the stationarity of the signal, and in order to anticipate and impact the next generation of applications of the field, the BADASS project intends to push theory and application of MAB to the next level by incorporating non-stationary observations while retaining near optimality against the best not necessarily constant decision strategy. Since a non-stationary process typically decomposes into chunks associated with some possibly hidden variables (states), each corresponding to a stationary process, handling non-stationarity crucially requires exploiting the (possibly hidden) structure of the decision problem. For the same reason, a MAB for which arms can be arbitrary non-stationary processes is powerful enough to capture MDPs and even partially observable MDPs as special cases, and it is thus important to jointly address the issue of non-stationarity together with that of structure. In order to advance these two nested challenges from a solid theoretical standpoint, we intend to focus on the following objectives: *(i)* To broaden the range of optimal strategies for stationary MABs: current strategies are only known to be provably optimal in a limited range of scenarios for which the class of distribution (structure) is perfectly known; also, recent heuristics possibly adaptive to the class need to be further analyzed. *(ii)* To strengthen the literature on pure sequential prediction (focusing on a single arm) for non-stationary signals via the construction of adaptive confidence sets and a novel measure of complexity: traditional approaches consider a worst-case scenario and are thus overly conservative and non-adaptive to simpler signals. *(iii)* To embed the low-rank matrix completion and spectral methods in the context of reinforcement learning, and further study models of structured environments: promising heuristics in the context of e.g. contextual MABs or Predictive State Representations require stronger theoretical guarantees.

This project will result in the development of a novel generation of strategies to handle non-stationarity and structure that will be evaluated in a number of test beds and validated by a rigorous theoretical analysis. Beyond the significant advancement of the state of the art in MAB and RL theory and the mathematical value of the program, this JCJC BADASS is expected to strategically impact societal and industrial applications, ranging from personalized health-care and e-learning to computational sustainability or rain-adaptive river-bank management to cite a few.

9.2.4. Grant of Fondation Mathématique Jacques Hadamard

Participants: Michal Valko, Ronan Fruit.

Title: Theoretically grounded efficient algorithms for high-dimensional and continuous reinforcement learning

Type: PGMO-IRMO, funded by Criteo

PI: Michal Valko

Criteo contact: Marc Abeille

Duration: 2018–2020

Abstract: While learning how to behave optimally in an unknown environment, a reinforcement learning (RL) agent must trade off the exploration needed to collect new information about the dynamics and reward of the environment, and the exploitation of the experience gathered so far to gain as much reward as possible. A good measure of the agent's performance is the regret, which measures the difference between the performance of optimal policy and the actual rewards accumulated by the agent. Two common approaches to the exploration-exploitation dilemma with provably good regret guarantees are the optimism in the face of uncertainty principle and Thompson Sampling. While these approaches have been successfully applied to small environments with a finite number of states and action (tabular scenario), existing approach for large or continuous environments either rely on heuristics and come with no regret guarantees, or can be proved to achieve small regret but cannot be implemented efficiently. In this project, we propose to make a significant contribution in the understanding of large and/or continuous RL problems by developing and analyzing new algorithms that perform well both in theory and practice.

This research line can have a practical impact in all the applications requiring continuous interaction with an unknown environment. Recommendation systems belong to this category and, by definition, they can be modeled has a sequence of repeated interaction between a learning agent and a large (possibly continuous) environment.

9.2.5. With CIRAD and CGIAR

Participants: Philippe Preux, Odalric-Ambrym Maillard, Romain Gautron.

Title: Crop management

Duration: 2019–2022

Abstract: We study how reinforcement learning may be used to provide recommendations of practices to small farm holders in under-developped countries. In such countries, agriculture remains mostly a non mechanized activity, dealing with fields of very small surface.

This is a very challenging application for RL: data is scarce, recommendations made to farmers should be of quality: we can not just learn by making millions of bad recommendations to people who use them to live and feed their family. Modeling the problem as an RL is yet an other challenge.

We feel that it is very interesting to challenge RL with such complex tasks. Solving games with RL is nice and fun, but we should assess RL abilities to solve real risky tasks.

This pioneering work is done within Romain Gautron's PhD, in collaboration with CIRAD, the CGIAR, and in relation with the Africa Rising program.

