LABORATOIRE JEAN KUNTZMANN

HIGHLIGHTS
FAITS MARQUANTS

[2017-2018]

DEPARTMENT	DEPARTMENT	DEPARTMENT
ALGORITHMS, MODELS, ANALYSIS & COMPUTATIONS	**DATA AND STOCHASTIC: THEORY & APPLICATIONS**	**GEOMETRY & IMAGES**
Élise Arnaud	Adeline Samson	Nicolas Holzschuch
Mathematical analysis, PDE's, dynamical systems, control and optimization, inverse problems, numerical analysis, scientific and symbolic computing	*Probability, statistics, reliability, uncertainty modeling, data mining, signal processing*	*Geometric modeling, shape/image analysis, computer graphics, computer vision*
AIRSEA Laurent Debreu	**DAO** Jérôme Malick	**CVGI** Édouard Oudet
CASYS Jean-Guillaume Dumas	**FIGAL** Olivier Gaudoin	**IMAGINE** Rémi Ronfard
EDP Christophe Picard	**IPS** Karim Benhenni	**MAVERICK** Nicolas Holzschuch
ELAN Florence Descoubes-Bertails	**MISTIS** Florence Forbes	**MORPHEO** Edmond Boyer
NANO-D Sergei Grudinin	**SVH** Frédérique Letué	**PERCEPTION** Patrice Horaud
STEEP Emmanuel Prados		**THOTH** Julien Mairal
TRIPOP Vincent Acary		

December 2018

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FOREWORD

Since July 2016, I have the pleasure to chair the Jean Kuntzmann Laboratory. Founded ten years ago, the quality of this research unit has been forged by the work of the first two chairmen: Georges-Henri Cottet and Éric Bonnetier. In particular, they initiated the publication of these Highlights in order to emphasize the achievements of the members of the Laboratory. Pursuing this excellent initiative, I am happy to introduce this new edition. The period, as can be seen in this document, has been very rich and the presented results illustrate the great dynamism of the research teams.

Scientific developments, that are the heart of laboratories activities, are presented, and are complemented by three portraits of colleagues. Moreover several other aspects and projects are presented: scientific animations and technology transfer ensuring the diffusion of ideas, funding sustaining the research efforts...

In particular, the LJK is implied in the « Grange des Maths » project, an exposition space for mathematical objects, a showroom and playground, intended for a broad cross-section of the public. Moreover, several industrial collaborations, start-ups and computation platforms have been developed, from sea ice modeling to neurology. These activities are examples illustrating the dynamism of our laboratory. Furthermore, the funded projects highlighted in this document are examples of the scientific credibility of the researchers of the Laboratory throughout the community, and illustrate our wide disciplinary spectrum from applied mathematics to computational sciences.

This great dynamism of the LJK comes first from the people working in the lab, researchers and administrative teams, supported by our institutions (CNRS, UGA, G-INP, Inria).

Stéphane Labbé

Julien Mairal

Julien Mairal is a research scientist at Inria and leader of the Thoth team at LJK since 2018. His research interests are about statistical machine learning, optimization, computer vision, and image processing.

Julien Mairal graduated from Ecole Polytechnique in 2005 and obtained his PhD in 2010 from Ecole Normale Supérieure, Cachan. He was then a post-doctoral researcher at the Statistics department of UC Berkeley, before joining Inria Grenoble (and the LJK laboratory) in 2012. His work received several awards, including the Cor Baayen award in 2013, which is a European prize awarded by ERCIM each year to a promising young researcher in computer science and applied mathematics, the IEEE PAMI young research award in 2017, and the test-of-time award in 2019 at the International Conference on Machine Learning (ICML), which recognizes the most influential paper ten years after its publication.

A large part of his past research work has been devoted to a basic simplicity principle in science, which is called sparse coding. When modeling data, it is relatively common to look for a model that can explain observations, but when one has to choose between several models that seem equally plausible, the principle of sparsity tells us to select the simplest one, involving the smallest number of parameters. Implementing such a principle in practice requires developing algorithms that may process large amounts of data, in particular for learning visual recognition models in computer vision. In the context of images, the principle consists of representing images as a linear combination of a few elementary patterns from a learned dictionary.

More recently, Julien Mairal got interested in mathematical optimization in order to develop efficient algorithms for finding the parameters of machine learning models, and in developing theoretical and methodological foundations of deep learning by marrying deep learning with a classical paradigm called kernel methods. For that, he received a grant from the European Research Council (ERC) in 2016. One of the grand challenges of the project is to develop machine learning models that are more robust and use less annotated data, which are extremely costly to obtain in practice.

Last, Julien Mairal likes to establish pluri-disciplinary collaborations with other fields (which he typically knows nothing about), but which produce large amounts of (hopefully clean enough) data.

Adeline Leclercq-Samson

Adeline Leclercq Samson joined the LJK and "Université Grenoble Alpes" as a full professor in Statistics in 2013. Her main research themes are stochastic processes, mixed models, Bayesian statistics and stochastic algorithms. She is interested in both theoretical and practical aspects, in particular in biology and medicine. For many years, she has established many successful national and international collaborations.

She has written tens of international publications and participated in numerous national and international conferences. Adeline also supervises many PhD students and postdoctoral researchers.

Adeline is also interested in practical aspects and works with private companies on a wide variety of topics. Adeline has many responsibilities, whether at the local or national level. We cannot give an exhaustive list, but here is a small sample in which she is involved: Vice-President of SFDS (the French statistical society), in charge of training for the Data Institute of Univ. Grenoble Alpes, the lead of the department DATA of LJK and so on...

Since few years, she is interested in applying mathematical methods in the field of sport. She is a member of a new research group, called "Maths et Sport".

Adeline is also very involved in teaching, and is the lead of master SSD of UGA.

Finally, Adeline is a very enthusiastic person and is very appreciated by her students and her many colleagues and by all those who collaborate with her.

PORTRAITS

Clément Pernet

Clément Pernet is Maître de Conférence of Univ. Grenoble Alpes in Computer Science since 2008 and joined the CASYS group of the LJK lab in 2016. His research covers several complementary aspects of computational mathematics, and lies at the intersection between computer algebra, high performance computing, and security.

In linear algebra algorithmic, his outstanding contributions deal with the computation of the characteristic polynomial (showing the first complexity reduction to matrix multiplication) [1] or with the notion of rank profile and its relation with elimination algorithms (for which he received the distinguished paper award at ISSAC'15) [2].

