LABORATOIRE
JEAN KUNTZMANN
MATHÉMATIQUES APPLIQUÉES - INFORMATIQUE

LABORATOIRE JEAN KUNTZMANN

# HIGHLIGHTS

## FAITS MARQUANTS

## [ 2013-2014 ]

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LABORATOIRE JEAN KUNTZMANN

# HIGHLIGHTS

## FAITS MARQUANTS

## [ 2013-2014 ]

# FOREWORD

The 4th edition of the highlights of the Laboratoire Jean Kuntzmann presents some of our achievements of 2013/2014. It focuses on people, projects and results that illustrate the spirit of LJK: interdisciplinary research in mathematics and computer science, with a strong taste for applications.

LJK is thriving ! Taking full advantage of their complementary expertise, its teams are pioneering new directions of research (see the pages about data science or narrative design below), publishing in the best journals of our fields and pursuing fruitful international collaborations. The lab's participation in the organization of international conferences, its growing number of doctoral students, its involvement in many industrial projects and projects addressing environmental and social issues, along with the development of MaiMoSINe and Amies, are other indicators of a bustling activity.

The period covered has also been rich in collective events, such as the launching of the Fédération des Mathématiques Rhône-Alpes-Auvergne, and the first edition of the Jean Kuntzmann Prize, a distinguished lectures series created by LJK and the labex Persyval-lab, which was awarded last June to Emmanuel Candès, Barnum-Simons Chair in Mathematics and Statistics at Stanford University.

We hope you will enjoy reading this short compendium!

Eric Bonnetier

PART I

# PORTRAITS

## Maëlle Nodet

Maëlle Nodet joined the LJK lab in 2006 as maître de conférence in applied mathematics. She enjoys and is very much involved in both aspects of this position, namely teaching and research. Maëlle has been interested for years by alternative pedagogical approaches, and in particular by so called "active learning" and "problem-based learning". She introduced such approaches a few years ago in undergraduate mathematics classes. More and more colleagues are now interested in this experiment, and such alternative teaching methods are spreading across the university.

Maëlle also enjoys popularizing science. She regularly gives outreach talks about mathematics to high school teenagers. She is also active in the "Math en Jeans" association, which brings researchers to secondary schools, to help students work on year-long mathematical research problems and discover mathematics from another viewpoint. In the context of the worldwide initiative Mathematics for Planet Earth 2013 (MPE'13), she was nominated for an award and invited to Unesco during the MPE'13 launch ceremony for a package entitled "Bottles and oceanography", developed with A. Rousseau and S. Minjeaud. This package consisted in an outreach paper, a video of a physical experiment, as well as numerical experiments, which are now used by various institutions across Europe and by various educational journals.

But foremost, Maëlle is a researcher in applied maths. She is a member of the MOISE team, whose activities are focused on mathematical and numerical methods for geophysical fluids. Her research topics are related to inverse methods and data assimilation. They cover a wide spectrum ranging from theoretical aspects of the control of PDEs to applications to ocean circulation models and ice cap models.

These last years, in collaboration with F.-X. Le Dimet and A. Vidard, Maëlle worked on the assimilation of images (or rather of the data they represent) into numerical models. A tremendous amount of images is indeed available (in the context of Earth observation or elsewhere), which is often largely under-used due to the lack of automatic ways to relate pixel contents to physical quantities (e.g. velocities). Innovative ways of dealing with images using multiscale analysis have been proposed by I. Souopgui and O. Titaud during their respective PhD and postdoc (dir. A. Vidard and F.-X. Le Dimet). This work is further developed in the PhD theses of V. Chabot and N. Feyeux, both co-advised by Maëlle and A. Vidard. The former focused on improving the error description, while the latter is currently investigating the use of optimal transportation theory, producing interesting results and raising even more interesting open questions.



## Antoine Girard

Antoine Girard is maître de conférence at the University Joseph Fourier and a member of the team CASYS of LJK. In October 2014, he was awarded the CNRS Bronze Medal from the Institute for Information Sciences and Technologies (INS2I). This prestigious distinction aknowledges the impact of a researcher's first contribution to a field, in which he later developed his expertise and talent.

The research of Antoine Girard deals with hybrid systems (dynamical systems exhibiting both discrete and continuous behaviors). The originality of this work lies in the joint utilization of tools and concepts from applied mathematics, computer science and automatic control. He has made several important contributions on the methodological as well as on the theoretical sides.

Antoine Girard has developed computational approaches to reachability analysis of hybrid systems, proposing decisive improvements in terms of algorithms and data structure, which contributed to a spectacular improvement of scalability with respect to existing approaches. Today, these algorithms form the core of the verification platform for hybrid systems SpaceEx, developed in the laboratory Verimag. He has also proposed a new theoretical framework for approximation of dynamical systems, which makes it possible to consider discrete, continuous and hybrid dynamics in a unified way. There are numerous applications of this approximation framework, including model reduction or symbolic and hierarchical control approaches. In 2009, he received the George S. Axelby Outstanding Paper Award from the IEEE Control Systems Society for this work.

Antoine Girard is currently the principal investigator of the ANR project COMPACS (Computation Aware Control Systems) and he is a co-director of the labex Persyval-lab, in charge of education.

***Approximate bisimulation: a bridge between computer science and control theory***. *A. Girard and G. J. Pappas. European Journal of Control, 17(5-6):568-578, 2011.*

***Controller synthesis for safety and reachability via approximate bisimulation***. *A. Girard. Automatica, 48(5):947:953, 2012.*

***CoSyMA: a tool for controller synthesis using multi-scale abstractions***. *S. Mouelhi, A. Girard and G. Goessler. Hybrid Systems: Computation and Control, Philadelphia, USA, 2013.*

PART I

# PORTRAITS

## Rémi Ronfard

Rémi Ronfard is an INRIA researcher with a rich experience in industry and academia, in France and North America. He graduated from Mines Paris Tech, where he obtained his PhD.

He has conducted research in a variety of domains, from geometric design to 3D animation and computer vision. This includes work on non-manifold topology in CATIA (Dassault Systèmes, 1991), mesh LODs (IBM Research, 1992), digital cartoon storyboarding (INA, 1995), aesthetic surface design (IBM Research and Dassault Systèmes, 2000), video indexing (INA, 2000), action recognition and statistical analysis of image and film styles (INRIA 2002-2007).

He was an expert in the international MPEG group from 1997 to 2000. He has been an active member of the CNRS/GDR ISIS (action indexation multimedia, action geste) for the last 20 years.

In 2007, he joined a start-up company in Montreal (Xtranormal Technologie) where he became R&D director for automatic cinematography and movie editing. His team created the patented "magicam" system, which has been used to produce over two million user-generated animation movies.

He came back to INRIA and LJK in 2009, with a new research program devoted to "directing virtual worlds". He helped create the IMAGINE team in 2012, where he leads the "narrative design" part of the project.

In this context, Rémi Ronfard investigates computational models of visual storytelling and movie-making. This leads to inspiring collaborations with the national film school (ENS Louis Lumière), the Theatre des Célestins in Lyon, the University of Geneva, and with companies such as Thalès-Angénieux and Binocle 3D.

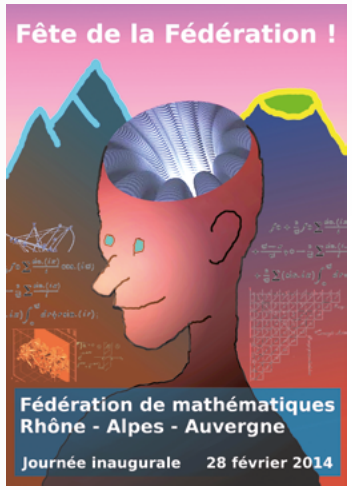
Rémi Ronfard has co-chaired international workshops on modeling people and human interaction (Beijing, 2005), 3-D cinematography (New York City, 2006; Banff, 2008; Providence, 2012), intelligent cinematography and editing (Quebec, 2014). He will co-chair the sixth international workshop on Computational Models of Narratives (Atlanta, 2015).

He is the current coordinator of the lab's "Geometry and Image" Department.



PART 2

# MULTI-DISCIPLINARY INTERACTIONS




## Fête de la Fédération !

Launched in February 2014 by Geneviève Fioraso Secrétaire d'Etat à la Recherche et à l'Enseignement Supérieur, and operated with the help of CNRS, the Fédération brings together a community of more than 400 mathematicians across Rhône-Alpes and Auvergne, covering the complete spectrum of mathematics, from fundamental topics to industrial applications. It is also a community open to interactions with other disciplins, particularly with computer science, and open to interactions with the regional socio-economic and cultural world.