9.2.6. Project CNRS-INSERM REPOS

Participants: Émilie Kaufmann, Clémence Réda [INSERM].

Title: Repositionnement de médicaments basé sur leurs effets transcriptionnels par des approches de réseaux géniques

Type: Appel à projet Santé Numérique

PI: Pr. Andrée Delahaye-Duriez (INSERM, UMR1141)

Duration: 2019

Abstract: Drug repurposing consists in studying molecules already commercialized and find other therapies in which they may be efficient. The quality of therapeutic components is often assessed by their affinity to a given protein, but it can also be assessed in terms of their impact at the transciptomic level. The aim of this project is to develop a method for selecting which drugs could be used for a given disease based on their ability to inverse the transcriptomic signature of a pathological phenotype. We will propose a new method based on algorithms for sequential decision making (bandit algorithms) to adaptively select which drug should be explored, where exploring a drug means performing simulations to propagate the perturbation (using for example gene regulatory networks) and estimate the transcriptomic impact of the perturbation induced by the drug. These simulations will hinge on existing gene expression data that are already available for many drugs, but also on new transcriptomic data generated for a mouse model of a rare disease called the Ondine syndrom.

9.2.7. National Partners

- ENS Paris-Saclay
  - M. Valko collaborated with V. Perchet on structured bandit problem. They co-supervise a PhD student (P. Perrault) together
  - O-A. Maillard collaborates with V. Perchet on automated feature learning. They co-supervise a PhD student (R. Ouhamma) together
  - E. Kaufmann collaborated with V. Perchet and E. Boursier on Multi-Player bandits
- Institut de Mathématiques de Toulouse, then Ecole Normale Supérieure de Lyon

  - E. Kaufmann collaborated with Aurélien Garivier on sequential testing and structured bandit problems
- Centrale-Supélec Rennes:
  - E. Kaufmann co-advises Lilian Besson, who works at CentraleSupélec with Christophe Moy on MAB for cognitive radio and Internet-of-Things communications
- Participation to the Inria Project Lab (IPL) "HPC – Big Data": Started in 2018, this IPL gathers a dozen Inria team-projects, mixing researchers in HPC with researchers in machine learning and data science. SEQUEL contribution in this project is about how we can take advantage of HPC for our computational needs regarding deep learning and deep reinforcement learning, and also how such learning algorithms might be redesigned or re-implemented in order to take advantage of HPC architectures.
- Participation to the Inria Project Lab (IPL) "HYAIAI": Started in 2019, this IPL gathers Magnet and SEQUEL in Lille, Tau in Saclay, Lacodam in Rennes, Orpailleur and Multispeech in Nancy. The goal of this IPL is to study machine learning combining symbolic and numeric approaches, to obtain interpretable AI systems.
- PCIM (École Polytechnique)
  - Ph. Preux collaborates with Tanguy Levent (PhD student) on the control of smartgrids with reinforcement learning
- Defrost (Inria Lille)
  - Ph. Preux collaborates with Pierre Schegg (PhD student) on the control of soft robots with reinforcement learning

9.3. European Initiatives

9.3.1. Collaborations in European Programs, Except FP7 & H2020

9.3.1.1. DELTA

Participants: Michal Valko, Émilie Kaufmann, Omar Darwiche Domingues, Pierre Ménard.

Program: CHIST-ERA

Project acronym: DELTA

Project title: Dynamically Evolving Long-Term Autonomy

Duration: October 2017 - December 2021

Coordinator: Anders Jonsson (PI)