Throughout his research, he takes a special care to conciliate theoretical improvements on asymptotic complexities and the efficiency in practice for high performance computing. For instance, his first research contribution, demonstrating how exact linear algebra over a finite field can rely on the numerical BLAS routines has since then been widely adopted in almost all mathematical software [3]. More generally, he leads or contributes to the development of the broadly distributed libraries LinBox, fflas-ffpack and Givaro and the open-source mathematical software SageMath. These projects involve large international collaborations, such as the H2020 OpenDreamKit project for which he leads the High Performance Computing work package.

More recently, he started to investigate some of the many security concerns raised by the increasing use of externalized computing infrastructures. He applies tools from coding theory, interactive proof protocols or secure multiparty protocols to define algorithm-based security enhancing protocols for outsourced computations.
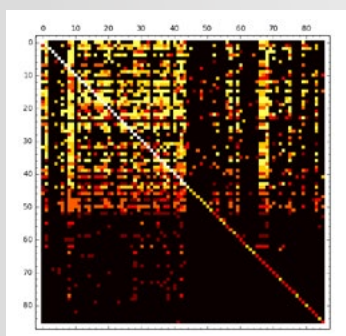
Heat-map for the coefficient degrees of a weak-Popov form arising in the computation of the characteristic polynomial.
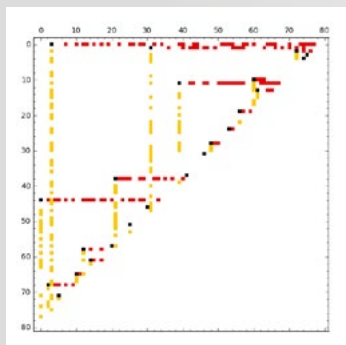
The new Compact Bruhat generator for quasi-separable matrices, relying on the rank profile matrix invariant, introduced in 2016.

[1] *Faster algorithms for the characteristic polynomial*. C. Pernet and A. Storjohann. Proceedings of the International Symposium on Symbolic and Algebraic Computation - ISSAC'07, 307-314 (2007).

[2] *Computing the Rank Profile Matrix*. J.-G. Dumas, C. Pernet, and Z. Sultan. Proceedings of the International Symposium on Symbolic and Algebraic Computation - ISSAC'15, 149-156 (2015)

[3] *Finite field linear algebra subroutines*. J.-G. Dumas, T. Gautier, and C. Pernet Proceedings of the International Symposium on Symbolic and Algebraic Computation - ISSAC'02, 63-74 (2002).
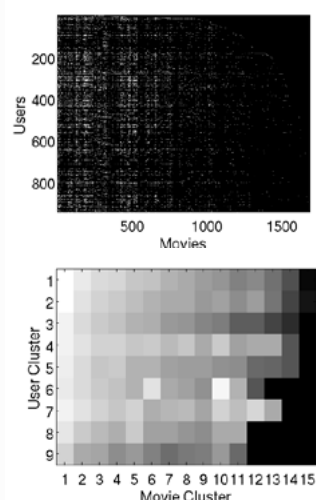
Transport data to better classify
› SVH team

Figure 1 - Raw matrix of the dataset MOVIELENS-100K (above) then reorganized and summarized in blocks (below).
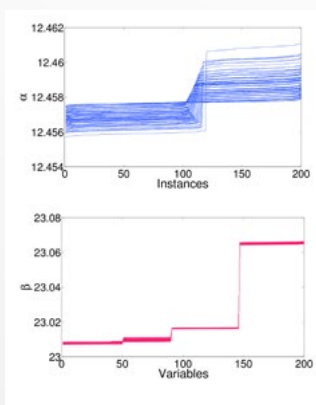
The goal of co-clustering is to partition the rows and columns of a matrix to highlight a grid of side-by-side heterogeneous, homogeneous blocks. For example, Figure 1 displays the challenge matrix of the MovieLens 100K Dataset [1] representing the votes of 943 users on 1682 movies. In the lower part of Figure 1, the matrix is reorganized in blocks resulting in nine groups of users who like in the same way fifteen groups of movies. Until now, two disciplines were mainly concerned with this problem: *statistics* and *machine learning*.

The idea of paper [2] is to associate optimal transport in the search for clusters when dealing with square matrices. Optimal transport theory was first introduced in [3] to study the problem of resource allocation: assuming that there is a set of factories and a set of mines, the goal of optimal transport is to move the ore from mines to factories in an optimal way, i.e., to minimize the overall transport cost.

In the case of co-clustering, authors propose to *transport* rows on columns and vice versa. In theory, similar rows, respectively similar columns, will be transported in the same way. In practice, we observe that once rearranged in ascending order, the transport cost vectors form a function with plateaus that correspond to the clusters of the rows and columns (see Figure 2).

The interest of this collaboration has been to pool the already existing results of each community including the theoretical convergence results obtained by the statisticians and the performance of the algorithms proposed by the members of *machine learning* and *optimal transport* communities. A CNRS news has been published on this work [4].

[1] *Data available at https://grouplens.org/datasets/movielens/100k/*

[2] **Co-clustering through optimal transport.** *C. Laclau, I. Redko, B. Matei, Y. Bennani, and V. Brault. Proceedings of the 34th International Conference on Machine Learning, Journal of Machine Learning Research, 70, 1955–1964 (2017).*
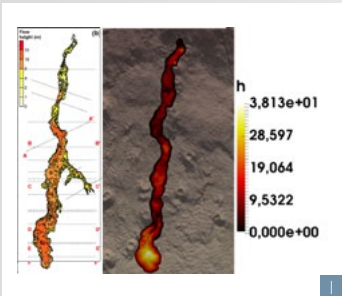
[3] **Mémoire sur la théorie des déblais et des remblais.** *G. Monge. Histoire de l'Académie Royale des Sciences de Paris, 666–705 (1781).*

[4] *Data available at https://ins2i.cnrs.fr/fr/cnrsinfo/transporter-les-donnees-pour-mieux-les-classer*

Figure 2 - Transport cost vectors obtained from simulations of 1000 datasets, reordered in ascending order. We recognize the four trays corresponding to four clusters (below).

Predicting volcanic lava flows
› EDP team

Observed final deposit of the 2001 Etna flow together with its numerical prediction.
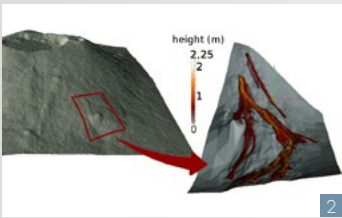
Simulation of the 2010 Piton de la Fournaise eruption.