In addition to LJK, the participating laboratories include

- the Institut Camille Jordan, UMR 5208 CNRS,
Université Claude Bernard - Lyon
- the Institut Fourier, UMR 5582 CNRS,
Université Joseph Fourier - Grenoble,
- the Laboratoire de Mathématiques (LAMA), UMR 5127 CNRS,
Université de Savoie - Chambéry,
- the Unité de mathématiques pures et appliquées (UMPA), UMR 5669 CNRS, ENS de Lyon,
- the Laboratoire de Mathématiques (LM), UMR 6620 CNRS,
Université Blaise Pascal - Clermont-Ferrand.

The main objectives of the Fédération are:

• to promote the quality of the regional mathematical research, so as to attract young talents to the associated laboratories, and develop a privileged relationship with the local industry.

• to sponsor initiatives that increase the employability of its doctoral students in mathematics in the regional socio-economic world.

• to facilitate communication, exchanges and common actions between the participating laboratories (guest professors, access to scientific documentation, common seminars and events).

• to reinforce the international visibility of its laboratories, by developing associations with international research units, and organizing specific actions with our Swiss and Italian neighbors.

Dorin Bucur, professor at the University of Savoie, is the current director of the Fédération.

**http://frmraa.math.cnrs.fr**

PART 2

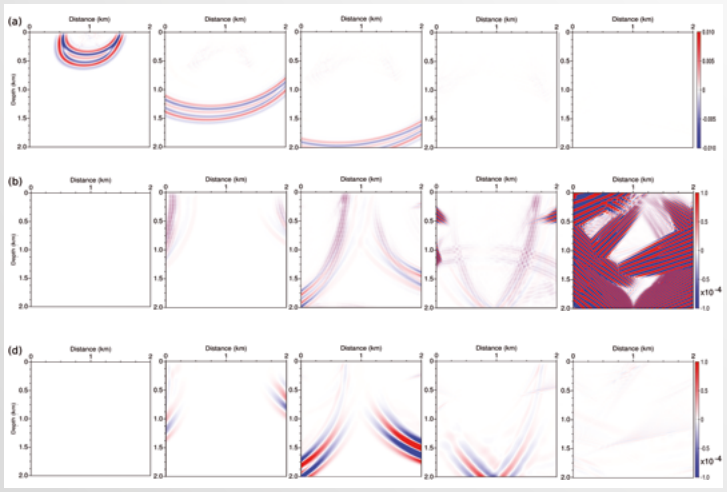
# MULTI-DISCIPLINARY INTERACTIONS

SEISCOPE

The SEISCOPE consortium is a team composed of researchers from the geosciences laboratories ISTerre (Grenoble) and Géoazur (Nice Sophia Antipolis). Its activity focuses on high resolution seismic imaging. LJK joined the SEISCOPE team in 2012. This collaboration has been a great opportunity to develop new tools for seismic wave propagation modeling.

One of our contributions concerns the design of new absorbing layers. To date, these are the only techniques that allow seismic wave propagation simulation to focus on a small subsurface domain, without introducing spurious reflections on the edges of this domain. When applied to elastodynamics, standard methods based on Perfectly Matched Layers may produce severe instabilities, depending on the discretization scheme or the presence of anisotropy. On the contrary, the method which has been developed, called SMART layers, is demonstrated to be unconditionally stable (Métivier et al.,2014a,b,c; Tago et al., 2014) (Fig. 1).

A second contribution is related to the development of an efficient iterative solver for time-harmonic elastodynamics equations (Li et al., 2014a,b). Preliminary results show that our method is robust, even for 3D problems that involve more than 500 millions of discrete unknowns in a complex subsurface environment (Fig. 2). Based on these results, a PhD project between LJK and ISTerre, financed by the SEISCOPE consortium, has started in 2013. It is dedicated to improving the efficiency of this robust iterative solver.



*Time evolution of a pressure wavefield generated by a explosive source in an anisotropic media. The reference wavefield is presented on the top row. The second row show the difference between the reference wavefields and the wavefield computed with a standard absorbing layer technique (PML). The instability is clearly visible at time t = 3 s. The last row presents the difference between the reference wavefield and the wavefield computed with the new absorbing layer (SMART). The instability has been removed.*


***CARP-CG : A robust parallel iterative solver for frequency-domain elastic wave modeling, application to the Marmousi2 model***. *Y. Li, L. Métivier, R. Brossier, B. Han, and J. Virieux (2014a). In Expanded Abstracts, 84th Annual SEG Meeting (Denver).*

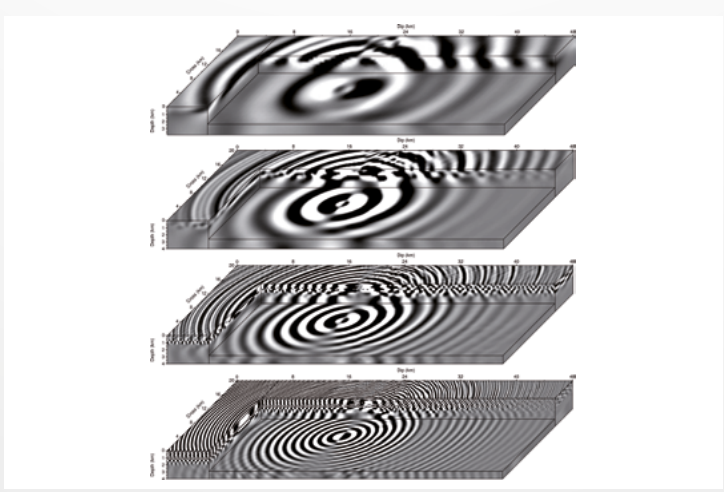
***A robust parallel iterative solver for frequency-domain elastic wave modeling***. *Y. Li, L. Métivier, R. Brossier, B. Han, and J. Virieux (2014a). In Expanded Abstracts, 76th Annual EAGE Meeting (Amsterdam).*

***A robust absorbing layer method for anisotropic seismic wave modeling,*** *2014, Journal of Computational Physics, L. Métivier, R. Brossier, S. Labbé, S. Operto, J. Virieux, 279, p. 218-240*

***A robust absorbing layer method for seismic wave simulation in anisotropic media***. *L. Métivier, R. Brossier, S. Operto and J. Virieux (2014a). In Expanded Abstracts, 76th Annual EAGE Meeting (Amsterdam).*

***Smart : Robust absorbing layer and s-waves, Itering for acoustic anisotropic wave simulation***. *L. Métivier, R. Brossier, S. Operto and J. Virieux (2014a). In Expanded Abstracts, 84th Annual SEG Meeting (Denver).*

***SMART layers: a simple and robust alternative to PML approaches for elastodynamics***, *2014, Geophysical Journal International, J. Tago, L. Métivier, J. Virieux, 199(2), p. 700-706*

*Horizontal particle velocity displacement wavefield for the frequencies 0.625 Hz, 1.25 Hz, 2.5 Hz and 5 Hz (top to bottom). The source is located in a layer with a low velocity, surrounded by two layers with high velocity. This "waveguide" configuration makes the corresponding linear system very hard to solve. Our solver is able to converge to the solution, even at 5 Hz, for which more than 500 millions unknowns are computed.*

PART 2

# MULTI-DISCIPLINARY INTERACTIONS

## Gargantua

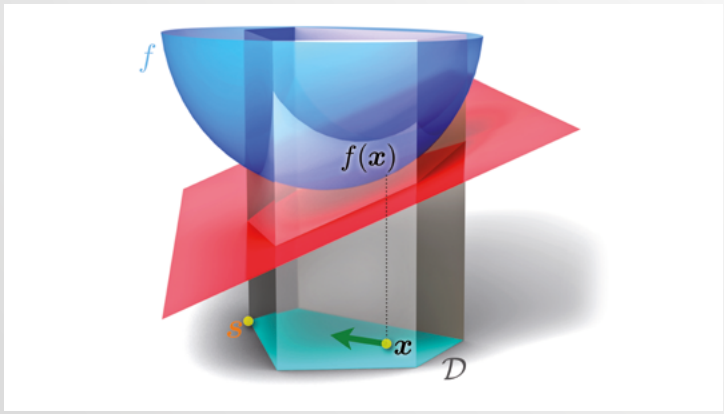
› Zaid Harchaoui (LEAR)

The amount of digital data is currently increasing at an exponential rate, with a staggering 4.4 zettabytes in 2014, and forecasted 44 zettabytes by 2020. This data deluge is now considered a wonderful opportunity to extract previously unknown information from the data, and therefore a major leverage for scientic advances. Yet, big data raises several major challenges for the upcoming decades, at the crossroad of two scientific domains: machine learning and mathematical optimization. Indeed, big datasets require machine learning methods that are highly predictive in terms of prediction and inference, yet rely on numerical optimization algorithms both quick and suciently accurate, which scale up to high-dimensional datasets potentially constantly increasing in dimensions over time.