Inria Coordinator: Michal Valko

Other partners: UPF Spain, MUL Austria, ULG Belgium

Abstract: Many complex autonomous systems (e.g., electrical distribution networks) repeatedly select actions with the aim of achieving a given objective. Reinforcement learning (RL) offers a powerful framework for acquiring adaptive behaviour in this setting, associating a scalar reward with each action and learning from experience which action to select to maximise long-term reward. Although RL has produced impressive results recently (e.g., achieving human-level play in Atari games and beating the human world champion in the board game Go), most existing solutions only work under strong assumptions: the environment model is stationary, the objective is fixed, and trials end once the objective is met. The aim of this project is to advance the state of the art of fundamental research in lifelong RL by developing several novel RL algorithms that relax the above assumptions. The new algorithms should be robust to environmental changes, both in terms of the observations that the system can make and the actions that the system can perform. Moreover, the algorithms should be able to operate over long periods of time while achieving different objectives. The proposed algorithms will address three key problems related to lifelong RL: planning, exploration, and task

decomposition. Planning is the problem of computing an action selection strategy given a (possibly partial) model of the task at hand. Exploration is the problem of selecting actions with the aim of mapping out the environment rather than achieving a particular objective. Task decomposition is the problem of defining different objectives and assigning a separate action selection strategy to each. The algorithms will be evaluated in two realistic scenarios: active network management for electrical distribution networks, and microgrid management. A test protocol will be developed to evaluate each individual algorithm, as well as their combinations.

9.4. International Initiatives

9.4.1. Inria International Partners

- É. Kaufmann visited CWI, Amsterdam for one week in February, working with Wouter Koolen, Rémy Degenne and Rianne De Heide. Pierre Ménard also collaborated with them.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Anders Jonsson, Pompeu Fabra University, Spain ,sabbatical year Sep 2019 – Jul 2020
- Kaige Yang, University College London, UK, Oct 9 & Jan 9 2020
- Rianne de Heide, CWI, The Netherlands, April 23 – August 3, 2019
- Chuan-Zheng Lee, Stanford University, USA, June – October 2019
- Arun Verma, IIT Bombay, June 1 – November 30, 2019

9.5.1.1. Internships

- Alessio Della Libera, from Jul 2019 until Sep 2019

  TD-Gammon, and his github with the gym-backgammon code

SIERRA Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

Alexandre d'Aspremont: IRIS, PSL "Science des données, données de la science".

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

ERC Sequoia Title: Robust algorithms for learning from modern data

Programm: H2020

Type: ERC

Duration: 2017-2022

Coordinator: Inria

Inria contact: Francis Bach

Abstract: Machine learning is needed and used everywhere, from science to industry, with a growing impact on many disciplines. While first successes were due at least in part to simple supervised learning algorithms used primarily as black boxes on medium-scale problems, modern data pose new challenges. Scalability is an important issue of course: with large amounts of data, many current problems far exceed the capabilities of existing algorithms despite sophisticated computing architectures. But beyond this, the core classical model of supervised machine learning, with the usual assumptions of independent and identically distributed data, or well-defined features, outputs and loss functions, has reached its theoretical and practical limits. Given this new setting, existing optimization-based algorithms are not adapted. The main objective of this project is to push the frontiers of supervised machine learning, in terms of (a) scalability to data with massive numbers of observations, features, and tasks, (b) adaptability to modern computing environments, in particular for parallel and distributed processing, (c) provable adaptivity and robustness to problem and hardware specifications, and (d) robustness to non-convexities inherent in machine learning problems. To achieve the expected breakthroughs, we will design a novel generation of learning algorithms amenable to a tight convergence analysis with realistic assumptions and efficient implementations. They will help transition machine learning algorithms towards the same widespread robust use as numerical linear algebra libraries. Outcomes of the research described in this proposal will include algorithms that come with strong convergence guarantees and are well-tested on real-life benchmarks coming from computer vision, bioinformatics, audio processing and natural language processing. For both distributed and non-distributed settings, we will release open-source software, adapted to widely available computing platforms.

9.3. International Research Visitors

9.3.1. Visits of International Scientists

- Sebastian Pokutta from TU & Zuse Institute, Berlin, December 2019.
- Critobal Guzman from Universidad Católica de Chile, July 2019.
- Quentin Berthet from University of Cambridge, from Feb 2019 until Apr 2019.
- Eduard Gorbunov from Moscow Institute of Physics and Technology, Oct 2019.
- Song Mei, from Stanford University, from Sep 2019 until Oct 2019.
- Anant Raj, from M.P.I. Tubingen, from Oct 2019.
- Aadirupa Saha, from Indian Institute of Technology, Bangalore, from Nov 2019