Lava flowing through a forest

Pierre Saramito (DR CNRS) is one of the principal investigators of LAVA, a project sponsored by the ANR (ANR-16-CE39-0009). This project, initiated in 2017, involves some major laboratories working on volcanoes in Europe (Clermont-Ferrand, IPGP, Torino, Catane, Lancaster). LJK's contribution concerns modeling and simulations. The main objective of this project is to understand the non-Newtonian behavior of lava flows, develop software and study some strategies for the protection of populations.

Lava flows present a specific aspect ratio: a large length of about several kilometers, together with a small height, typically of few meters. Based on a specific asymptotic analysis, we propose a mathematical model reduction of the 3D free surface flow of this viscoplastic fluid to a 2D model. The lava flow simulation software is based on the Rheolef C++ finite element library [1]. The model reduction enhances dramatically the efficiency of the numerical simulations and opens the way to realistic simulations: the interaction of lava flow with the complex topographies of the volcanoes is of major importance [2] (Figure 1 and 2).

A new strategy is studied during this project: the development of vegetation barriers for the protection of populations. Of course, all vegetation will be burnt and buried (see Figure 3). However, even though most effusive centers with significant populations are heavily vegetated, the possible effect of vegetation on the ability to have a cooling effect, slow down and stop the flow, is of major interest. We propose to describe a lava flow through vegetation as a viscoplastic flow through a porous media and performed its model reduction from 3D to 2D via a new asymptotic analysis [3]. This is an ongoing work and the project continues until 2020.

[1] *The Rheolef C++ finite element library*. P. Saramito. https://www-ljk.imag.fr/membres/Pierre.Saramito/rheolef

[2] *Modelling lava flow advance using a shallow-depth approximation for three-dimensional cooling of viscoplastic flows*. N. Bernabeu, P. Saramito, and C. Smutek. in A.J.L. Harris et al. eds, Detecting, modelling and responding to effusive eruptions, Geological Society, London, Special Publications 426(1), 409—425 (2016).

[3] *Laminar shallow viscoplastic fluid flowing through an array of vertical obstacles*. N. Bernabeu, P. Saramito, and A. Harris, Journal of Non-Newtonian Fluid Mechanics, 257, 59—70 (2018).

# Parametric estimation of dynamical systems
› DAO team

Given an input and an output data set, one wishes to build a model of the underlying dynamical system in order to predict or estimate future output from future input. This problem setting arises in situations when the input has to be chosen subject to constraints on the output (control) or when the measurement of the future output is too costly or impossible (estimation). Typical application areas are chemical and electrical engineering.

The input-output transfer function model is built by assuming an overall shape of the input-output dependence containing a number of parameters and then learning the parameters by minimizing the error between the output predicted from the input and the model on the one hand and the actual output available from the data set on the other hand. The error can also serve to construct a model of the measurement and/or system noise.

The parametric model can be chosen from a variety of classes ranging from simple linear ones such as ARX (auto-regressive with external input) to complicated non-linear customized models incorporating available a priori information on the system or derived from physical first principles. While learning the parameters of the former amounts to a convex optimization problem which can be solved by standard software packages, the latter leads to non-convex problems which can be challenging on their own. In our research group the necessary experience has been developed in order to balance the complexity and number of parameters of the model and the resulting optimization problems against the accuracy needed for the given application. The ultimate choice is usually made by an iterative procedure involving the evaluation of different statistical error assessment criteria.

In the framework of the collaboration with the company Odit-e we analyzed data sets of voltages, currents, and powers in order to predict these quantities at one point of the electrical power grid from measurements at another point which is cheaper and better accessible.
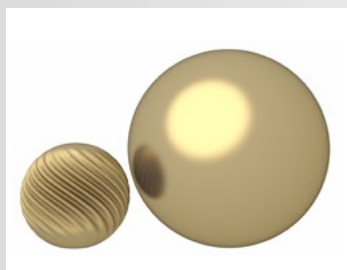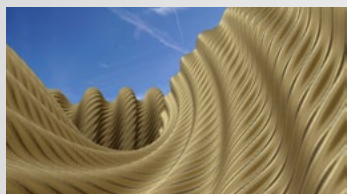

ARX model structure
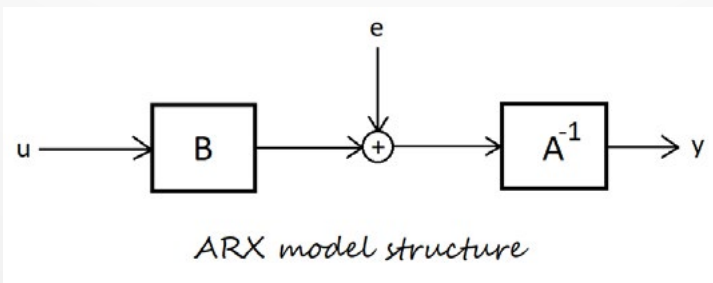
Odit-e power-transformer.

Reducing the earth surface inside a table tennis ball
› CVGI team

A reduced sphere (left) isometric to the round sphere (right).

The first construction of a reduced sphere has been obtained by a team[1] of mathematicians and computer scientists. Reduced spheres are known to be rigid: they cannot be isometrically deformed, i.e. they cannot be deformed while preserving the lengths of all the curves on the surface, with a regularity of class C^2. A result from John Nash and Nicolas Kuiper shows that this impossibility does not hold anymore if we allow a regularity of class C^1. As a noticeable consequence, it is possible to isometrically reduce a sphere in order to put it inside a ball with a radius arbitrarily small. In particular, if we assimilate the surface of the earth to a round sphere, the theory allows us to reduce its diameter to the one of the earth globe or to the one of a table tennis ball, while preserving geodesic distances.

The construction of such a "reduced sphere" amounts to solving nonlinear partial differential equations with boundary conditions. The resulting surface looks very much deformed and scrambled. It is composed of two spherical polar caps connected by an equatorial band whose structure has a C^1-fractal structure. An intriguing question concerns the transition between the smooth polar caps and the equatorial band. The team showed that such a transition is similar to the one observed when we connect together a Von Koch curve to a line segment.


Over a reduced sphere.