The purpose of the **Gargantua** project[1], funded by the "Défi Mastodons" program of CNRS, is to form an alliance between researchers resp. in machine learning and mathematical optimization, to take up these challenges. The goal of the project is to come up with new methods of automatic extraction of knowledge from data, both quick and highly-predictive, enjoying theoretical guarantees. The project partners are LJK (Laboratoire Jean Kuntzmann), LIG (Laboratoire d'Informatique de Grenoble), DIENS (Departement d'Informatique de l'Ecole Normale Superieure), and LPP (Laboratoire Paul Painleve, Lille). The international workshop "Optimization and Statistical Learning" in Les Houches[2] (2013, 2015), organized as part of the project, gathers every two years a unique line-up of expert researchers in areas of both elds.

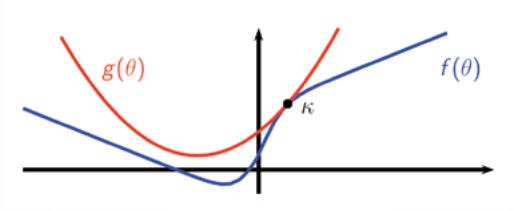
Several new approaches, tailored for machine learning and mathematical optimization problems in high-dimensions, were proposed, including:

• **Composite Conditional Gradient**, a first-order convex optimization algorithm, projection-free i.e. tailored for high-dimensional problems where projection is computationally expensive or intractable, only using a linear minimization oracle at each iteration.



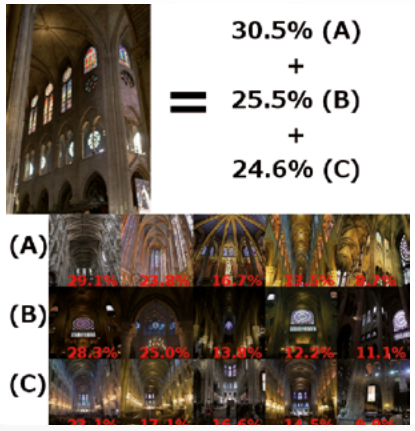

*Conditional Gradient Algorithm. In order to minimize a function **f** (blue) in the domain **D** (green), the algorithm performs at each iteration a linear minimization (red) in the domain **D** yielding a descent direction **s**.*

• **Stochastic Majorization-Minimization**, a stochastic optimization algorithm able to deal with datasets with large or possibly infinite number of datapoints, using iterative minimization of majorizing surrogates.




*Stochastic Majorization-Minimization. At each iteration, the algorithm minimizes a majorizing function g (red) of f (blue), that exactly matches f at the point .*

• **Robust Archetypal Analysis**, a method for visualizing large collections of datapoints, computing representations of each datapoint as a convex combination of "archetypes", each archetype being itself represented as a convex combination of datapoints.




*Robust Archetypal Analysis of an image downloaded from Flickr using the query "Paris".*
*The image (top left) is decomposed into a convex combination of three archetypes (resp. A, B, C; top right). Each archetype is decomposed into a convex combination of Flickr images (three bottom rows).*

[1] lear.inrialpes.fr/people/harchaoui/projects/gargantua/

[2] lear.inrialpes.fr/workshop/osl2013/

***Conditional gradient algorithms for norm-regularized smooth convex optimization**, Z. Harchaoui, A. Juditsky, A. Nemirovski, Mathematical Programming (Series A), 2014.*

***Stochastic Majorization-Minimization Algorithms for Large-Scale Optimization**, Julien Mairal, Advance in Neural Information Processing Systems (NIPS), 2013.*

***Fast and Robust Archetypal Analysis for Representation Learning**, Y. Chen, J. Mairal, Z. Harchaoui, IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2014.*

PART 2

# MULTI-DISCIPLINARY INTERACTIONS

## The Jean Kuntzmann Prize

*Professor Emmanuel Candès*

Professor Emmanuel Candès, from Stanford University, is the first recipient of the Jean-Kuntzmann Prize, which was awarded on June 13th 2014, during a ceremony organized at the Grenoble Museum of Art.

The Jean Kuntzmann prize was created by LJK and the labex Persyval-lab on the model of the "distinguished lecture series", which are popular in American universities. The prize is awarded to academics who made exceptional contributions, which may be transverse to the fields of mathematics, computer science, or operational research, and who, like Jean Kuntzmann, have an interest for the application of their research to solve some of our society's problems.

Emmanuel Candès holds the Barnum-Simons Chair in Mathematics and Statistics at Stanford University. He is also professor of electrical engineering and a member of the Institute of Computational and Mathematical Engineering of Stanford University. Former student of Ecole Polytechnique, he obtained his PhD in statistics in 1998 from Stanford University under the supervision of Professor David Donoho. His research interests are quite broad and include computational harmonic analysis, optimization, statistics, information theory and signal processing with applications to the imaging sciences, scientific computing and inverse problems.

Emmanuel Candès had been internationally appraised for his role in developing the theory of compressed sensing. This technique enables efficient reconstruction of sparse, high-dimensional data based on very few measurements, and is at the origin of a new sampling theory. Today, compressed sensing is used in a wide range of real-world applications, such as analog-to-digital converters, radar, wireless sensor networks, communications, computational biology, geophysical imaging, and fast Magnetic Resonance Imaging where it helped reduce drastically the time of data acquisition in scanners. In this respect, Emmanuel Candès is emblematic of the spirit of Jean Kuntzmann.

More recent works include the matrix completion problem (with connection to the Netflix prize), subspace clustering (a generalization of PCA, which fits at best a collection of points taken from a high-dimensional space, a problem arising in diverse fields like hyper-spectral imaging, classification of diseases or text categorization), and a mathematical theory for super-resolution (a crucial challenge for electronic imaging, astronomy, medical imaging or microscopy).

During his visit to LJK, Emmanuel Candès gave a series of lectures attended by a large audience of researchers from the Persyval-lab community (LJK, Gipsa-Lab, Timc-Imag,...). His visit to Grenoble was also the opportunity for young PhD students to discuss with him about his career, his scientific discoveries.

During the Award Ceremony, Emmanuel Candès was presented with a 3d model of the flat torus, a mathematical object that was first visualized by a team of mathematicians and computer scientists from Gipsa-lab, ENS Lyon and LJK, as a symbol of Jean Kuntzmann's broad view about science.



PART 3

# SCIENTIFIC RESULTS OF THE TEAMS

*A horse chestnut seedling split up into elementary units.*

## Shape and motion analysis for life sciences

› Team MORPHEO

The team Morpheo is specialized in the automatic acquisition and analysis of moving shapes, notably from multi-video systems. Such a problem is interesting for life sciences since manually measuring the shape or the motion of a plant, an animal or any other anatomical entity is often tedious, imprecise and even sometimes impossible.

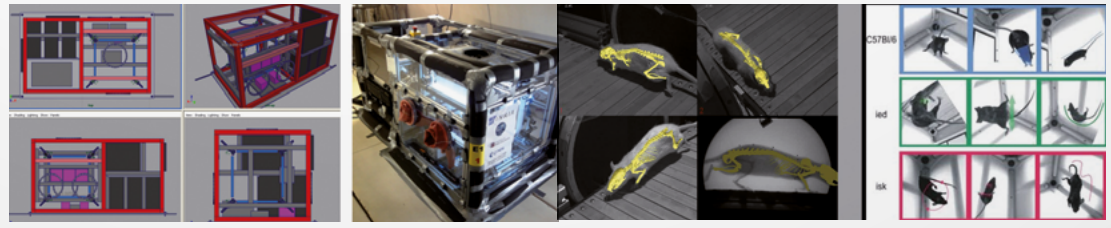
Morpheo collaborates with scientists from other fields in order to help them taking fast, accurate and as automated as possible measurements. Here are two examples of such collaborations:

Ethomice is a simulation and analysis platform for small lab animals, such as rats and mice, which is developped in collaboration with the University Paris Descartes (Institute for Neuroscience and Cognition) and with the Mouse Clinical Institute. This hardware and software platform relates the internal skeleton structure of the animal to 3D observations of its external appearance. It aims at delivering a three-dimensional analysis of the animal's posture and behaviour from a multiview video stream.

Together with Forest Research, a British research centre specialized in forest studies, Morpheo has developed a method to split a 3D digitalization of a plant into elementary units (branches, petioles, leaves). The collaboration is now focusing on the study of the acquisition noise created by laser scanners during 3D digitalizations.