TAU Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

- **EPITOME** 2017-2020 (225kEuros), *Efficient rePresentatIon TO structure large-scale satellite iMagEs* (Section 7.5.2).
  Coordinator: Yuliya Tarabalka (Titane team, Inria Sophia-Antipolis)
  Participant: Guillaume Charpiat
- **HUSH** 2020-2023 (348kEuros), *The HUman Supply cHain behind smart technologies*.
  Coordinator: Antonio A. Casilli (Telecom Paris)
  Participant: Paola Tubaro

9.1.2. Others

- **Nutriperso** 2017-2020, 122 kEuros. Personalized recommendations toward healthier eating practices (Section 7.3.2).
  U. Paris-Saclay IRS (*Initiative de Recherche Stratégique*)
  Partners: INRA (coordinator), INSERM, Agro Paristech, Mines Telecom
  Participants: Philippe Caillou, Flora Jay, Michèle Sebag, Paola Tubaro
- **IRS CDS** 2017-2020, 75 kEuros. Personalized recommendations toward healthier eating practices
  U. Paris-Saclay IRS (*Initiative de Recherche Stratégique*)
  Partners: INRA (coordinator), INSERM, Agro Paristech, Mines Telecom
  Participants: Philippe Caillou, Flora Jay, Michèle Sebag, Paola Tubaro
- **PIA Adamme** 2015-2019 (258 kEuros) Machine Learning on a mass-memory architecture.
  Coordinator: Bruno Farcy (Bull SAS)
  Participants: Marc Schoenauer, Guillaume Charpiat, Cécile Germain-Renaud
- **NEXT** 2017-2021 (675 kEuros). Simulation, calibration, and optimization of regional or urban power grids (Section 4.2).
  ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie)
  Coordinator: ARTELYS
  Participants Isabelle Guyon, Marc Schoenauer, Michèle Sebag, Victor Berger (PhD), Herilalaina Rakotoarison (PhD), Berna Bakir Batu (Post-doc)
- **DATAIA Vadore** 2018-2020 (105 kEuros) VAlorizations of Data to imprOve matching in the laboR markEt, with CREST (ENSAE) and Pôle Emploi (Section 7.3.1).
  Coordinator: Michèle Sebag
  Participants: Philippe Caillou, Isabelle Guyon
- **PIA JobAgile** 2018-2021 (379 kEuros) *Evidence-based Recommandation pour l'Emploi et la Formation* (Section 7.3.1).
  Coordinator: Michèle Sebag and Stéphanie Delestre (Qapa)
  Participants: Philippe Caillou, Isabelle Guyon
- **HADACA** 2018-2019 (50 kEuros), within EIT Health, for the organization of challenges toward personalized medicine (Section 7.6).
  Coordinator: Magali Richard (Inria Grenoble)
  Participants: Isabelle Guyon

- **IPL HPC-BigData** 2018-2022 (100 kEuros) High Performance Computing and Big Data (Section 7.5.5)
  Coordinator: Bruno Raffin (Inria Grenoble)
  Participants: Guillaume Charpiat, Loris Felardos (PhD)
- **ScGlass** 2016-2020 (10 M$), "Cracking the Glass problem" international collaboration on cracking the glass problem, funded by the Simons Fundation (NY, NYC, USA).
  Coordinator: 13 PIs around the world (see https://scglass.uchicago.edu/)
  Participants: (alumni, actively collaborating with members) François Landes

9.2. European Initiatives

9.2.1. Collaborations with Major European Organizations

CERN: collaboration with two major CERN experiments (ATLAS and CMS) on the role of machine learning at all stages of the scientific discovery process. C. Germain supervises a CERN-funded PhD.