FloeDyn: Modeling rigid ice floes
› EDP team

The sea-ice modeling is a huge industrial and environmental challenge. In particular, the variations of albedo, the reflection of the energy into the atmosphere, have an impact on the warming process of the earth. Hence, the sea-ice disappearance would heat the sea and freeze the atmosphere, with an important impact on ocean circulation, and then on climate. In the project FloeDyn, we focus on the floe (block of sea-ice) dynamics. This study, in collaboration with IsTerre and TOTAL, is a long-term program which began six years ago with Matthias Rabatel PhD and continues with Dimitri Balasoiu PhD. The first PhD, seed of the study, focused on the movement and interaction of floes in an assembly (pack). This first part of the work has led to the development of the software FloeDyn, managed with Quentin Jouet, engineer. Thanks to FloeDyn, we have been able to simulate the real time evolution of packs with almost one million floes [1]. The second part of the work, topic of the PhD of Dimitri Balasoiu, is the fracturing of the floes. In order to treat the problem, we focused on the Gritffith model [2] based on a variational approach. The main bottlenecks to overcome were the efficiency of computations and the adaption of a finite element method able to manage fractures without re-meshing. The first problem has been tackled exploiting the assumption that fractures are almost straight lines in floes, the second developing finite elements allowing fractures, discontinuities, through the floes.
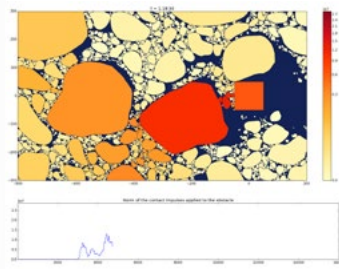
Ice pack collision on an island. Image of the pack during the impact and stress induced on the island.

Collaborators

Mathias Rabatel, former PhD, is now working in a specialized society in ice simulation.
Stéphane Labbé, Université Grenoble Alpes,
Jérôme Weiss, Université Grenoble Alpes,
Dimitri Balasoiu, Université Grenoble Alpes,
Quentin Jouet, free lance developer.

*[1] **Dynamics of an assembly of rigid ice floes**. M. Rabatel, S. Labbé, and J. Weiss. Journal of Geophysical Research. Oceans, 120 (9), 5887-5909 (2015).*

*[2] **The phenomena of rupture and flow in solids**.A.A. Grifith, Philosophical Transactions of the Royal Society of London, A, 221 (582–593), 163–198 (1921).*

Analysis and synthesis of rock climbing motion, from LJK to Paris 2024
› CVGI team

Rock climbing is fun. It is also an interesting scientific challenge as, unlike locomotion on a horizontal ground which is already a complex problem for biomechanics modeling, climbing involves multiple contacts. Indeed, while mechanics of free fall is rather straightforward, as soon as more than just gravity is concerned, all external forces such as contacts are the first unknowns to track down to obtain a good understanding on how the motor control of muscles is managed.

For the study of locomotion, this starts with the measurement of contact forces using equipment such as force plates. A similar experimental approach is difficult for climbing as it is complicated to equip holds with force sensors. This raised the following practical question: is it possible to measure forces without force sensors?

We cast this question as an optimization problem: given a steady posture of the human body in contact at different points on the wall and the Newton laws of dynamics, as several force solutions exist - all strength in the left arm, or in the right arm or more likely a balance of both, we tested the hypothesis that the solution is the one with minimal torques at joint angles.

To validate this, we confronted the results to experimental measurements with force sensors in a climbing wall. This has been the topic of research with colleagues at GIPSA Laboratory and McGill University at Montreal. This approach has also led to a method to simulate motion of a climber on a virtual wall (Quaine et al., 2017 [1]).

This work caught the attention of the French Federation for Climbing (FFME). Starting in Tokyo 2020, climbing is now Olympic with three disciplines: lead, boulder, and speed. Coaches of the French national team requested an

Building the athlete's 3D avatar.
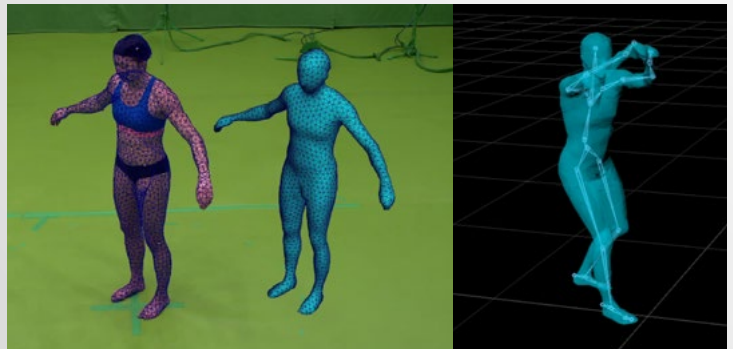
objective assessment of the athletes' performance. Before forces, measuring kinematics turned out already to be a challenge as the wall is 15m high and the average speed of international athletes ranges between 2 and 3 m/s. We thus proposed a video-based only technique which consists in aligning a 3D biomechanical twin of the athlete (3D avatar) onto the video of the performance.

This approach requires to first build this model, which is done thanks to the collaborative platform KINOVIS installed at Montbonnot (INRIA, CNRS, UGA, G-INP). Preliminary results showed that a satisfying prediction of the center of mass of the athlete can be achieved (Reveret et al., 2018 [2]). A personalization of the method for forces prediction is the future development of this research.

[1] *Postural regulation and motion simulation in rock climbing*. F. Quaine, L. Reveret, S. Courtemanche, and P. Kry, The science of climbing and mountaineering, III-128, Routledge Research in Sport and exercise Science (2017).

[2] *3D motion analysis of speed climbing performance*. L. Reveret, S. Chapelle, F. Quaine, and P. Legreneur. International Rock Climbing Research Association Congress, Chamonix, France (2018).
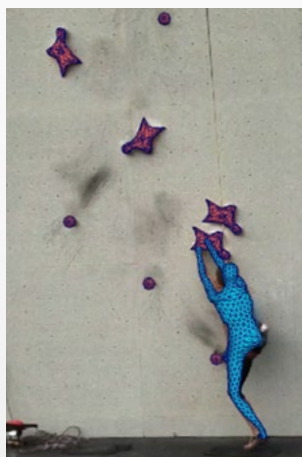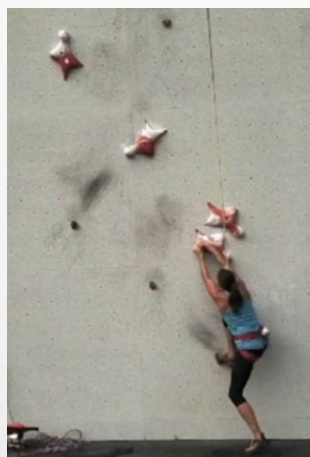
Video of the performance (left) and alignment of the 3D avatar (right).

