Activity Report 2016

Section Highlights of the Team

Stochastic approaches

<p style="text-align:center">**ACUMES Project-Team**</p>

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

- P. Goatin got the *Trophée des Femmes en Or* for the "Smart City" category.

CAGIRE Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

From Cagire to ... Cagire !

Last April 2016, after near five years of existence and a 1-year preparation/evaluation process of the new project, the common team Cagire (**C**omputational **A**pproximation with discontinuous **G**alerk**I**n methods and compa**R**ison with **E**xperiments) died and was reborn as the common **project** team Cagire (**C**omputational **AG**ility for internal flows s**I**mulations and compa**R**isons with **E**xperiments) with the much broader scope presented above.

A first step towards the dissemination of the AeroSol library

A deposit procedure of the AeroSol library (around 78000 lines of C++) with APP [0] has been finalized in 2016. This will protect the library authors' rights and will open the possibility of disseminating the library in a sound way.

Launching of a long-term collaboration with a new industrial partner, PSA

In January 2016, we have been contacted by the R & D department of the PSA Group (Peugeot Citroën Automobile SA) in order to elaborate a long-term, 10-year project on the modelling and simulation of the turbulent flow in the under-hood space of road vehicles, in the framework of their *Full Digital 2025 Ambition*, i.e, their plan to switch to a design of future vehicles entirely based on simulation. In order to overcome the technological barrier of the prediction of the natural convection regime, a long-term collaboration program has been established, starting with an internship (Saad Jameel), defended in September 2016, a CIFRE PhD (same student), going to start in February 2017, and the deposit of the ANR PRCE project MONACO-2025, coordinated by R. Manceau, involving the institute PPrime of Poitiers, PSA and EDF.

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[0]http://www.app.asso.fr/en/welcome.html

CARDAMOM Project-Team (section vide)

DEFI Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

- L. Audibert obtained the PhD prize Paul CASEAU of EDF.
- Grégoire Allaire was appointed as president of the scientifique board of IFP Energies Nouvelles.
- Grégoire Allaire broke 15 bones in a climbing accident on the 19th of July, 2016. It takes a long time to fully recover...

ECUADOR Project-Team (section vide)

ECUADOR Project-Team (section vide)

GAMMA3 Project-Team (section vide)

IPSO Project-Team (section vide)

MATHERIALS Project-Team (section vide)

MEMPHIS Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

Numerical simulation of zebrafish larvae C-bend

This part is performed in collaboration with the MRGM laboratory (Laboratoire Maladies Rares : Génétique et Métabolism, https://mrgm.u-bordeaux.fr/). They are interested in the swimming of a zebrafish larvae under genetic modifications. One aim is to quantify the power spent by such fishes to swim after a stimuli reaction. The numerical simulation we develop can help computing integral quantities such the power [39]. This simulation is challenging due to coupling several methods like image treatment (from movies given by MRGM), optimal transport [58] and numerical simulations.

First 2D numerical results have been performed from a series of 615 pictures obtained at a rate equal to $15\,000$ images per second. The fish is a 8-day zebrafish larvae (length is $\ell = 7\,mm$) presented in figure 5 .

Figure 5. Pictures of a 8-day zebrafish larvae. Source: MRGM.

All the 615 pictures have been post-processed to remove the displacement of the center of mass (due to the hydrodynamic forces) as well as the rotation angle (due to the hydrodynamic torques) to isolate the kinematic of the deformation. Indeed, the displacement of the mass center and the rotation angle have to be computed as being the results of the flow effects generated by the fish deformation. The numerical solver requires however more than 615 images for the overall simulation due to small times steps limitation. The missing images are thus computed using optimal transportation with the algorithm presented in [40]. This method gives also the deformation velocity inside the body that is necessary for our numerical simulation based on the penalty method (see figure 4 for an example of deformation velocity computation).

A comparison between experimental and numerical swimming behaviors is presented in figure 6 . The qualitative behaviors look quite similar. In a more quantitative way, figures 7 and 8 show the temporal evolution of the rotating angle as well as the position of the center of mass. The numerical results (displacement of the mass center and the rotation) are quite close to the experimental ones (the ones removed in the post-processed of the original pictures).