**http://morpheo.inrialpes.fr/people/reveret/ethomice/**

***A spectral clustering approach of vegetation components for describing plant topology and geometry from terrestrial waveform LiDAR data**. D. Boltcheva, E. Casella, R. Cumont, F. Hétroy-Wheeler. 7th International Conference on Functional-Structural Plant Models, Jun 2013, Saariselkä, Finland.*



*The Ethomice platform: multiview video acquisition and mouse posture and behaviour analysis.*

PART 3

# SCIENTIFIC RESULTS OF THE TEAMS

## Mutation modeling

› Team IPS

Accurately estimating mutation probabilities is of crucial importance in several domains of medicine and biology, such as microbiology and the diagnosis and treatment of cancer and tuberculosis, microbiology. A general construction of mutation models has been proposed in [1]. It generalizes the so called Luria-Delbrück model, which assumed quite unrealistic hypotheses: exponential life durations, independence, time homogeneity, no cell death, etc. Estimating the parameters of a model, when reality follows a different one, necessarily leads to biased estimates. It is therefore necessary to design robust estimation methods, for which the bias, in particular that on the mutation probability, remains as small as possible, under any realistic model. Different sources of bias have been partially treated: non exponential life durations [2,7], cell deaths [4], variablity of final cell numbers [5], dependent life durations [3,6].

Part of the theoretical work is a collaboration with Agnès Hamon and Sana Louhichi. Applications have been developed for the Labex TOUCAN (Toulouse Cancer), and also as a partnership with Nicolas Veziris (Centre d'Immunologie et des Maladies Infectieuses, UPMC Paris 6). The work is continued as the doctoral project of Adrien Mazoyer. Practical methods will be integrated in the R package "flan", currently under development by Stéphane Despréaux.


*[1]* ***Statistics for the Luria-Delbrück distribution***.
*A. Hamon, B. Ycart. Elect. J. Statist. Vol. 6 1251-1272 (2012)*

*[2]* ***Fluctuation analysis: can estimates be trusted?***
*B. Ycart. PLoS One 8(12) e80958 (2013)*

*[3]* ***Exponential transform of quadratic functional and multiplicative ergodicity of a Gauss-Markov process***. *M. Kleptsyna, A. Le Breton, B. Ycart. Statist. Probab. Letters 87, 70-75 (2014)*

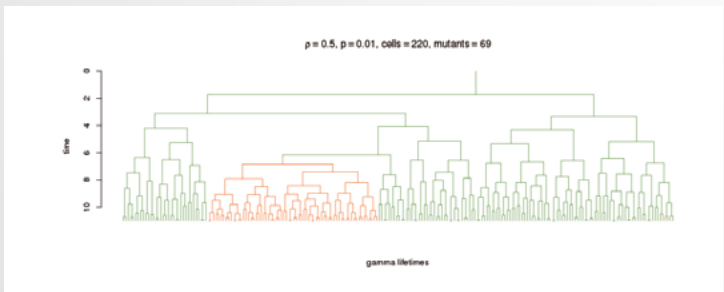
*[4]* ***Fluctuation analysis with cell deaths***.
*B. Ycart. J. Appl. Probab. Statist. 9(1), 12-28 (2014)*

*[5]* ***Unbiased estimation of mutation rates under fluctuating final counts***. *B. Ycart, N. Veziris. PloS One, 9(7) e101434 (2014)*

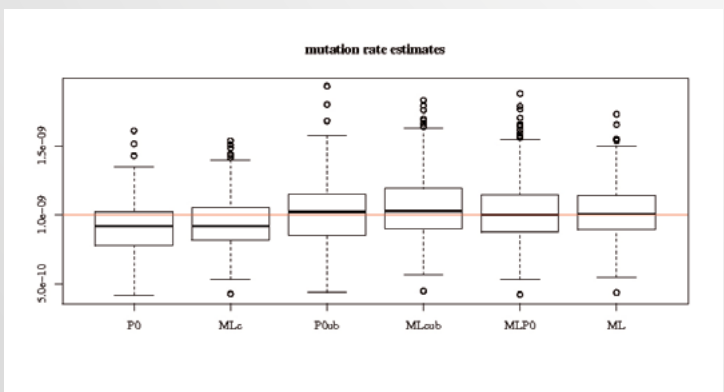
*[6]* ***Exponential growth of bifurcating processes with ancestral dependance***.
*S. Louhichi, B. Ycart. Adv. Appl. Probab, 47(2), to appear (2015)*

*[7]* ***Simultaneous growth of two cancer cell lines evidences variability in growth rates***.
*A. Hamon, M. Tosolini, F. Pont, B. Ycart, J.-J. Fournié. Open Access Medical Statistics, to appear (2014)*

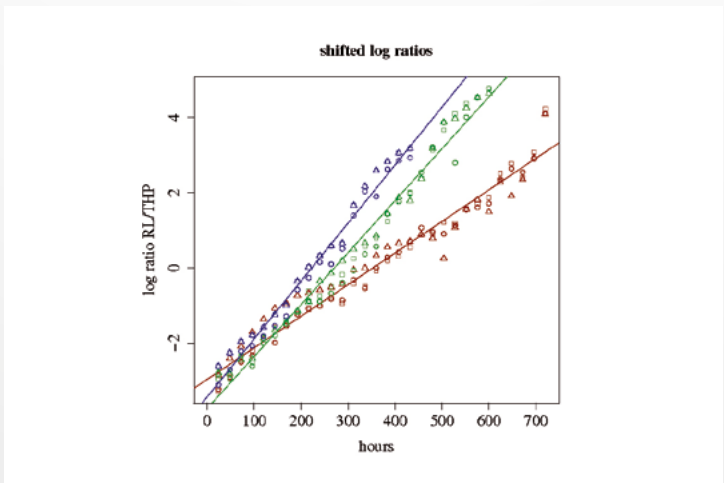

*Simulated development of a clone with mutations*




*Mutation rate estimates comparison*




*Comparative growth of two cancer cell lines*



PART 3

# SCIENTIFIC RESULTS OF THE TEAMS

## Spatial point processes (conditional) intensity estimation

› Team FIGAL

Spatial point processes are stochastic models at the interface between stochastic geometry and spatial statistics. Such processes model random sets of points in interaction (or more generally geometric objects in interaction) and are applied to a broad range of fields: they can model the position of galaxies in astrophysics, the position of trees in forestry, the sources of outbreak of a disease in epidemiology,...

A spatial point pattern observed in a bounded window W consists in the observation of a set of the form $X = \{x_1,...,x_n\}$, where $x_i \in R^d$ and $n$ are random (usually $d = 2,3$). The 2 main issues are: (I) Is the distribution of points homogeneous or inhomogeneous? In the latter case, can it be explained by (spatial) covariates? (2) Does the pattern exhibit a particular structure, for instance clusters (the expression of an attractive phenomenon) or a regular distribution (as in a repulsive phenomenon) ?

The estimation of a parametric form of the intensity function (resp. conditional intensity function) denoted by $\lambda(u; \theta)$ *(resp.* $\lambda(u, X; \theta)$*)* and interpreted as the probability to observe a point in a neighborhood of $u$ (resp. given that the rest of the configuration of points is $X$), partially anwsers these questions. Statistical inference requires the establishment and resolution of estimating equations of the form

$$\sum_{u \in X \cap W} h(u) - \int_W h(u)\lambda(u;\theta)\,du \quad \text{or} \quad \sum_{u \in X \cap W} h(u, X \setminus u) - \int_W h(u)\lambda(u, X;\theta)\,du.$$

Obtaining asymptotic properties for estimators derived from such equations is crucial to ensure efficiency and to construct validation tools. The choice of test functions $h$ is also crucial in view of reducing computational costs. We address these questions in [I]-[3]: how to specify the intensity (construction of goodness-of-fit tests, estimation of single-index type models), how to design alternative methods that avoid serious numerical difficulties in computing the above integrals when $n$ or $d$ are large.

Regarding applications, the trend is to involve more and more complex and massive data: This is the case in one of our recent projects, where the goal is to understand the distribution of visual fixations by newborns, see Figure I. Several interesting new questions arise there: How to select the most relevant characteristics of an image among the large number of available variables like the saliency map, the contour map, the spectral decomposition of the image along each RGB level, etc ? How to take into account the multiple test characteristics which appear while comparing estimated intensities from different images or from different age groups ?

A part of this work has beeen carried out in collaboration with Aalborg University (Denmark), Western Australia University, the University of Miami (USA) and the University of Nantes. The application to vision modelling for newborns is an ongoing project carried by LJK, LPNC (Baby-Lab) and Gipsa-lab.