MULTI-DISCIPLINARY INTERACTIONS

Professor Eva Tardos.

The Jean Kuntzmann Prize

Professor Eva Tardos, from Cornell University, is the third recipient of the Jean-Kuntzmann Prize, and has been awarded on February 21st 2018 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. It is now delivered by PERSYVAL-lab, the MSTIC pole and INRIA Grenoble. 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.

Eva Tardos is a Jacob Gould Schurman Professor of Computer Science at Cornell University, and she was Computer Science department chair from 2006 to 2010. She was trained in Hungary, and received her PhD in 1984 from Eötvös University in Budapest under the supervision of András Frank. She joined the faculty at Cornell in 1989.

Her research concerns algorithmic game theory and the development of efficient algorithms to solve problems such as optimization of traffic routing performance in large-scale communications networks. She studies design systems used by diverse and self-interested users, such as the Web, social networks or financial markets. In particular, she analyses the outcomes of selfish behavior in such complex systems, quantifying the efficiency loss due to the selfish behavior of the participants, and designing systems where selfish behavior results in close to optimal outcomes. Prof. Tardos has supervised 18 PhD students.

She has been elected to the National Academy of Engineering, the National Academy of Sciences, the American Academy of Arts and Sciences, and is an external member of the Hungarian Academy of Sciences. She is the recipient of a number of fellowships and awards including the Packard Fellowship, the Goedel Prize, Dantzig Prize, Fulkerson Prize, ETACS prize, and the IEEE Technical Achievement Award. She gave the Association for Women in Mathematics/SIAM Sonia Kovalevsky Lecture in 2018.

She is editor-in-Chief of the Journal of the ACM, and was editor in the past of several other journals.

During her stay in Grenoble, Eva Tardos gave a series of talks on the understanding of the efficiency of outcomes in games. She also gave during her award ceremony a public lecture entitled "Learning in games".

SCIENTIFIC RESULTS OF THE TEAMS

Asynchronous Optimization for Distributed Learning
› DAO team

The widespread use of artificial intelligence has led to tremendous transformations in machine learning systems. One of these changes consists in the development of larger scale learning systems relying on more powerful but often more heterogeneous computing architectures: network of hand-held devices, scattered data-servers, etc. Since optimization is at the core of machine learning [1], tackling such massive problems over these distributed architectures calls for a change in objective formulation, new mathematical tools, and new performance measures so that the whole system is less prone to attacks and robust to loosely connected agents.

Learning over a distributed architecture means exchanging frequently between the workers; in heterogeneous networks, this can cause synchronization issues and communications bottlenecks (for instance, if a worker is temporarily unavailable or if several workers want to reach a common coordinator). Given the trend towards more and more heterogeneous data acquisition and computing devices (e.g. Google's federated learning [2]), the need for resilient distributed learning systems is paramount.

In this context, we provide a distributed optimization procedure targeted at asynchronous master slave computing systems [3]. Our method adapts to local workers parameters and, in contrast with all existing literature, can handle any kind of delays: in practice, delays impact the observed convergence but i) the algorithms parameters are delay-independent; and ii) our convergence analysis relies on the proposed notion of epochs subsuming the delays produced by asynchrony. We thus propose both an efficient method and an efficient analysis for the optimization of learning problems over recent asynchronous distributed systems.
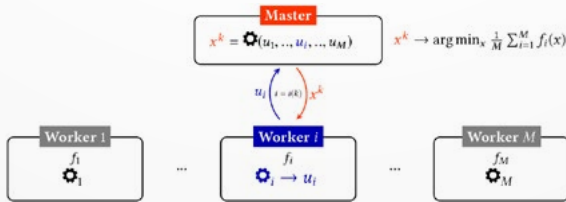

Illustration of an asynchronous distributed optimization method to minimize the average of the workers' functions.

[1] **Optimization methods for large-scale machine learning**. L. Bottou, F. Curtis, and J. Nocedal. SIAM Review, 60(2), 223—311 (2018).

[2] https://ai.googleblog.com/2017/04/federated-learning-collaborative.html

[3] **A Delay-tolerant Proximal-Gradient Algorithm for Distributed Learning**. K. Mishchenko, F. Iutzeler, J. Malick, and M.-R. Amini. International Conference on Machine Learning (ICML), Proceedings of Machine Learning Research, 80, 3587—3595 (2018).
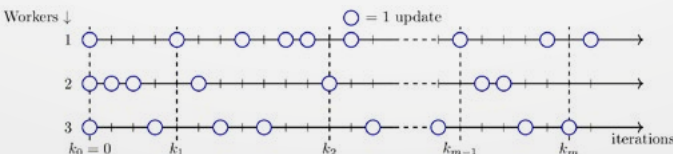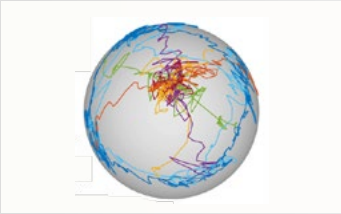
We propose a new analysis for asynchronous methods by considering "epochs" rather than iterations.
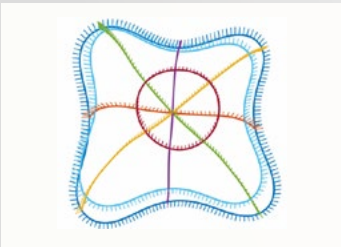
Shape from Sensors
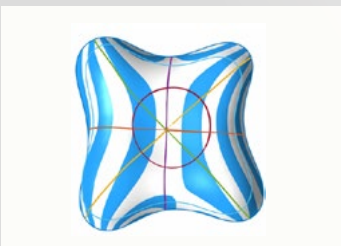› IMAGINE & MAVERICK teams
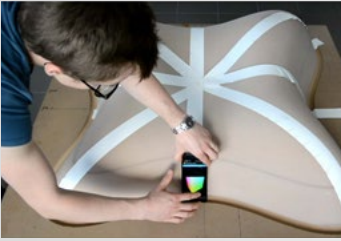
Shape acquisition by sliding a smartphone along a physical surface.

Orientation data and distances estimated from inertial and magnetic sensors.