9.3. International Initiatives

9.3.1. Inria International Labs

IIL CWI-Inria
Associate Team involved in the International Lab:

9.3.1.1. MDG-TAO

Title: Data-driven simulations for Space Weather predictions

International Partner (Institution - Laboratory - Researcher):

CWI (Netherlands) - Multiscale Dynamics Group - Enrico Camporeale

Start year: 2017

See also: http://pages.saclay.inria.fr/cyril.furtlehner/html/mdg-tao.html

We propose an innovative approach to Space Weather modeling: the synergetic use of state-of-the-art simulations with Machine Learning and Data Assimilation techniques, in order to adjust for errors due to non-modeled physical processes, and parameter uncertainties. We envision a truly multidisciplinary collaboration between experts in Computational Science and Data assimilation techniques on one side (CWI), and experts in Machine Learning and Data Mining on the other (Inria). Our research objective is to realistically tackle long-term Space Weather forecasting, which would represent a giant leap in the field. This proposal is extremely timely, since the huge amount of (freely available) space missions data has not yet been systematically exploited in the current computational methods for Space Weather. Thus, we believe that this work will result in cutting-edge results and will open further research topics in space Weather and Computational Plasma Physics.

CQFD Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. QuAMProcs of the program Project Blanc of the ANR

The mathematical analysis of metastable processes started 75 years ago with the seminal works of Kramers on Fokker-Planck equation. Although the original motivation of Kramers was to « elucidate some points in the theory of the velocity of chemical reactions », it turns out that Kramers' law is observed to hold in many scientific fields: molecular biology (molecular dynamics), economics (modelization of financial bubbles), climate modeling, etc. Moreover, several widely used efficient numerical methods are justified by the mathematical description of this phenomenon.
Recently, the theory has witnessed some spectacular progress thanks to the insight of new tools coming from Spectral and Partial Differential Equations theory.
Semiclassical methods together with spectral analysis of Witten Laplacian gave very precise results on reversible processes. From a theoretical point of view, the semiclassical approach allowed to prove a complete asymptotic expansion of the small eigenvalues of Witten Laplacian in various situations (global problems, boundary problems, degenerate diffusions, etc.). The interest in the analysis of boundary problems was rejuvenated by recent works establishing links between the Dirichlet problem on a bounded domain and the analysis of exit event of the domain. These results open numerous perspectives of applications. Recent progress also occurred on the analysis of irreversible processes (e.g. on overdamped Langevin equation in irreversible context or full (inertial) Langevin equation).
The above progresses pave the way for several research tracks motivating our project: overdamped Langevin equations in degenerate situations, general boundary problems in reversible and irreversible case, non-local problems, etc.

8.1.2. Chaire Stress Test of the Ecole Polytechnique

The Chaire "Stress Testing" is a specific research program between Ecole Polytechnique, BNP Paribas, Fondation de l'Ecole Polytechnique, and is hosted at Polytechnique by the Center of Applied Mathematics. This research project is part of an in-depth reflection on the increasingly sophisticated issues surrounding stress tests (under the impulse of the upcoming European Banking regulation). Simulation of extreme adverse scenarios is an important topic to better understand which critical configurations can lead to financial and systemic crises. These scenarios may depend on complex phenomena, for which we partially lack information, making the modeling incomplete and uncertain. Last, the data are multivariate and reflect the dependency between driving variables. From the above observations, different lines of research are considered:
1. the generation of stress test and meta-modeling scenarios using machine learning;
2. the quantification of uncertainties in risk metrics;
3. modeling and estimation of multidimensional dependencies.

8.1.3. 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.

8.1.4. 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.

8.1.5. 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.

8.1.6. Mission pour les initiatives transverses et interdisciplinaires, Défi Modélisation du Vivant, projet MISGIVING

The aim of MISGIVING (MathematIcal Secrets penGuins dIVING) is to use mathematical models to understand the complexity of the multiscale decision process conditioning not only the optimal duration of a dive but also the diving behaviour of a penguin inside a bout. A bout is a sequence of succesive dives where the penguin is chasing prey. The interplay between the chasing period (dives) and the resting period due to the physiological cost of a dive (the time spent at the surface) requires some kind of optimization.

8.2. European Initiatives

8.2.1. Collaborations in European Programs, Except FP7 & H2020

Program: Direcion 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, Direcion 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. 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 Politécnica da Universidade de São 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 2019.

Tomas Prieto-Rumeau (Department of Statistics and Operations Research, UNED, Madrid, Spain) visited the team during one week in 2019. The main subject of the collaboration is the approximation of Markov Decision Processes

Anna Jaskiewicz (Politechnika Wrocławska) visited the team during one week in 2019. The main subject of the collaboration is the approximation of Markov Decision Processes

8.4.2. Visits to International Teams

Pierrick Legrand visited the Instituto Tecnológico de Tijuana from 08/12/2019 to 17/12/2019.