**www-ljk.imag.fr/membres/Jean-Francois.Coeurjolly**


*[I]* ***Residuals and goodness-of-fit tests for stationary marked Gibbs point processes****. J.-F. Coeurjolly and F. Lavancier, Journal of the Royal Statistical Society, Series B, 75(2), 247-276, 2013.*

*[2]* ***Variational approach to estimate the intensity of spatial point processes****. J.-F. Coeurjolly and J. Møller, Bernoulli, 20(3):1097-1125, 2014.*

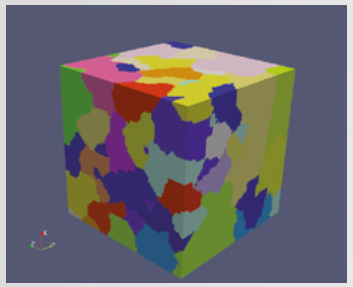
*[3]* ***Logistic regression likelihood for spatial point processes****. A. Baddeley, J.-F. Coeurjolly, E. Rubak and R. Waagepetersen, Biometrika, 101(2):377-392, 2014.*

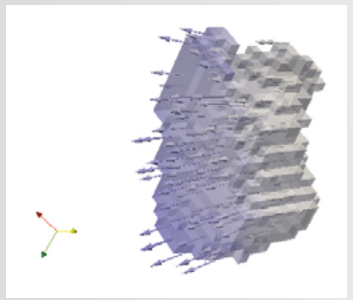


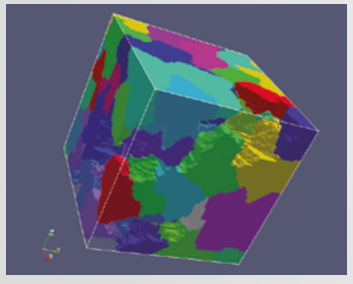
*Ocular fixations for several subjects (distinguished by colours) and colour images. Subjects are grouped together by age, from bottom to top: 3, 6, 9 and 12-month-old babies and adults (test group).*

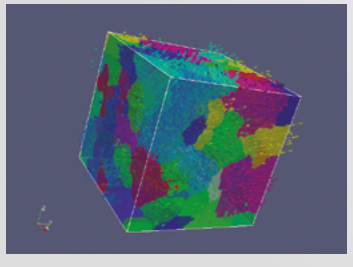
PART 3

# SCIENTIFIC RESULTS OF THE TEAMS









*From top to bottom*
*1. Visualisation of grains in a steel sample.*
*2. Equilibrium state of magnetization in a grain.*
*3. Details of grain configuration.*
*4. Equilibrium state in the sample.*
*5. Hysteresis curve.*

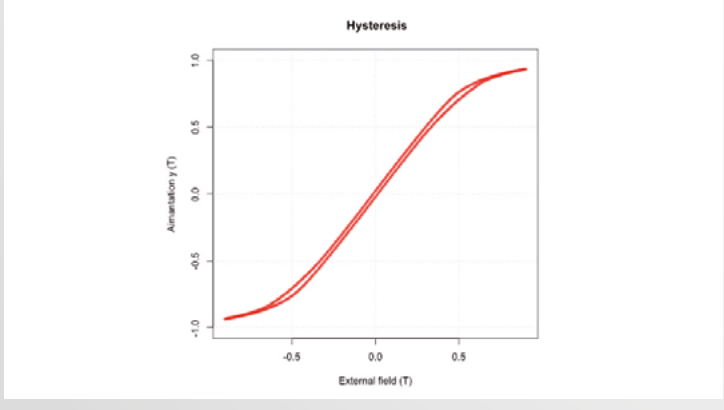
## Modeling and simulation for the non destructive control of steels

› Team EDP

Stéphane Labbé (PR UJF) is one of the principal investigators of PUC, Product Uniformity Control, a project sponsord by the ERC (RFCS project 2003-2012, TGS9). This project, initiated in 2012, involves the main European steel industries (from France, the Netherland, Sweeden, Germany), and academic laboratories specialized in material science (from the UK, the Netherland, Italy and Spain) as well as a French SME specialized in the edition of software for electromagnetic simulations. LJK's contribution concerns modeling and high computing simulations.

The main objective of this project is to understand the electromagnetic behavior of steels at several scales: from microscopic structures to macroscopic behaviors. We particularly focus on the hysteretic behavior of steels, which can be used to characterize their mechanical properties, in view of enhancing the reliability of manufactured steel products. This requires understanding the behavior of the magnetization in complex microstructures that involve magneto-strictive interactions (magnetico-mechanical interactions).

Together with Stéphane, two engineers are developping models and sotware for the simulation of hysteresis cycles. Two main work packages are being developped: The first concerns the C++ version of EMicroM/ SMicroM (parallel version on the platform Froggy). The second package has two main goals: the understanding of magneto-strictive interactions and the development of distributed parallel algorithms for the simulation of magnetization dynamics in ferromagnetic materials.




## Jordan-Kinderlehrer-Otto schemes and gradient flows

› Teams MGMI & EDP

Jordan, Kinderlehrer and Otto showed in [2] how to interpret the Fokker-Planck equation as a gradient flow in the space of probability measures endowed with the Wasserstein distance. This type of formulation has proved to be a powerful tool for studying partial differential equations that contain generalized diffusion terms and non-local interaction terms.

The construction of Jordan, Kinderlehrer and Otto of the gradient flow of an energy E on the space of probability measures relies on a time-discretization through an implicit Euler scheme. Its time steps can be written as

$$\rho_1 \quad := \quad \operatorname{argmin} W_2^2(\rho_0, \rho) + E(\rho),$$

where $\rho 0$ and $\rho$ are probability measures, and $W2$ is the quadratic Wasserstein distance. Despite their potential applications, only a few numerical methods are available for this type of schemes, and most of them are restricted to the ID case. Letting $\rho = \rho 0 \circ (\nabla \varphi)^{-1}$, where $\varphi$ is a convex function, a time step in the above scheme can be reformulated as an optimization problem over the space of convex functions.

When the energy E contains an entropy term, which corresponds to a diffusion term in the underlying PDE, the formulation using $\varphi$ involves the Monge-Ampère operator, which is not a classical operator in the calculus of variations.

With G. Carlier and J.-D. Benamou, we introduced a new way to discretize optimization problems over the space of convex functions, that involves the Monge-Ampère operator [I]. In our formulation, an entropy term is transformed into a barrier for the convexity of the discrete approximating functions. This allows use of Newton's method for the resolution of the discrete problem, which has a quadratric rate of convergence. The figures present numerical applications of our scheme to the fast diffusion equation, to the porous medium equation and to the simulation of crowd motion.

*Simulation of crowd motion under congestion using the gradient flow: a population (in black) escapes from a domain with an obstacle in the middle.*


*[I] **A Discretization of functionals involving the Monge-Ampère operator**. J.-D. Benamou, G. Carlier, Q. Mérigot, and E. Oudet, submitted, 2014.*

*[2] **The variational formulation of the Fokker- Planck equation**. R. Jordan, D. Kinderlehrer, and F. Otto, SIAM Journal on Math. Anal. 29, I (1998), 1-17.*

# SCIENTIFIC RESULTS OF THE TEAMS

## VHIA : Vision and Hearing in Action

› Team PERCEPTION

In 2013, Radu Horaud was awarded an ERC Advanced Grant to pursue his project Vision and Hearing in Action, or how to make robots interact as mere humans !

Audio and visual perception play a complementary role in human interaction. Perception enables people to communicate based on verbal (speech and language) and non-verbal (facial expressions, visual focus, head movements, hand and body gesturing) communication. These two modes of communication have a large degree of overlap, in particular in social contexts. Moreover, the two modalities disambiguate each other whenever one of the modalities is weak, ambiguous, or corrupted by various perturbations. Human-computer interaction (HCI) has attempted to address these issues, e.g., using smart & portable devices. In HCI the user is in the loop for decision taking: images and sounds are recorded purposively in order to optimize their quality with respect to the task at hand.

However, the robustness of current speech recognition HCI modules degrades significantly if the microphones are located a few meters away from the speakers. Similarly, face detection and recognition work well under limited lighting conditions and if the camera is properly oriented towards a person. Altogether, the HCI paradigm cannot be easily extended to less constrained interaction scenarios which may involve several users and where the "social context" may be important.

The VHIA project investigates the fundamental role played by audio and visual perception in human-robot interaction (HRI). The main difference between HCI and HRI is that, while the former is user-controlled, the latter is robot-controlled, namely it is implemented with intelligent robots that take decisions and act autonomously. In the near future, VHIA's findings will allow to understand non-verbal and verbal interactions between people, to analyze their intentions and their dialogue, to extract information and to synthesize appropriate behaviors. For instance, a robot will be able to wave to a person, to turn its head towards the dominant speaker, to nod, gesticulate, ask questions, give advice or wait for instructions. The following topics are at the heart of the VHIA proejct: audio-visual sound-source separation and localization in natural environments (for example detection and tracking of moving speakers), inference of temporal models of verbal and non-verbal activities (diarization), continuous recognition of particular gestures and words, context recognition, and multimodal dialogue.