Reconstructed smooth curve network with cell complex topology and normal vectors (RMS error ‹2%).

Final reconstructed smooth 3D freeform surface.

How to reconstruct a 3D shape by simply sliding a smartphone along a few curves on the surface?

The use of inertial micro sensors is common in many domains. Traditionally, they are at the heart of navigation systems to maneuver aircrafts, satellites or unmanned vehicles. Only recently, the use of inertial sensors for curve and surface reconstruction has emerged. The novelty of this reconstruction problem is to deal purely with orientation and distance data instead of point clouds traditionally acquired using optical 3D scanners. While a few pioneering methods were proposed in the last decade, shape sensing still remains a challenging task due to the inherent issues: inertial sensors only provide local orientations but no spatial locations; moreover, raw data from inertial sensors are inconsistent and noisy.

In collaboration with the CEA/LETI, we developed a complete framework for acquisition and reconstruction of 3D shapes using orientations provided by inertial and magnetic sensors. The reconstruction is composed of two steps, which are formulated as a set of optimization problems. First, a novel method for creating well-connected curve networks with cell-complex topology using only orientation and distance measurements has been introduced [1]. By working directly with orientations, the method robustly resolves problems arising from data inconsistency and sensor noise. Acquisition noise is filtered by combining pre-filtering of the raw orientations in the quaternion space with a spline-based smoothing in the group of rotations. A curve-based Poisson reconstruction method, then transforms the orientation samples into a smooth and consistent curve network by satisfying in particular the topological constraints. Second, the problem of surfacing a closed 3D curve network with given surface normal was solved by combining a Laplacian-based variational method with the mean curvature information extracted from the input normal [2].

This work has received the « SMI Best Paper Award » at the Shape Modeling International conference in Berkeley 2017.

[1] *Shape from sensors: Curve networks on surfaces from 3D orientations*. T. Stanko, S. Hahmann, G.-P. Bonneau, N. Saguin-Sprynski. Computers & Graphics 66, 74—84 (2017).

[2] *Surfacing curve networks with normal control*. T. Stanko, S. Hahmann, G.-P. Bonneau, N. Saguin-Sprynski. Computers & Graphics 60, 1—8 (2016).

Characterization of brain abnormalities in de novo Parkinsonian patients
› MISTIS team

Cerebral blood flow, mean diffusivity and fractional anisotropy maps extracted from MR images.

The diagnosis of Parkinson's disease (PD) is primarily based on the identification of motor symptoms that appear late in the course of the disease. However, non-motor symptoms and abnormalities in subcortical brain structures appear earlier and could serve as PD biomarkers. We take advantage of the informative nature of quantitative MRI to construct statistical models that characterize the physiological properties of subcortical structures in Healthy Controls (HC) and recently diagnosed ("de novo") PD patients.

Our approach is based on the modeling of multiparametric MRI data by Mixtures of Multiple-scale Student distributions (MSD) [1, 2], which offer great shape flexibility, as they are not constrained to elliptical shapes. A reference model (RM) is constructed by fitting an MSD mixture to the values of all voxels belonging to HC. Then, we measure the proximity of each voxel of each subject to the RM by calculating their log-density (or log-score). The rationale is that HC voxels are more likely to have a high log-score than PD voxels. From this point, we consider all voxels with a log-score below a certain threshold τ as abnormal and their corresponding measures are fitted with a new MSD mixture taken as the abnormality model (AM). Classically, τ is associated to a false positive error rate α of 5%. For each subject, the proportion of voxels assigned to each abnormal class may constitute a signature. AM is eventually used to account for the fact that voxels detected as abnormal may reveal different patient phenotypes.
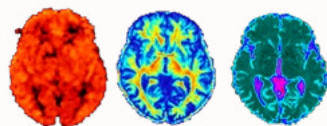
We have demonstrated the feasibility of our approach on a small dataset consisting of 3 parameter maps (cerebral blood flow, mean diffusivity and fractional anisotropy) of 3 HC and 10 PD. 12% of the PD voxels were detected as abnormal and subsequently modeled by an AM. The most important abnormalities were mainly found in the subcortical structures, the brainstem and the diencephalon, in accordance with the physiopathology of the disease.

Although more subjects and MRI maps are required to robustly define biomarkers, these preliminary results show that the combination of quantitative MR data with relevant mixture models renders early PD detection possible.
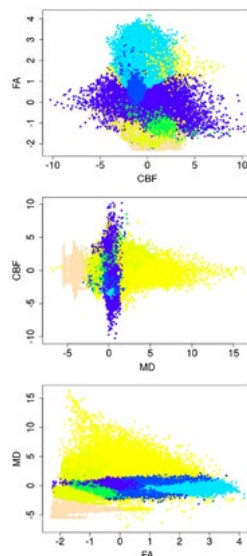
This work has been presented at SFRMBM 2019, ISBI 2019 IEEE Conference and OHBM 2019 and can be accessed at https://hal.archives-ouvertes.fr/hal-01970682v2.

Visualization of the RM, each color represents a component of the MSD mixture.

[1] **A new family of multivariate heavy-tailed distributions with variable marginal amounts of tail weight: application to robust clustering**. F. Forbes and D. Wraith. Statistics and Computing, 24, 971–984 (2014).
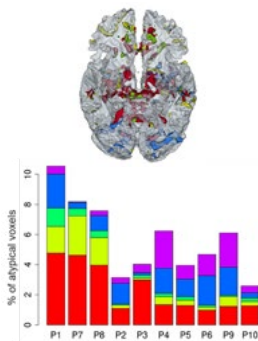
[2] **Fully Automatic Lesion Localization and Characterization: Application to Brain Tumors Using Multiparametric Quantitative MRI Data**. A. Arnaud et al., IEEE Transactions on Medical Imaging, 37, 1678–1689 (2018).

Signatures of 10 patients, each signature represents the proportion of every component of the AM in the subject's brain.

COMPUTING PLATFORMS AND VALORIZATION

La Grange des Maths

La Grange des Maths is a project of scientific culture, organized in an association (created in 2015). It aims to make people, regardless of age, education or social background, (re)discover the pleasure of mathematics, through entertaining activities involving manipulation and thinking. Several LJK members are strongly involved in La Grange des Maths, and the project benefits from a strong support from Univ. Grenoble Alpes.