The small differences can be explained by the fact the the actual simulation is only two-dimensional. Another explanation is that the deformation velocity obtained by optimal transportation is by definition irrotational and *a priori* non divergence free. We are now working on the 3D simulation as well as a modified (sub-)optimal transportation including rotational effects for a divergence free field.
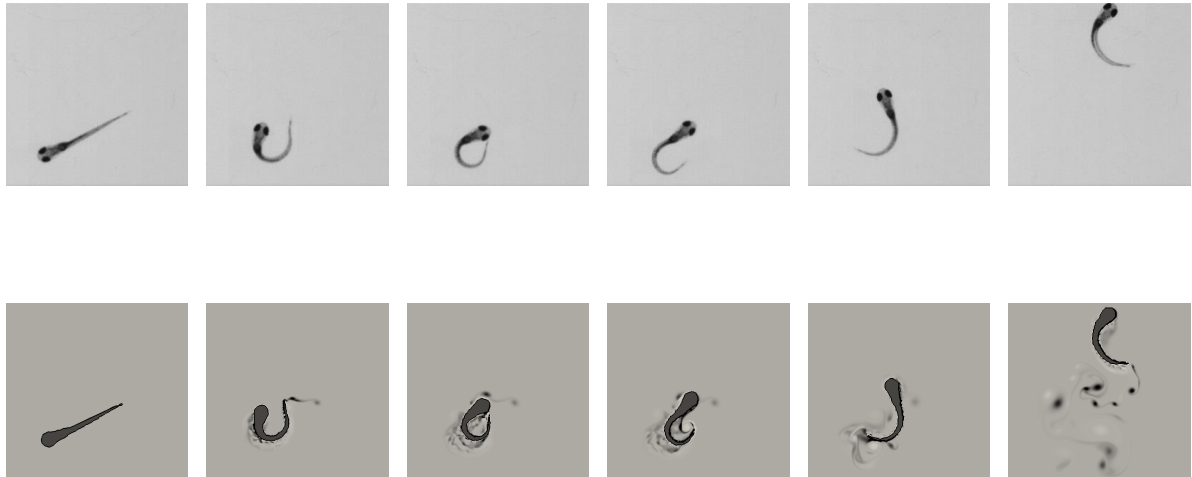
Figure 6. Comparison between experimental (top) and numerical results (bottom) at t_0, $t_0 + 0.7$ ms, $t_0 + 1.1$ ms, $t_0 + 1.3$ ms, $t_0 + 2$ ms and $t_0 + 4.1$ ms from left to right. Experiments results given by MRGM.
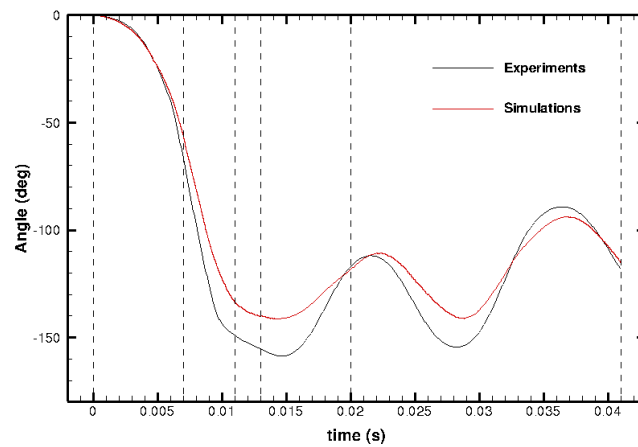
Figure 7. Temporal evolution of the rotation angle.
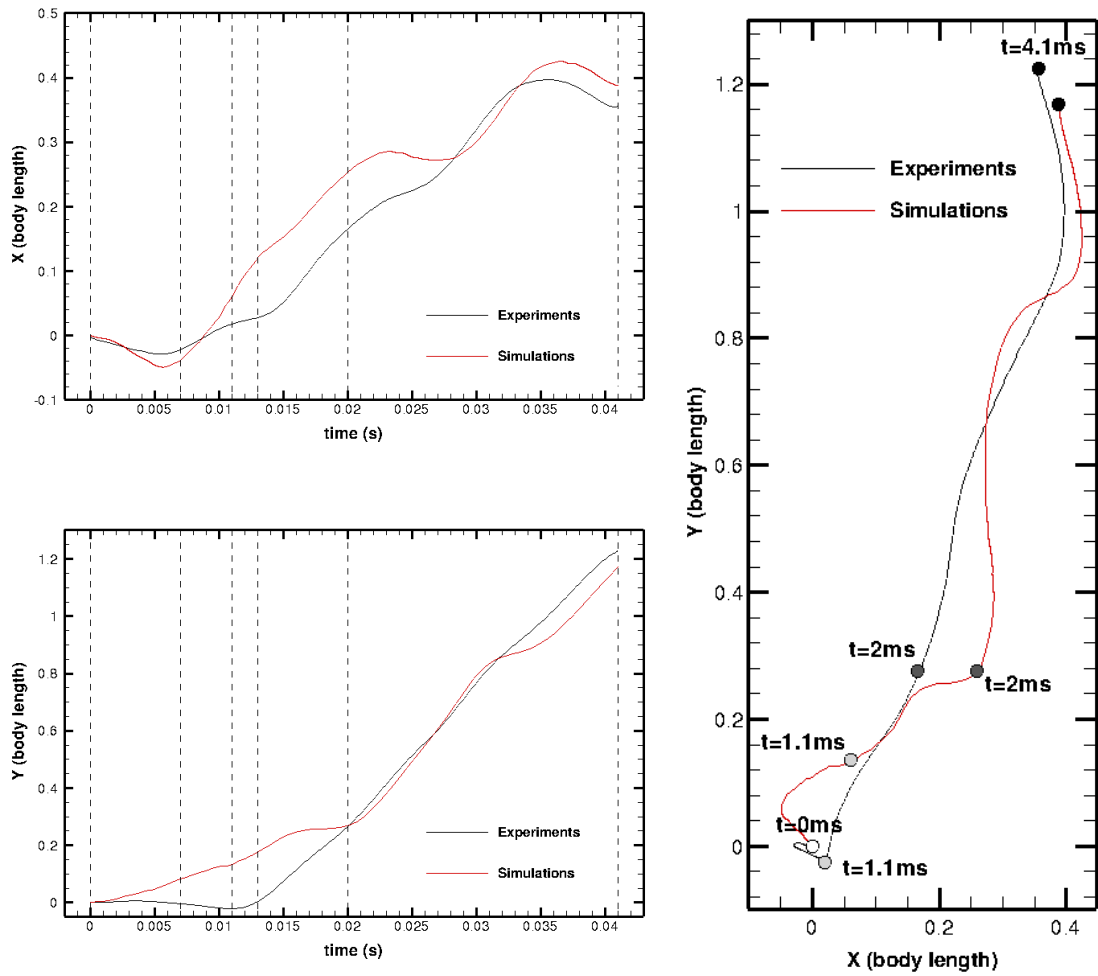
(a) Temporal evolution of the center of mass.   (b) Position of the center of mass.