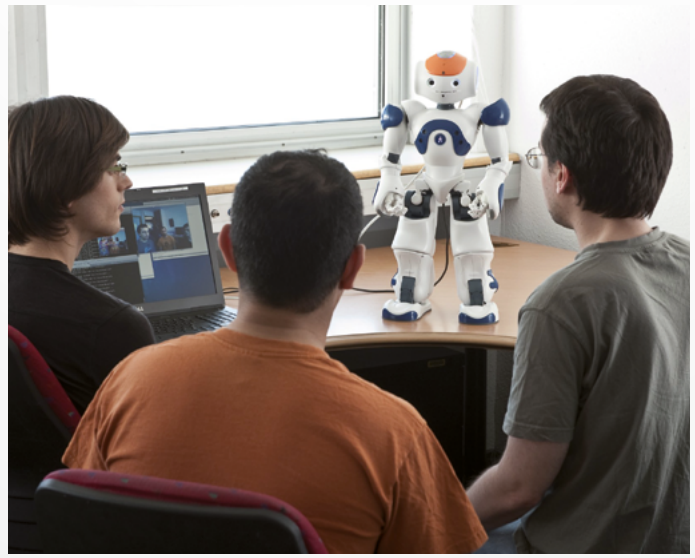
*[1]* ***Continuous Action Recognition based on Sequence Alignment Kaustubh Kulkarni****. G. Evangelidis, J. Cech, R. Horaud. International Journal of Computer Vision, Springer Verlag (Germany), 2014, 26p. ‹10.1007/s11263-014-0758-9›*

**https://hal.inria.fr/hal-00863468/file/submission_rev.pdf**

*[2]* ***High-Dimensional regression with Gaussian mixtures and Partially-Latent Response Variables****. A. Deleforge, F. Forbes, R. Horaud. Statistics and Computing, Springer Verlag (Germany), 2014, ‹http://link.springer.com/article/10.1007/s11222-014-9461-5›. ‹10.1007/s11222-014-9461-5›*

**https://hal.inria.fr/hal-00863468/file/submission_rev.pdf**

**https://team.inria.fr/perception/vhia**



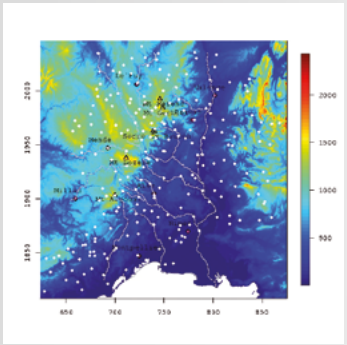
*The VHIA project investigates the role played by visual and auditory perception in human-robot interaction.*

PART 3

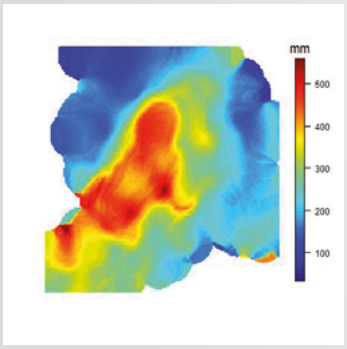
# SCIENTIFIC RESULTS OF THE TEAMS

## Estimation of extreme risk measures

› Team MISTIS



*Map of the Cévennes-Vivarais region, horizontally: longitude (km), vertically: latitude (km), the color scale represents the altitude (m), the white dots represent some raingauge stations.*




*Estimation of the CTE for a 100-year return period.*

Risk management is a major concern in hydrology, insurance, or finance. In insurance, anticipating extreme risks is essential to assess the probability of ruin. In hydrology, the study of extreme rainfalls or river flows is of great interest to anticipate disasters such as floods.

One of the most popular risk measures is the Value-at-Risk (VaR). In statistical terms, the VaR at level $\alpha \in (0,1)$ corresponds to the upper $\alpha$-quantile of the loss distribution. An alternative risk measure is the Conditional Tail Expectation (CTE) or Expected Shortfall. It is defined as the expected loss given that the loss lies above the upper $\alpha$-quantile. In hydrology, the VaR of the rainfall distribution is interpreted as a return level while the CTE is the mean of the rainfalls larger than the VaR.

Mistis introduced new tools for estimating various risk measures in case of extreme losses ($\alpha \to 0$) based on extreme-value theory. Nonparametric smoothing methods are also used to take into account of covariate information. An extrapolation factor is introduced in classical kernel estimators in order to estimate risks associated with non-observed extreme events.

It is then necessary to estimate the conditional extreme-value index which indicates the tail heaviness of the distribution as a function of the covariate.

The proposed methods are used to assess the risks due to extreme rainfalls in the Cévennes-Vivarais region. The covariate permits to capture the geographical characteristics of the regions of interest.

**http://mistis.inrialpes.fr/**


***On kernel smoothing for extremal quantile regression***.
*A. Daouia, L. Gardes & S. Girard. (2013). Bernoulli, 19, 2557-2589.*

***Nonparametric estimation of extreme risks from conditional heavy-tailed distributions***. *J. El Methni, L. Gardes & S. Girard. (2014). Scandinavian Journal of Statistics, 41, 988-1012.*


## GigaVoxels - Handling complex scenes

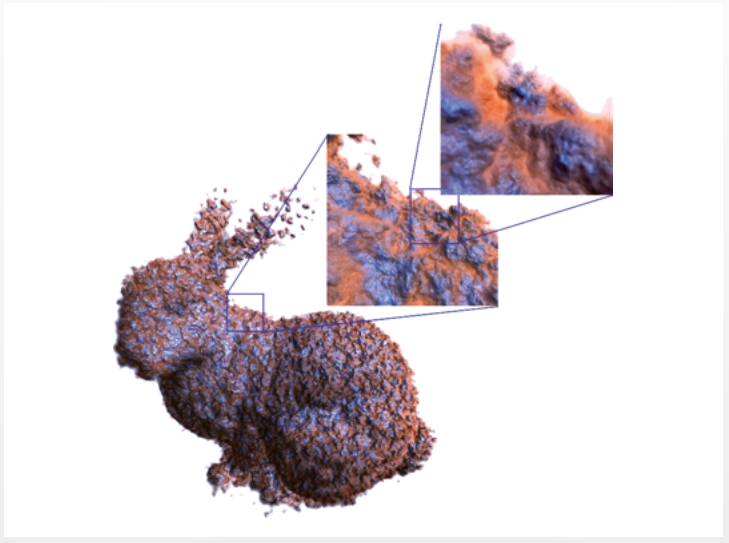
› Team MAVERICK

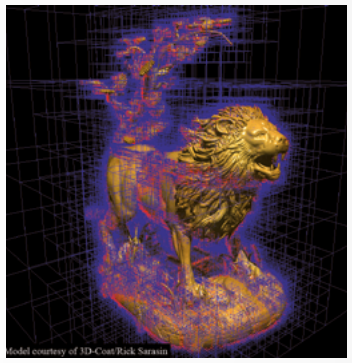
How to explore virtual worlds both very large and very detailed in real-time ?

GoogleEarth shows that it is possible to charge or build them "on the fly", depending on the view point and on the spatial resolution. But what if you seek representations that have no visual artefacts and that can produce features with the realism required by video games and special effects? The filtering of appearance is then a real challenge: how to ensure that fewer pixels (thus fewer calculations) could reflect the same visual richness (i.e., integrate the emerging lighting effects of small details) as richer representations ? Several studies at Maverick have tackled this problem, including those around Proland for natural objects (**http://proland.inrialpes.fr**) or LeadR for complex surfaces (**http://maverick.inria.fr/Membres/Eric.Heitz/index html#publi**).

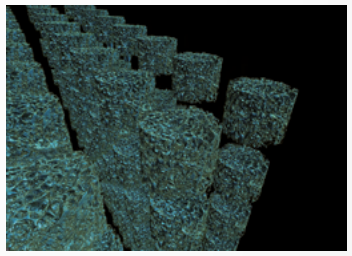
Started as a thesis which led to the development of a software platform (**http://gigavoxels.inrialpes.fr/-dual-licensed**), the GigaVoxel project addresses the case of general virtual scenes. Matter is represented as SVO's - Sparse Voxels Octrees - organized into a GPU of voxels blocks. These are the visualization rays - the cones through the pixels - which, visiting the scene, determine if useful blocks are lacking, which are then produced on the fly, with the resolution of the cones.

It is interesting to note that the structure of voxels allows a natural definition of notions of order, neighborhood, filtering. Voxels are also more economical than meshes in the representation of microscopic details. Better performance is obtained, for larger complexity and greater visual effects (depth of field, soft shadows).






*Octree volume encoding a complex object.*



*An ultra-huge scene explored in realtime with GigaVoxels.*

*Complex illumination computed in realtime in octree space.*

*An ultra-detailed object. Details are generated on demand when closeby.*

PART 4

# COMPUTING PLATFORMS AND VALORIZATION

MaiMoSiNE was created jointly by CNRS, UJF and Grenoble-INP in 2010, as an agency to promote interdisciplinary research in mathematical modeling and numerical simulation. Coordinated by Stéphane Labbé and hosted at LJK, MaiMoSiNE also ambitions to develop interactions between academic research units and regional companies (see **http://www.maimosine.fr**).