MATHRISK Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

- ANR Cosmos 2015-2018, Participant: B. Jourdain ; Partners : Ecole des Ponts, Telecom, INIRIA Rennes and IBPC
- Labex Bezout
  http://bezout.univ-paris-est.fr

9.1.1. Competitivity Clusters

Pôle Finance Innovation

9.2. International Initiatives

9.2.1. Inria International Partners

9.2.1.1. Informal International Partners

- Center of Excellence program in Mathematics and Life Sciences at the Department of Mathematics, University of Oslo, Norway, (B. Øksendal).
- Cornell University, ORIE department (Andreea Minca)
- Roma Tor Vergata University (Lucia Caramellino)
- Ritsumeikan University (A. Kohatsu-Higa).

9.3. International Research Visitors

9.3.1. Visits of International Scientists

- Oleg Kudryavtsev (Rostov University, Russia)
- B. Stemper (Weierstrass Institute, Berlin)
- A. Kohatsu Higa (Ritsumeikan University)
- Justin Kirkby (Georgia Institute of Technology, Atlanta)
- Xiao Wei (Beijing University)
- Anton Arnold (TU Vienna)

9.3.1.1. Internships

- Baba Abdel Hamid, Inria
- Asma Sassi, Inria

9.3.2. Visits to International Teams

9.3.2.1. Research Stays Abroad

In the period 15.05 - 15. 06. 2019 Vlad Bally was an invited professor at the University Tor Vergata, Roma. Here he gave a course of 20h entitled "Integration by Parts and Convergence in Total Variation".

SIMSMART Project-Team

7. Partnerships and Cooperations

7.1. Regional Initiatives

Inter-Labex SEACS: V. Monbet, F. Le Gland, C. Herzet and Thi Tuyet Trang Chau (PhD student) are part of the *inter Labex Cominlabs-Lebesgue-Mer SEACS, http://www.seacs.cominlabs.ueb.eu/fr*, which stands for Stochastic modEl-dAta-Coupled representationS for the analysis, simulation and reconstruction of upper ocean dynamics. This project which concerns mainly Objectives 2 and 3, aims at exploring novel statistical and stochastic methods to address the emulation, reconstruction and forecast of fine-scale upper ocean dynamics.maths-computer-sea science for ocean dynamics.

CMEMS 3DA (2018-2019): C. Herzet is part of the project *CMEMS 3DA* on data assimilation of oceanographic events with non-parametric data assimilation methods. The goal of the project is to demonstrate the relevance of data-driven strategies to improve satellite derived interpolated products and especially the geostrophic surface currents. The project is made in collaboration with IMT Atlantique Brest, Ifremer and the Institue of Geosciences and Environment in Grenoble.

Action Exploratoire – Labex Cominlabs: C. Herzet is part of a project on sparse representations in continuous dictionaries. Partners: R. Gribonval (Inria Rennes PANAMA), A. Drémeau (IMT Atlantique) and P. Tandeo (IMT Atlantique).

7.2. National Initiatives

7.2.1. ANR

ANR BECOSE (2016-2020): Beyond Compressive Sensing: Sparse approximation algorithms for ill-conditioned inverse problems.

Cédric Herzet is part of the BECOSE project. The BECOSE project aims to extend the scope of sparsity techniques much beyond the academic setting of random and well-conditioned dictionaries. In particular, one goal of the project is to step back from the popular L1-convexification of the sparse representation problem and consider more involved nonconvex formulations, both from a methodological and theoretical point of view. The algorithms will be assessed in the context of tomographic Particle Image Velocimetry (PIV), a rapidly growing imaging technique in fluid mechanics that will have strong impact in several industrial sectors including environment, automotive and aeronautical industries.

ANR Melody (2020-2024): Bridging geophysics and MachinE Learning for the modeling, simulation and reconstruction of Ocean DYnamics.

Cédric Herzet is part of the MELODY project. The MELODY project aims to bridge the physical model-driven paradigm underlying ocean/atmosphere science and AI paradigms with a view to developing geophysically-sound learning-based and data-driven representations of geophysical flows accounting for their key features (e.g., chaos, extremes, high-dimensionality).