Figure 8. Kinematic results for the zebrafish swimming.

<p style="text-align:center">**MEPHYSTO Project-Team**</p>

5. Highlights of the Year

5.1. Highlights of the Year

The team obtained two striking results in 2016:

- In collaboration with O. Blondel, T. Franco, and P. Gonçalves, M. Simon has made significant progress towards the *weak KPZ universality conjecture*, which states that a large class of one-dimensional weakly asymmetric conservative systems should converge to the KPZ equation, cf. [28], [7].

- In collaboration with F. Otto, M. Duerinckx and A. Gloria developed a complete theory of fluctuations in stochastic homogenization, cf. [39].

MOKAPLAN Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

New ERC Grant for G. Peyré

Gabriel Peyré is the recipient of a second ERC grand (consolidator), project NORIA (http://www.gpeyre.com/noria/) on Numerical Optimal tRansport for ImAging, that will start on Oct. 2017.

Pisa

Four members of Mokaplan : G. Peyré, G. Carlier, J-D. Benamou, Simone di Marino (starting 2017) have been invited speakers at the Pisa Scuola Normale Bi-Annual Optimal Transport Conference (November 7-11). This is considered as the most prestigious conference in the field.

NACHOS Project-Team (section vide)

NANO-D Project-Team (section vide)

<p style="text-align:center">**POEMS Project-Team**</p>

5. Highlights of the Year

5.1. Highlights of the Year

Workshop METAMATH

This event marked the end of the project METAMATH,

funded by the French National Research Agency (ANR). The METAMATH project, led by Sonia Fliss, involved:

- from POEMS, Sonia Fliss, Anne-Sophie Bonnet Ben Dhia, Patrick Ciarlet, Patrick Joly, Camille Carvalho and Valentin Vinoles;

- from DEFI, Lucas Chesnel, Houssem Haddar, Mathieu Chamaillard and Thi Phong Nguyen;

- from Laboratoire Jacques Louis Lions, Xavier Claeys ;

- from IMATH, Université de Toulon, Guy Bouchitté and Christophe Bourel.