In this spirit, MaiMoSiNE fosters collaborations between companies located in the Rhône-Alpes région, and researchers from several laboratories of the Université Grenoble-Alpes. The involved companies may be startups and SMEs (e.g. DOCEA-Power for heat-flow control in electronic circuits) or major industries (e.g. TOTAL for modeling sea-ice). MaiMoSiNE also organises or sponsors various training courses (e.g. the ASPEN school for statistics), seminars (e.g. the MODANT seminar) and study groups. Doctoral courses are also organized, jointly with the Ecole Doctorale of the Université Grenoble-Alpes. All this allows MaiMoSiNE to fulfill its role of initiator of scientific collaborations and of dissiminator of new results and techniques for modeling and simulation.

MaiMoSiNE and the Labex AMIES have been associated since their creation. The latter is the French agency for mathematics in interaction with the economic and socio-cultural world, which has a national scope (see **http://www.agence-maths-entreprises.fr**).

AMIES collaborators relay local requests for industrial collaborations to MaiMoSiNE, which organizes and implements them, sometimes with financial support from AMIES via the PEPS mechanisms (with funding levels of 20% to 40%). In return, MaiMoSiNE is constructing a catalogue of French experts in mathemtatics, the main goal of which is to facilitate industrial collaborations and increase the visibility of mathematics in the socio-economic world.

Since its launching, MaiMoSiNE has also been closely associated with the high permornace computing platform CIMENT. In particular, CIMENT/MaiMoSiNE has recently acquired a new HPC platform called Froggy, with the financial support of the Equipex project equip@meso. CIMENT and MaiMoSiNE have also developed common projects of scientific animation, HPC-PME programming, and communication. The synergy between the two entities is likely to intensify in the coming years.

**The year 2014 in a glimpse**

*Scientific animations:*
- 8 MODANT seminars.
- Two seminars and a training course on high performance computing, organized in collaboration with BULL.
- A training course in scientific computing and HPC organized jointly with the doctoral school.
- A training course in statistics, organized jointly with the doctoral school, on the request of UJF Physics department.
- 2 scientific schools and 4 workshops have been financially supported.

*Industrial collaborations:*
- 7 research collaborations have been started,
- 6 are being negotiated.

A particular academic collaboration has been initiated with INSERM this year. Its goal is to understand and model the human effort, in view of optimization and coaching. In order to collect data for this study, MaiMoSiNE supports an expedition to the Himalayas, whose objective is the first ascent of the Damodar Himal Peak, culminating at 6 450 m. MaiMoSiNE will be providing the mountain climbers with measuring devices to record their heart rates, pace, tracks, etc.

PART 4

# COMPUTING PLATFORMS AND VALORIZATION

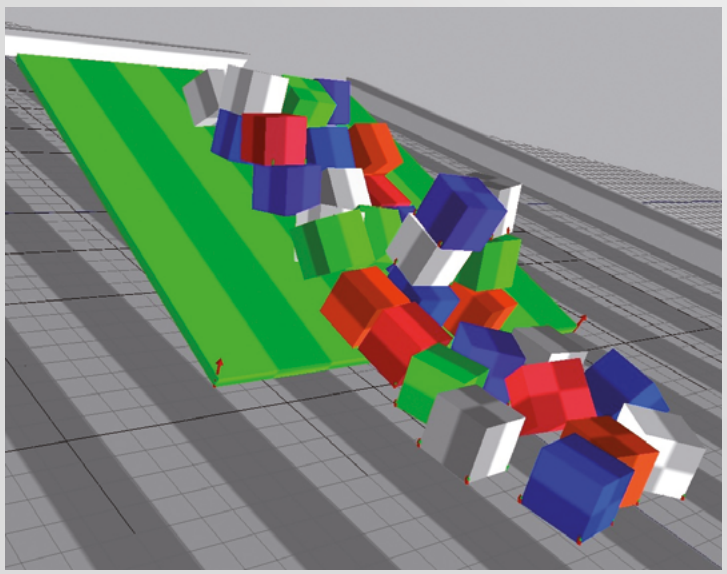
## SICONOS

SICONOS is an Open Source scientific software primarily targeted at modeling and simulating nonsmooth dynamical systems:

• Mechanical systems (Rigid body or solid) with unilateral contact and Coulomb friction, such as those encoutered in non-smooth mechanics, contact dynamics or granular material.

• Switched Electrical Circuits such as electrical circuits with ideal and piecewise linear components, power converters, rectifiers, phase-locked loops (PLL) or analog-to-digital converters.

• Sliding mode control systems. Other applications are found in systems and control (hybrid systems, differential inclusions, optimal control with state constraints), optimization (complementarity systems and variational inequalities), biology (gene regulatory networks), fluid mechanics and computer graphics,...



*Collection of polyhedrial bodies with friction*

**The software is based on 3 main components:**

• *Siconos/Numerics (C API)*

A collection of low-level algorithms for solving basic algebra and optimization problems arising in the simulation of nonsmooth dynamical systems:

- Linear complementarity problem (LCP)
- Mixed linear complementarity problem (MLCP)
- Nonlinear complementarity problem (NCP)
- Quadratic programming problems (QP)
- Friction-contact problems (2D or 3D, Second-order cone programming (SOCP))
- Primal or Dual Relay problems.

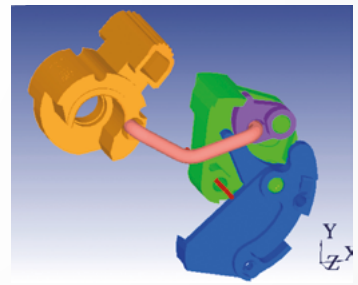
• *Siconos/Kernel (API C++)*

Allows one to model and simulate NonSmooth dynamical systems. It contains both dynamical systems classes (first order, Lagrangian systems, Newton-Euler systems) and nonsmooth laws (complementarity, relay, friction/contact, impact).

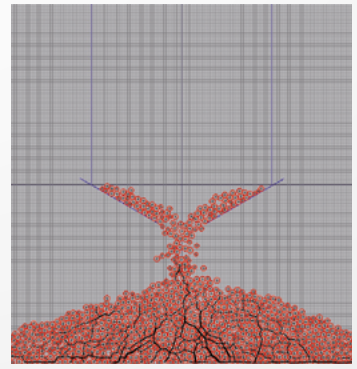
• *Siconos/Front-end (API Python)*

Mainly an auto-generated SWIG interface of the API C++ which a special support for data structure.

**http://siconos.gforge.inria.fr/**




*Circuit Breaker (courtesy of Schneider Electric).*



*Granular matter*

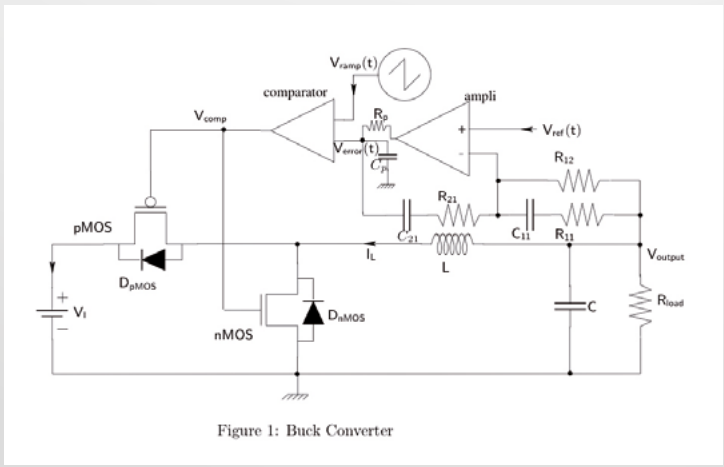



Figure 1: Buck Converter

PART 5

# AWARDS

## 2013

**M.-P. Cani (Imagine)**

elected member of the Academia Europae in 2013.

**D. Weinland, R. Ronfard (Imagine) and E. Boyer (Morpheo)**

2013 Computer Vision and Image Understanding Most Cited Paper Award.

**Z. Harchaoui (Lear)**

NIPS 2013 Outstanding Reviewer Award.

**Thomas Mensink (Lear)**

AFRIF 2013 best PhD thesis Prize.

**E. Heitz, D. Nowrouzezahrai, P. Poulin and F. Neyret (Maverick)**

2013 best paper award at the ACM SIGGRAPH Symposium on Interactive 3D Graphics and Games.

**V. Khalidov, R. Horaud (Perception) and F. Forbes (Mistis)**

best paper award at the IEEE International workshop on Multimedia Signal Processing (MMSP'13, Pula, Italy).

## 2014

**M.-P. Cani, professor at Grenoble-INP**

has been appointedto the chair of Informatics and Computational Sciences of College de France for the year 2015. The inaugural lecture `Shaping the imaginary world: from 3D digital design to animated virtual worlds' will be held on February 12th 2015.