Its activities are organized in three main areas:

Mediation to the general public

A stand of varied activities, designed for all ages and levels, is present in 15 to 20 events per year, mainly in the Grenoble region but also elsewhere in France. The association also organizes each year its "Maths à l'Oriel", a convivial afternoon for all public, with a popularization conference followed by a session of mathematical games. Moreover a mathematical course, in the spirit of a treasure hunt and an escape game, is presently in preparation, which should be available from spring 2020.

Traveling teaching suitcases of fun mathematics activities

Mathematical activities have been developed specifically, in collaboration with the IREM, to be integrated in a transportable suitcase, able to circulate in schools. Pupils can then "do math differently", alone or in a small group, in an autonomous way, in a playful spirit. A first suitcase for the middle school level, La Grange Vadrouille, was used by 6,000 pupils in 2017-2018, and 12,000 in 2018-2019. A second suitcase, designed for primary school, will be launched in 2019. These suitcases are presently distributed at a regional scale, in collaboration with the local education authority (Rectorat de Grenoble).

Preparation of a future animation center dedicated to math

La Grange des Maths should also hopefully be a center for scientific animation for all audiences, which will offer a huge variety of mathematical hands-on activities. The building, a former barn, is located in the heart of the park of Varces-Allières-et-Risset (southern suburbs of Grenoble). Its restoration and the way it will be operated are presently being discussed with the town council of Varces and with Grenoble Alpes Métropole.
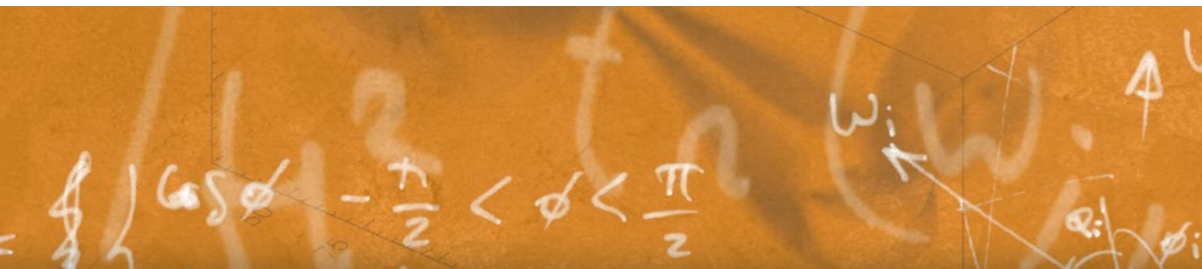
© Association La Grange des Maths.

More information

www.la-grange-des-maths.fr

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Artist view of the future center in Varces-Allières-et-Risset.
*© F. Golay - N. Guimbard, architects.*

Detecting defects in semiconductors
› DAO & FIGAL teams

Unity SC is a European leader in metrology and inspection solutions for semiconductor manufacturing. They came to us through MaiMoSiNE in 2017 for expertise on a defect classification problem from their measured data. Part of their service include detecting defects in semiconductor production chains using metrology and then classifying them to determine their severity and which part of the manufacturing process may be defective. So far, this classification task was performed by highly qualified engineers, which was very costly and time-consuming; in addition, the produced classification suffered from consistency issue depending on which person was in charge of the classification. They contacted us with the idea that artificial intelligence could enable them to automatize that classification process.

Indeed, they were right! A few meetings later, it became clear how we could integrate AI in their process. We proposed a solution based on a machine learning toolbox to learn how to perform this classification process without any human action thanks to the provided manually-classified defects. We quickly agreed on the specifications of the toolbox and decided to rely on the well-known scikit-learn Python library to produce a defect classifier using decision trees. Our solution enabled them to replace the non-reproducible one-month-work of a highly qualified engineer by a decision tree providing a robust result within 30 seconds that can be trained again easily should new defects come up. For Unity SC, this has been a major breakthrough that brought them a competitive advantage.

The collaboration was a successful partnership for all parts. Unity SC came to us with a well identified problem, which we turned into a mathematical question. At a time when big data has become the new standard, working in a small data environment was very motivating and challenging. Unity SC's inspection solution monitors several hundreds of variables leading to as many features in the classification but at the same time very few semiconductors were defective. Therefore, the set available for training the classification algorithm was relatively small. As challenging as this classification problem may look, AI solved it efficiently.
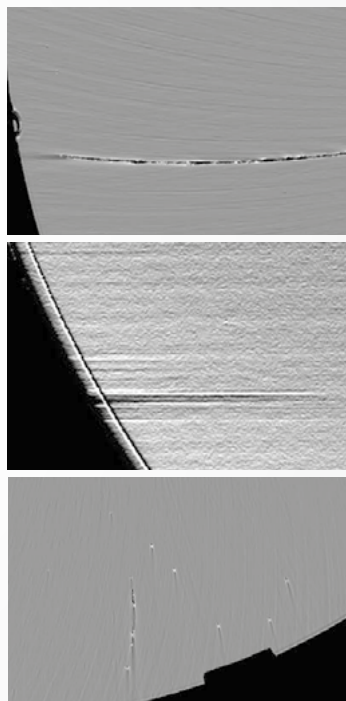
Defects on a semiconductor wafer.

Design of detectors in airbags for motorcycle racers
› CVGI team

Motorcycle racer airbag

In&motion is a firm based in Annecy and is specialized in designing airbags for ski cross, horse riding and motorcycle racers. In the last few years, they have worked specifically on improving their airbag for motorcycle racers. Indeed, two-wheels users are among the more vulnerable transport users, and in&motion is committed to better protect them with a significantly higher level of protection.

The issue that In&motion wanted to solve was, based on recordings of an accelerometer and gyrometer using a sensor placed on the vest containing an airbag system, to define a simple trigger to inflate the latter in case of an imminent fall.

The aim of the collaboration was to define a robust detector of when to trigger the airbag of motorcycle racers from measurements collected by a sensor put on a vest worn by the motorcyclist. It was of paramount importance not to have spurious detections of imminent fall, because unwanted airbag inflation could cause the fall of the racer, so we had to pay a particular attention to this aspect.

From a mathematical point of view, the data consisted at each time instant of a vector of six components, i.e. three accelerations and three rotations, which we had to analyze in order to select those most relevant in the context of fall detection. We considered the six fields separately and modeled each of them with generalized Gaussian densities. We then built a detector of imminent fall based on the analysis of the data assuming they were distributed according to a generalized Gaussian density model.

The results we obtained were very conclusive and the detector has actually been implemented of the new generation of vest.