The motivation of this project was to contribute to the development of mathematical models for the study of periodic media and metamaterials, which are both physically relevant and available for numerical computations.

The aim of the workshop was to bring together physicists and mathematicians to make an overview of the recent researches and the new perspectives on the field.

The colloquium has taken place at Institut d'études scientifiques de Cargese, near Ajaccio, at Corsica from November 23rd until November 25th. There were about 40 participants.

Workshop on Mathematical and Numerical Modeling in Optics

This workshop, co-organized by Anne-Sophie Bonnet-Ben Dhia, was a part of the yearlong IMA (Institute of Mathematics and Applications) program in Mathematics and Optics, which brings together applied mathematicians, physical scientists and engineers to confront challenging problems arising in optics. It has taken place in Minneapolis from December 12th to December 16th.

It concerned more specifically researchers interested in the mathematical and numerical modeling of optical phenomena, especially spectral problems arising in photonics involving dispersion relations and band structures, eigenfunctions, and scattering resonances. Specific areas of focus included: (i) efficient computational methods for scattering and spectral problems and (ii) properties and optimal design of extreme materials and photonic devices. These problems arise in the study of photonic crystals and periodic media, diffraction gratings, metamaterials, graphene and related materials with Dirac points, and cloaking devices.

There were about 70 participants.

5. Highlights of the Year

5.1. Highlights of the Year

The paper [31], written by Giacomo Dimarco, Raphaël Loubère, Jacek Narski and Thomas Rey presents a new deterministic numerical scheme for the resolution of the full 7d Boltzmann equation. The scheme combines a robust and fast method for treating the transport part based on an innovative Lagrangian technique supplemented with fast spectral solvers to treat the collision operator. This approach along with several implementation features related to the parallelization of the algorithm permits to construct an efficient simulation tool which is numerically tested against exact and reference solutions on classical problems arising in rarefied gas dynamics.
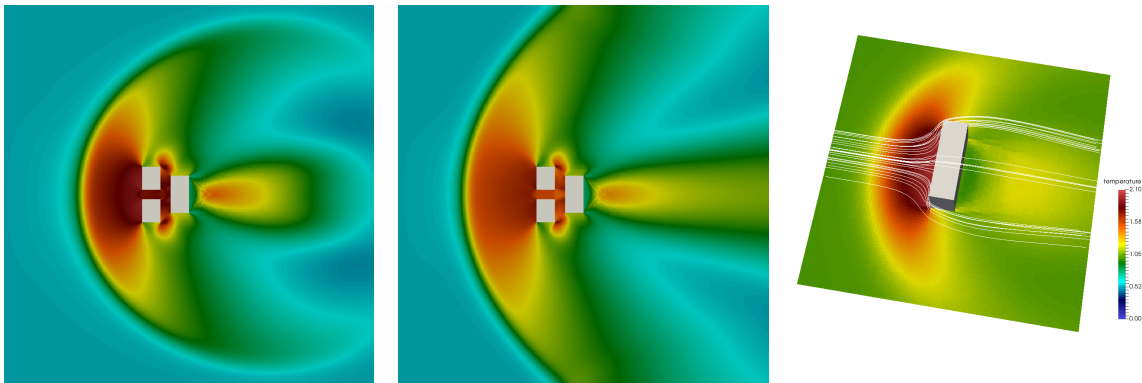
Figure 1. Simulation of a space shuttle atmospheric reentry (pictures from [31])

The paper presents results up to the very challenging 3D×3D case for unsteady flows arising during a space shuttle atmospheric reentry (which was simulated in the deterministic case in the paper for the first time up to our knowledge), which may serve as benchmark for future comparisons between different numerical methods for solving the multidimensional Boltzmann equation. For this reason, the paper also provide for each problem studied details on the implementation, computational cost and memory consumption as well as comparisons with the more standard BGK model or the limit model of compressible Euler equations.