More information on **http://www.college-de-france.fr/site/en-marie-paule-cani/course-2014-2015.htm**

**A. Deleforge (Perception)**

GDR Isis 2014 Signal, Image and Vision best PhD Prize.

**A. Girard (Casys)**

2014 CNRS Bronze Medal.

**C. Schmid (Lear)**

2014 Longuet-Higgins Prize.



PART 6

# CONFERENCES & WORKSHOPS





## 2013

### Workshop Optimization and Statistical Learning

› January 6-11th, Les Houches

*http://lear.inrialpes.fr/workshop/osl2013/index.html*

### Rencontres DYSCO – modeling of biological tissues 2013 › january 14-15th, Allevard

*www-ljk.imag.fr/membres/CHANT/consultation.php?INFO=CHANT2013*

### GDR CHANT – Transport in micro-structured media

› January 7-11th, Les 7 Laux

*www-liphy.ujf-grenoble.fr/IDySCo-Rencontre-2013*

### Uncertainty quantification and HPC

› March 28th, Grenoble

*www.gdr-mascotnum.fr/jt_2013.htmlComme*

### Workshop on Stochastic Geometry and its Applications (GDR GeoSto) › April 3-5th, Grenoble

*www-ljk.imag.fr/geoSto2013/*

### ASPEN: sensitivity analysis, uncertainty propagation and numerical modeling in the environmental sciences

› April 7-12th, Ecole de physique des Houches

*http://aspen.forge.imag.fr/*

### 2013 Meeting of the GDRE ConEDP, Modeling and control of systems : applications to nano-sciences, environment and energy › April 9-11th, Grenoble

*http://ljk.imag.fr/membres/Maelle.Nodet/GDRE2013/*

PART 6

# CONFERENCES & WORKSHOPS


## Conference Applied Analysis in Material Sciences

› May 27-31th, Luminy

*http://ljk.imag.fr/AAMS/*


## Modeling with optimal transport

› October 3rd-4th, Grenoble

*http://tommi.imag.fr/events/mot2013.html*

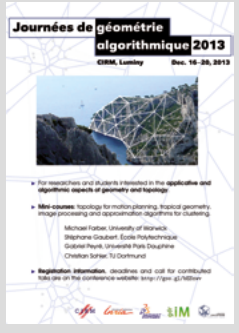
## Mathematics for graphene › October 14-15th 2013, Grenoble

*http://ljk.imag.fr/Graphene2013/*

## École Astrostatistique 2013 : Methods and applications of regression in astrophysics

› October 21-25th, Annecy

*http://ecastrostat2013.sciencesconf.org/*




## Journées de géométrie algorithmique

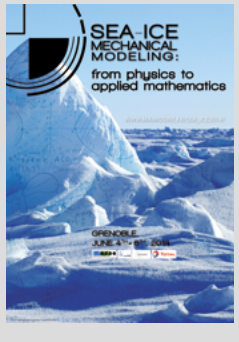
› December 16-20th, Luminy

*http://quentin.mrgt.fr/events/jga2013.html*

## 2014

## Inauguration of the Fédération Rhône-Alpes-Auvergne de Mathématiques › February 24th, Lyon

*http://frmraa.math.cnrs.fr/*




## 4th SIERRA Day: Adaptative models and methods for signal and image processing › March 25th, Saint-Etienne

*http://sierra2014.emse.fr/*

## Sea-Ice mechanical modeling : from physics to applied mathematics › June 4-6th, Grenoble

*www.maimosine.fr/sea_ice2014/*


## The Jean Kuntzmann Prize › June 16th, Grenoble

*https://persyval-lab.org/en/news/journ%C3%A9e-scientifiques-16-17-juin-2014*

## 8th international congress on Curves and Surfaces

› June 12-14th, Paris

*http://smai.emath.fr/curves2014/index.php*

## Rencontre Grenoble-Lyon de Statistique (GLyS)

› June 19th, Grenoble

*www-ljk.imag.fr/membres/Jean-Francois.Coeurjolly/lyongrel4/index.html*


## Multiwave imaging › June 25-27th, Grenoble

*www-ljk.imag.fr/membres/Faouzi.Triki/projetPbsInverses/workshopReg.html*

## Grenoble Optimization Day › November 5th, Grenoble

*http://bipop.inrialpes.fr/people/malick/Oday.html*

## International workshop on numerical methods and applications in fluid-structure interactions 2014

› November 24-25th, Grenoble

*https://sites.google.com/site/grenoblefsil4/*

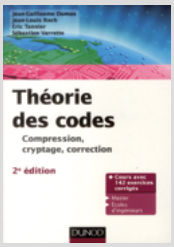
# Books


***Calcul avec Sage***
*A. Casamayou, N. Cohen, G. Connan, T. Dumont, L. Fousse, F. Maltey, M. Meulien, M. Mezzarobba, C. Pernet, N. M. Thiéry, P. Zimmermann*

*Creative Commons, Paternité-Partage des Conditions Initiales à l'Identique 3.0 France*
*468 pages, ISBN: 978148119l043*

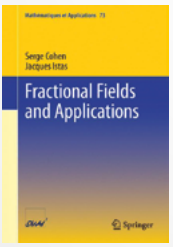

***Théorie de la mesure et de l'intégration pour les probabilités - Cours et exercices corrigés***
*M. Béguin*

*Collection Référence sciences, Ellipses, 2013*



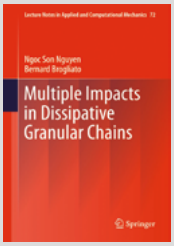

***Théorie des codes - 2e éd. - Compression, cryptage, correction***
*J.-G.Dumas, J.-L. Roch, E. Tannier, S. Varrette*

*Dunod Édition : 2e édition (août 2013)*



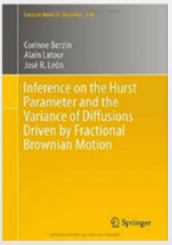

***Fractional Fields and Applications***
*Serge Cohen, Jacques Istas*

*Springer, 2013*



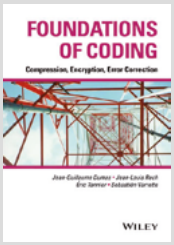

***Multiple Impacts in Dissipative Granular Chains***
*S. N. Ngoc, B. Brogliato*

*Lecture Notes in Applied and Computational Mechanics. Springer Verlag, 2013*




***Inference on the Hurst Parameter and the Variance of Diffusions Driven by Fractional Brownian Motion***
*C. Berzin, A. Latour, J. R. Léon*

*Lectures notes in statistics, Springer, 2014*




***Foundations of Coding: Compression, Encryption, Error Correction***
*J.-G. Dumas, J.-L. Roch, E. Tannier, S. Varrette*
*Wiley*

*ISBN: 978-1-118-88144-6, May 2015, 376 pages*


***The R Software: Fundamentals of Programming and Statistical Analysis***
*P. Lafaye de Micheaux, R. Drouilhet, B. Liquet*

*Springer, 2014*

## Some key figures for LJK

279 lab members

of which 73 professors and assistant professors

34 researchers

99 doctoral students and postdocs

200 publications in peer-reviewed journals per year

8 books in 2013-2014

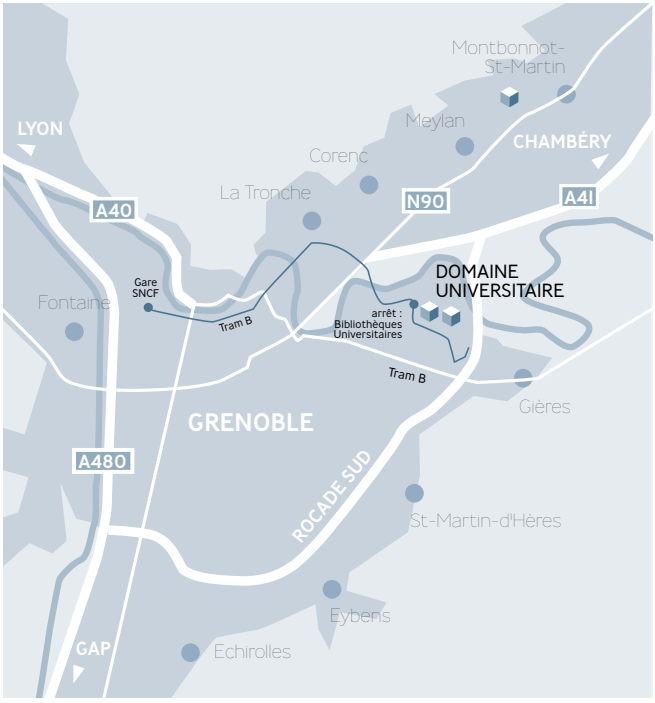
33 projects sponsored by the French ANR

10 European projects,

including 4 ERC individual grants

LABORATOIRE
JEAN KUNTZMANN
MATHÉMATIQUES APPLIQUÉES - INFORMATIQUE

## ljk.imag.fr





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