7.3. European Initiatives

7.3.1. FP7 & H2020 Projects

ERC MsMaths (2015-2019): M. Rousset is part of *ERC MSMaths* on molecular simulation (PI T. Lelièvre). With the development of large-scale computing facilities, simulations of materials at the molecular scale are now performed on a daily basis. The objective of the MSMath ERC project is to develop and study efficient algorithms to simulate such high-dimensional systems over very long, macroscopic times. ERC MsMaths especially focus on the computational issues related to 'metastable' states, that is to say specific molecular configurations that do evolve only on very large time scales. This results in a multi-timescale computational bottleneck that needs to be addressed by specific algorithms.

7.3.2. Collaborations with Major European Organizations

The agency European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) of Darmstadt. The transfer focuses on the estimation of atmospheric 3D winds from the future hyperspectral instrument (IRS on MTG-S, developed by ESA and IASI-NG on Metop-SG developed by CNES).

7.4. International Initiatives

7.4.1. Participation in Other International Programs

ECOS ARGENTINE (2018-2021): V. Monbet has obtained a funding program through the ECOS Sud - MINCyT intiative (http://www.univ-paris13.fr/cofecub-ecos/). The program involves a collaboration with the French-Argentinian Climate Institute (http://www.cima.fcen.uba.ar/UMI/), and focuses on non-parametric, analog methods, combined with data assimilation techniques to reconstruct complex meteorological dynamics (Objective 3).

TOSCA Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

- C. Henry is the coordinator of the PAIRE project, a TREMPLIN-COMPLEX project funded by University of Côte d'Azur. The project aims at creating new international and cross-sector collaborations to foster innovative solutions for particle contamination in the environment. This will be achieved by bringing together partners in a consortium to submit a research proposal to the European MSCA-RISE-2019 and MSCA-RISE-2020 calls.
- A. Lejay is a member of the Executive board of LUE Impact digistrust on citizens' trust in the digital world (grant of the i-site, U. Lorraine), since 2018.

8.2. National Initiatives

8.2.1. ANR

- N. Champagnat was member of the ANR NONLOCAL (Phénomènes de propagation et équations non locales), coordinated by F. Hamel (Univ. Aix-Marseille), which ended in October.
- C. Henry is the coordinator of the PACE project, a MRSEI project funded by the ANR to help prepare European projects. As for PAIRE, the project aims at creating new international and cross-sector collaborations to foster innovative solutions for particle contamination in the environment. This will be achieved by bringing together partners in a consortium to submit a research proposal to the European MSCA-RISE-2019 and MSCA-RISE-2020 calls.
- U. Herbach is member of the ANR SinCity (Analyses transcriptomiques sur cellules uniques dont la généalogie est identifiée au cours d'un processus de différentiation), coordinated by O. Gandrillon (ENS Lyon).

8.2.2. GDR

A. Lejay is leader of the GdR Project TRAG on rough paths founded by INSMI in 2019.

8.2.3. ITMO Cancer

N. Champagnat, C. Fritsch and U. Herbach are involved in an ITMO Cancer project (INSERM funding) on "Modeling ctDNA dynamics for detecting targeted therapy resistance" (2017-2020), involving researchers from IECL (Institut Elie Cartan de Lorraine), the Inria teams BIGS and TOSCA, ICL (Institut de Cancérologie de Lorraine), CRAN (Centre de Recherche en Automatique de Nancy) and CHRU Strasbourg (Centre Hospitalier Régional Universitaire). This project is coordinated by N. Champagnat.

8.2.4. PEPS

The project SECURE of C. Fritsch obtained a PEPS I3A (Intelligence Artificielle et Apprentissage Automatique).

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

Program: FP7

Project acronym: HBP

Project title: The Human Brain Project

Duration: April 2018 - Mars 2020 (third part)

Coordinator: EPFL

Other partners: see the webpage of the project.