APICS Project-Team (section vide)

BIPOP Project-Team (section vide)

COMMANDS Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

We started at the beginning of 2016 an Innovation Lab (Ilab) 'OSCAR', jointly with the startup Safety Line. The subject of the Ilab is the design of algorithmic tools for the (i) identification of aircraft dynamics, based on flight data recorders, and (ii) the computation of energy efficient flight trajectories.

DISCO Project-Team (section vide)

GECO Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

The European Research Council (ERC) has awarded Ugo Boscain with a "Proof of concept grant" for his project *An Artificial Visual Cortex for Image Processing*.

I4S Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

- In 2016, uncertainty quantification for modal analysis has been transferred to ARTeMIS software http://www.svibs.com/newsletter/newsletter_2016_09.aspx.

- In 2016, a patent has been filed by N. Berrabah and Q. Zhang, jointly with EDF and Inria [46].

- PEDAL-LORA monitoring sensor has been awarded by the European Railway Cluster Price in railway innovation.

MCTAO Project-Team (section vide)

<p style="text-align:center">**NECS Project-Team**</p>

5. Highlights of the Year

5.1. Highlights of the Year

- C. Canudas de Wit has been elevated to the grade of Fellow of the IEEE.
- C. Canudas de Wit has been named a Fellow of the IFAC (International Federation of Automatic Control).
- C. Canudas de Wit has received an ERC Advanced Grant for the project "Scale-FreeBack".
- The GTL platform and website went public in November.
- G. De Nunzio received the "Prix de thèse 2016 de la COMUE Université Grenoble Alpes" for his doctoral work, co-advised by C. Canudas de Wit and P. Moulin.
- A. Kibangou defended his HDR (Habilitation à diriger les recherches).
- P. Frasca and M.L. Delle Monache have joined the team as permanent researchers.
- H. Fourati has edited the book "Recent Advances on Multisensor Attitude and Heading Estimation: Fundamental Concepts and Applications", by Taylor & Francis Group LLC.

NON-A Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

UCoCoS

The H2020 project UCoCoS (Understanding and Controlling of Complex Systems, supervisors: W. Michiels, J.-P. Richard, H. Nijmeijer, 2016-2020) has started effectively this year: kick-off meeting in Eindhoven in March and, at the end of this year, recruitment of the 6 PhD students (including 4 jointly with Lille: H. Silm, J. Thomas, D. Dileep, Q. Voortman) in the 3 hosting institutions.

5.1.1. *Awards*

D. Efimov is Outstanding IEEE TAC reviewer.

QUANTIC Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

- Pierre Rouchon was a plenary speaker at 55th IEEE Conference on Decision and Control.

- First demonstration of a quantum error correcting code extending the lifetime of a quantum bit: this experiment performed at Yale in collaboration with the team of Robert J. Schoelkopf realizes the hardware-efficient quantum error correction protocol that we had proposed a few years ago. This is the first experiment where a redundant encoding of quantum information, together with continuous measurements of an error syndrome and real-time closed-loop error corrections, extend the lifetime of the encoded information beyond the best physical part. This result was published in Nature [22].

- An experimental marriage of two central concepts of mechanics, the Schrödinger cat states and the entanglement, was realized in collaboration with the team of Robert J. Schoelkopf at Yale. Following our earlier theoretical proposals, an entangled Schrödinger cat state of light shared between two boxes (two high-Q cavities) were successfully achieved and measured. Experimental realization of such states of light were proposed more than 20 years ago and have important applications in quantum information processing. This result was published in Science [28] and has attracted important press converge around the world.

- First experimental demonstration of the quantum-state diffusion associated with spontaneous emission that triggered the field of quantum trajectories in the 1990s. This result was published in Phys. Rev. X [16]. This also led us to implement a first experimental demonstration of multi-input multi-output (MIMO) feedback in the quantum regime. This result was published in Phys. Rev. Lett. [15].

<p style="text-align:center;color:red;font-weight:bold;">SPHINX Project-Team</p>

5. Highlights of the Year

5.1. Highlights of the Year

The CANUM ("Congrès d'Analyse Numérique", Conference on Numerical Analysis) is the major French-speaking conference on numerical analysis and scientific computing. It is held since 1967 (every year from 1967 to 2000, every two years from 2000). In 2016, the Institut Élie Cartan de Lorraine was in charge of the organization. Most of the members of our team were involved throughout the year. In particular, Karim Ramdani was head of the organizing committee.