AWARDS

2017

Achmad Choiruddin (FIGAL and SVH teams)

Mahar Schützenberger 2017 Prize in statistics awarded on July 3rd 2017 at the Indonesian Embassy in Paris for his work entitled "Variable selection in spatial point processes".

Julien Mairal (THOTH team)

2017 IEEE Pattern Analysis and Machine Intelligence Young Researcher Prize.

Gilles Daviet (BIPOP team)

GdR IG-RV Thesis Prize for his work "Modeling and simulating complex materials subject to frictional contact: application to fibrous and granular media" under the supervision of Florence Bertails-Descoubes.

Maëlle Nodet (AIRSEA team) and Jocelyne Erhel (Inria)

Winners of the second Mathematics of Planet Earth competition for their Software "Simulating the melting of ice caps".

Tibor Stanko (MAVERICK team)

Best Paper Award from the Shape Modeling International Symposium (SMI 2017), held in Berkeley, USA, for his paper entitled "Shape from sensors: Curve networks on surfaces from 3D orientations". The paper, also published in Computers & Graphics vol. 66, was co-authored by N. Saguin-Sprynski of CEA, and S. Hahmann and G.-P. Bonneau of INRIA.

CONFERENCES
& WORKSHOPS

2017

SEISCOPE Annual Meeting
April 5-6, Grenoble

https://seiscope2.osug.fr/?lang=en

6th Workshop on Intelligent Cinematography and Editing (WICED'17)
April 24, Lyon

https://wiced.inria.fr/program/

Calculus of Variations and Free Boundary Problems
June 17, Grenoble

https://www-ljk.imag.fr/membres/Edouard.Oudet/research/GeoSpec/workshop_geospec/workshop_geospec.html

10th International Conference on Mathematical Methods in Reliability (MMR 2017)
July 3-6, Grenoble

http://mmr2017.imag.fr/

Colloque Francophone International sur l'Enseignement de la Statistique
September 6-8, Grenoble

http://cfies2017.sfds.asso.fr/index.html

Workshop: Inverse problems and Neumann-Poincaré operators
November 29-30, Grenoble

https://www-ljk.imag.fr/membres/Faouzi.Triki/NPO.html

2018

Cross-Disciplinary Project RISK kick-off meeting
April 5, Grenoble

https://risk.univ-grenoble-alpes.fr/

SEISCOPE Annual Meeting
April 11-12, Grenoble

https://seiscope2.osug.fr/?lang=en

GRATWIT: Workshop sur la dynamique des communautés sur Twitter en période électorale
April 26-27, Grenoble

Grenoble workshop on models and analysis of eye movements
June 6-8, Grenoble

Localization, Control and Inversion of Waves I
June 28, Grenoble

Artificial Intelligence Summer School (PAISS)
July 2-6, Grenoble

https://project.inria.fr/paiss/

Bayesian learning theory for complex data modelling
September 6-7, Grenoble
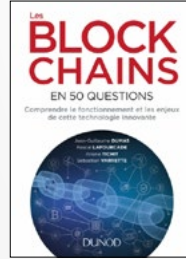
https://sites.google.com/view/bigworkshop/home

Books

Data Science
Massih-Reza Amini, Renaud Blanch, Marianne Clausel, Jean-Baptiste Durand, Éric Gaussier, Jérôme Malick, Christophe Picard, Vivien Quéma, Georges Quénot
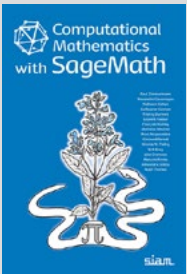
Eyrolles, 2018

Les blockchains en 50 questions : Comprendre le fonctionnement et les enjeux de cette technologie innovante
Jean-Guillaume Dumas, Pascal Lafourcade, Ariane Tichit, Sébastien Varette

Dunod, 2018

Computational Mathematics with SageMath
Paul Zimmermann, Alexandre Casamayou, Nathann Cohen, Guillaume Connan, Thierry Dumont, Laurent Fousse, François Maltey, Matthias Meulien, Marc Mezzarobba, Clément Pernet, Nicolas M. Thiery, Erik Bray, John Cremona, Marcelo Forets, Alexandru Ghitza, Hugh Thomas
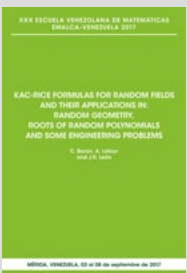
SIAM, 2018

Multimodal behavior analysis in the wild: Advances and challenge
Xavier Alameda-Pineda, Elisa Ricci, Nicu Sebe

Academic Press, 2018

Kac-Rice formulas for random fields and theirs applications in: random geometry, roots of random polynomials and some engineering problems
Corinne Berzin, Alain Latour, José R. León

Ediciones IVIC, 2017

Some key figures for LJK

300 lab members

of which 75 professors and assistant professors

40 researchers

95 doctoral students and postdocs

23 technical and administrative staff members

and around 50 trainees each year

150 publications in peer-reviewed journals per year
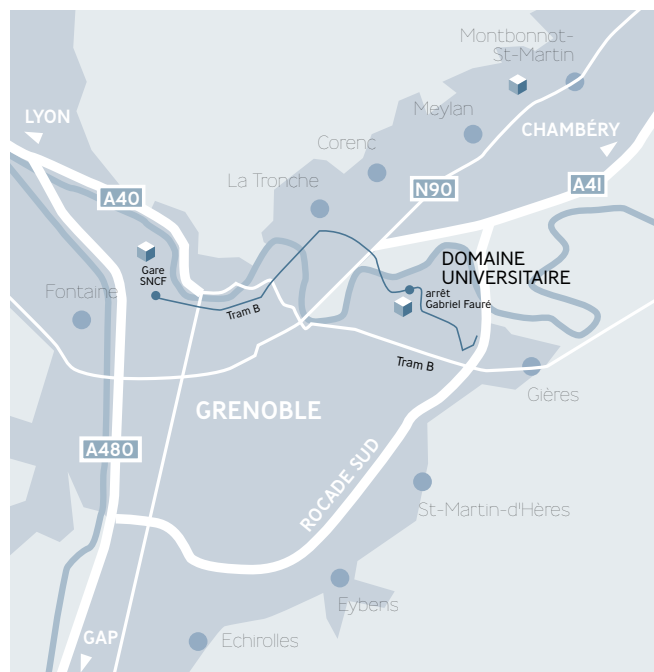
5 books in 2017-2018

24 projects sponsored by the French ANR

11 European projects,
including 6 ERC individual grants

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