Tosca contact: Etienne Tanré

Abstract: Understanding the human brain is one of the greatest challenges facing 21st century science. If we can rise to the challenge, we can gain profound insights into what makes us human, develop new treatments for brain diseases and build revolutionary new computing technologies. Today, for the first time, modern ICT has brought these goals within sight. The goal of the Human Brain Project, part of the FET Flagship Programme, is to translate this vision into reality, using ICT as a catalyst for a global collaborative effort to understand the human brain and its diseases and ultimately to emulate its computational capabilities. The Human Brain Project will last ten years and will consist of a ramp-up phase (from month 1 to month 36) and subsequent operational phases. This Grant Agreement covers the ramp-up phase. During this phase the strategic goals of the project will be to design, develop and deploy the first versions of six ICT platforms dedicated to Neuroinformatics, Brain Simulation, High Performance Computing, Medical Informatics, Neuromorphic Computing and Neurorobotics, and create a user community of research groups from within and outside the HBP, set up a European Institute for Theoretical Neuroscience, complete a set of pilot projects providing a first demonstration of the scientific value of the platforms and the Institute, develop the scientific and technological capabilities required by future versions of the platforms, implement a policy of Responsible Innovation, and a programme of transdisciplinary education, and develop a framework for collaboration that links the partners under strong scientific leadership and professional project management, providing a coherent European approach and ensuring effective alignment of regional, national and European research and programmes. The project work plan is organized in the form of thirteen subprojects, each dedicated to a specific area of activity. A significant part of the budget will be used for competitive calls to complement the collective skills of the Consortium with additional expertise.

M. Bossy and C. Henry are involved in the VIMMP H2020 project, started in January 2018. M. Bossy is responsible for the partner Inria. VIMMP is a four years development for a software platform and simulation market place on the topic of complex multiscale CFD simulations.

8.4. International Initiatives

8.4.1. Participation in Other International Programs

Math AmSud SARC

Title: Stochastic and Statistics analysis for Stochastic Differential equations driven by fractional Brownian motion with non regular coefficients.

International Partner (Institution - Laboratory - Researcher):

Universidade Estadual de Campinas (Brasil)

Universidad de Valparaiso (Chile) - CIMFAV – Facultad de Ingenieria

PI: C. Olivera (Brasil), E. Tanré (France), S. Torrès (Chile)

Duration: 2019 - 2020
Start year: 2019
Keywords: Stochastic differential equations, fractional Brownian motion, Malliavin calculus, Bayesian parametric, and nonparametric statistics.

BRN
Title: Biostochastic Research Network
International Partner (Institution - Laboratory - Researcher):
Universidad de Valparaiso (Chile) - CIMFAV – Facultad de Ingenieria - Soledad Torres, Rolando Rebolledo
CNRS, Inria & IECL - Institut Élie Cartan de Lorraine (France) - N. Champagnat, A. Lejay, D. Villemonnais, R. Schott.
Duration: 2018 - 2022
Start year: 2018

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- E. Horton (University of Bath) spent one week in IECL in April to work with D. Villemonais.
- E. Mordecki (U. de la República, Uruguay) spent 3 months in IECL, with an invited professor position (*poste rouge CNRS*).
- H. Olivero Quintos spent one month at Sophia Antipolis.

8.5.1.1. Internships

- Loubna Ben Allal
  subject: processus de Hawkes
  date: sept. 2019 - june 2020
  institution: École des Mines de Nancy
- Wejdene Ben Nasr
  subject: méthodes de signature pour les séries temporelles multi-variées
  date: sept. 2019 - june 2020
  institution: Master IMSD, U. Lorraine.
- Olivier Coudray
  subject: transmission de la longueur de télomères entre générations
  date: apr. 2019 - aug. 2019
  institution: École Polytechnique, Master Mathématiques de l'aléatoire
- Rémi Maréchal
  subject: processus de fragmentation pour les avalanches
  date: sept. 2019 - june 2020
  institution: École des Mines de Nancy
- Seyedafshin Shekarforush
  subject: particles in the environment: the adaptative grid generation problem in particle agglomeration and fragmentation dynamics
  date: apr. 2019 - aug. 2019
  institution: Université Nice Sophia Antipolis

8.5.2. Visits to International Teams

8.5.2.1. Sabbatical programme

D. Villemonais obtained a *délégation CNRS* which ended in August.