TROPICAL Team

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

- The Gaspard Monge Programme for Optimization and Operations Research (PGMO), a corporate sponsorship of EDF operated by Fondation Mathématique Jacques Hadamard, coordinated by Stéphane Gaubert, received the "Grand Prix AEF – meilleures initiatives partagées Universités Entreprises".
- Mateusz Skomra received the Dodu prize (distinction for the best talk of a young researcher) at the conférence SMAI-MODE 2016.

ANJA Team (section vide)

DOLPHIN Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

- Patent with the company Beckman: the invention relates to the handling of samples of biological material. In one aspect, the invention relates to optimization techniques for aliquoting such biological samples in a manner which accounts for various conditions and requirements as they may exist when the samples are to be processed.

GEOSTAT Project-Team

4. Highlights of the Year

4.1. Highlights of the Year

- N. Brodu is joining GEOSTAT as a research associate (2016).
- K. Daoudi has been invited to the Senate on June 20th 2016 to accompany BatVoice which was finalist of the 2016 edition of "Tremplin Entreprises".

4.1.1. Award

Hicham Badri is winning the AFRIF PhD price 2015 for his PhD *Sparse and Scale-Invariant Methods in Image Processing* [https://hal.inria.fr/tel-01239958].

<p align="center" style="color:red">INOCS Team</p>

5. Highlights of the Year

5.1. Highlights of the Year

- Creation of the Inria Innovation : Colinocs between Colisweb (start-up devoted to attended delivery service within the next 2 hours) and INOCS.

- Miguel Anjos joined us in September as part of the Inria International Chair program and will spend 20% of his time with us until 2020.

- A joint team between Ecole des Mines de St Etienne and INOCS involving N. Absi, D. Cattaruzza, D. Feillet, M. Ogier, F. Semet was finalist of the EURO/ROADEF Challenge 2016 devoted to an Inventory Routing Problem proposed by Air Liquid.

MISTIS Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

- The Pixyl startup (http://pixyl.io) created in March 2015 by F. Forbes (Mistis) with M. Dojat (INSERM), a former Mistis post-doctoral fellow S. Doyle (CEO) and IT Translation is one of the two Inria start-ups winners of the NETVA 2016 competition. S. Doyle travelled to Washington to take part in a personalized support program to learn about the North American markets. The NETVA competition is open to French hi-tech start-ups. It is organized by the science and technology departments of the French embassies in Canada and the USA. Pixyl develops neuro-imaging software which automatically analyses brain lesion load using MRI scans, for improved decision-making during clinical trials and routine clinical use.

- Vision 4.0 FUI Minalogic project: Mistis is one of the 4 partners in the Vision 4.0 project that started in October 2016. This is one of the 8 projects funded by the Minalogic Pôle de competitivité in 2016. The support is of 3.4 Meuros.

5.1.1. Awards

- 2016 Award for Outstanding Contributions in Neural Systems. Antoine Deleforge (now with the PANAMA team, Inria Bretagne-Atlantique), Florence Forbes (MISTIS team) and Radu Horaud (PERCEPTION team) received the 2016 Hojjat Adeli Award for Outstanding Contributions in Neural Systems for their paper: A. Deleforge, F. Forbes, and R. Horaud (2015), Acoustic Space Learning for Sound-source Separation and Localization on Binaural Manifolds, International Journal of Neural Systems, 25:1,(21 pages) [75]. The Award for Outstanding Contributions in Neural Systems established by World Scientific Publishing Co. in 2010, is awarded annually to the most innovative paper published in the previous volume/year of the International Journal of Neural Systems.

- MITACS Globalink Research Award - Inria - for research in Canada. Alexis Arnaud received the MITACS award and a 5 kdollars grant to spend 5 months in the Mathematics and statistics department of McGill University in Montreal, Canada, working with Prof. Russel Steele.

MODAL Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

The major highlight of Modal is related to transfer of its research towards the private sector. In 2016, several major bilateral contracts have been signed between Modal and leading international companies based in Hauts-de-France. Those collaborations directly proceed from the fundamental research carried within the team (see Section "Bilateral Contracts and Grants with Industry").

5. Highlights of the Year

5.1. Highlights of the Year

The Inria Innovation Lab with Ertus-consulting has reached the state of outputing a strategic planner for phytosanitary treatements in viticulture, showing significant potential saving margins. The prototype was presented to the press and the wine-making industry in September 2016. This event has been followed by some articles in the specialized press (such as "Réussir Vigne") and more generalist output (such as "Les Echos"). Industrial partnerships are being pursued with EDF (on nuclear maintenance planning) and Saint Gobain (on glas cutting optimization) and a new project has been launched with SNCF.

François Clautiaux published a book [24] about dual-feasible functions, their use to improve the resolution of several combinatorial optimization problems involving knapsack inequalities like cutting and packing, scheduling, and vehicle routing problems, and their strong links with column generation models and the underlying Dantzig-Wolfe decomposition. This book explores the general properties that identify the best dual-feasible functions, describes the general approaches that can be followed to derive new non-dominated functions, which leads on several problems to the best results reported in the literature.

Our research on decomposition based math-heuristics has led to new benchmarks, highlighting the performance of our generic procedures: for instance, we have managed to improve the best known solutions for several open Generalized Assignment Problem (GAP) instances of the litterature. Similarly, our algorithms based on aggregation and disaggregation techniques [6] allowed us to outperform previous approaches for the cutting-stock problem, which is a classical benchmark problem. On the most difficult instances to date, we were able to solve optimally 240 instances out of 250, whereas previous algorithms were only able to solve 29 instances. In a more practical setting, we have developed algorithms to compute team schedules for a roster of employees [9], and these algorithms are now embedded in a professional employee scheduling software of the Asys company. We have also obtained strong results for scheduling problems in a high performance computing context [27], [19], which allowed to significantly improve the performance of linear algebra routines on high-end heterogeneous systems.

SELECT Project-Team (section vide)

SEQUEL Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

- Grill, Valko & Munos gave an oral presentation at NIPS. Oral presentations at NIPS are rare: out of 2500+ submissions, only 1.8% are presented orally.
- Using a deep learning approach (sparse denoising autoencoders), Strub, Mary & Gaudel have obtained the best ever published results on the data from the Netflix challenge on recommendation systems. 10 years ago, such an achievement was worth 1M$.

SIERRA Project-Team (section vide)

<p align="center" style="color:red">TAO Project-Team</p>

5. Highlights of the Year

5.1. Highlights of the Year

- Yann Ollivier was invited to contribute to Yann LeCun's official series of talks on Deep Learning at College de France.

- Isabelle Guyon was program chair of the NIPS 2016 conference (in 2017 she will be general chair).

- The TAO team was selected by Microsoft to become the community lead of the competition plaform Codalab. We received a $20 000 Azure for research grant.

- Paola Tubaro co-organized the Second European Social Networks (EUSN) Conference, a major interdisciplinary event for the international research community interested in social networks. Jean-Daniel Fekete (AVIZ) was keynote speaker, and some TAO members contributed papers.

ASPI Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

Frédéric Cérou and Arnaud Guyader have received the prize of the best recent paper published in the journal *Annales de l'Institut Henri Poincaré, Probabilités et Statistiques* for their joint paper [3] in collaboration with Gérard Biau (université Pierre et Marie Curie). This paper analyzes ABC (approximate Bayesian computation) — a family of computational techniques which offer an almost automated solution in situations where evaluation of the likelihood is computationally prohibitive, or whenever suitable likelihoods are not available — from the point of view of k—nearest neighbor theory and it explores the statistical properties of its outputs. The paper discusses in particular some asymptotic features of the genuine conditional density estimate associated with ABC, which is an interesting hybrid between a k–nearest neighbor and a kernel method.

5. Highlights of the Year

5.1. Highlights of the Year

Publication of the book: *Stochastic Processes. From Applications to Theory* written by P. Del Moral and S. Penev, CRC Press, 1290 pages, Jan 2017.

Pierre del Moral has been invited to the IMS World Congress in Toronto to give a Medallion lectures in May 2016.

MATHRISK Project-Team

5. Highlights of the Year

5.1. Highlights of the Year

- Creation of a joint seminar on Numerical probability and Mathematical Finance with the LPMA laboratory, University Paris-Diderot.

- Organization by B. Jourdain with B. Bouchard (Université Paris-Dauphine) and E. Gobet (Ecole Polytechnique) of the 2015-2016 thematic semester on Monte Carlo methods (financed by the Institute Louis Bachelier) at Institut Henri Poincaré, Paris https://www.ceremade.dauphine.fr/montecarlo/MonteCarlo.html, and the international closing conference in July 2016. https://montecarlo16.sciencesconf.org

TOSCA Project-Team (section vide)