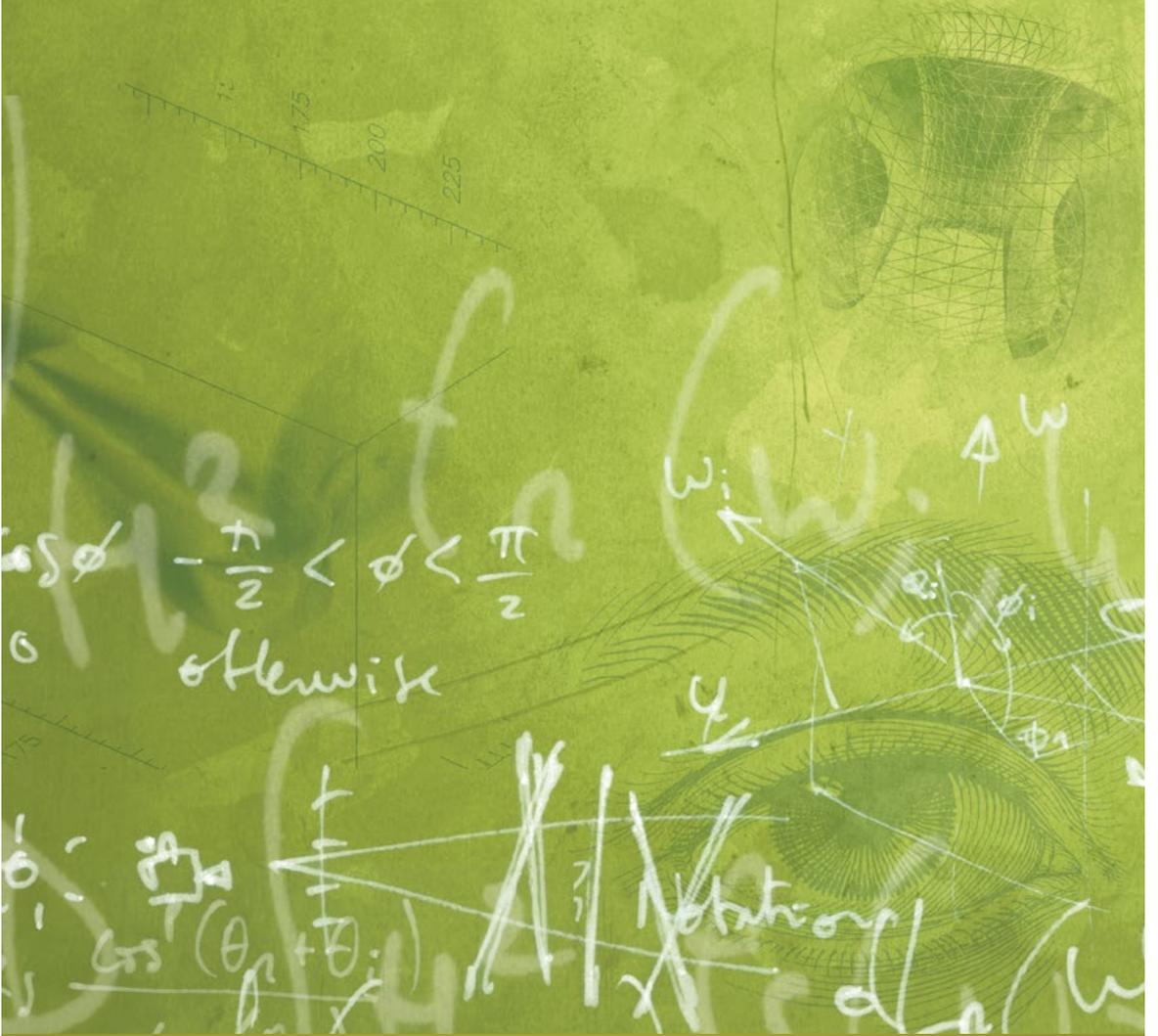




LABORATOIRE  
JEAN KUNTZMANN

MATHÉMATIQUES APPLIQUÉES - INFORMATIQUE



LABORATOIRE JEAN KUNTZMANN

# HIGHLIGHTS

FAITS MARQUANTS

[ 2015-2016 ]

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LABORATOIRE JEAN KUNTZMANN

# HIGHLIGHTS

FAITS MARQUANTS

[ 2015-2016 ]



# 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 etc.

In particular, on a regular basis and addressing a large audience, seminars linking modeling and societal issues have been organized by the STEEP team. Several industrial collaborations, startups and computation platforms have been developed. 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

## FOREWORD 2

We are pleased to introduce the 5<sup>th</sup> edition of the Laboratoire Jean Kuntzmann Highlights which covers the years 2015-2016, a period which was very rich in events.



Firstly, the laboratory moved into the brand new IMAG building, named after the former federation of laboratories that contributed to the reputation of Grenoble in computer science and applied math in the 1980's and 1990's. The building was created as a flagship of the math/info community and is now home to the three laboratories LIG, LJK and Verimag. Bringing these research units into a common space, will strengthen and further develop active collaborations among them, on a variety of forefront topics, such as data science, cybersecurity, embedded systems and high performance computing.

These labs now have spacious and comfortable office space, with plenty of natural light and an environmentally friendly heating and cooling system. They also have access to fully equipped seminar rooms and to a beautiful auditorium in the common space on the ground floor. Altogether, IMAG is a splendid tool and its occupants are ready to turn the building into a thriving beehive, where research is carried out at the highest level.

Secondly, LJK was evaluated by the HCERES in January 2015. This assessment was an important milestone for this relatively young unit, and gave us the opportunity to analyze in detail the development of its activities. We are very proud of the final report, which strongly praises LJK's scientific achievements. The forthcoming pages are a reflection of some of the people, projects, results and events that contributed to this recognition and illustrate the vitality of the laboratory.

Thirdly, the chairmanship of LJK changed in June of 2016. On a personal note, I would like to express my deep gratitude to all the people who helped make LJK the internationally recognized laboratory it is today and my term as chairman a worthwhile human experience.

Eric Bonnetier.



## Clémentine Prieur

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Clémentine Prieur is a mathematician internationally recognized for her contributions to both probability and statistics. Her pioneer results on characterizing the probabilistic notion of dependency have allowed the statistical community to deal with new problems. We can cite among others the statistical problems of parametric and non-parametric estimation for dependent data and diffusions. For example, she has greatly contributed to the problem of inference in stochastic damping Hamiltonian systems.

Clémentine arrived at LJK in 2008 in the MAD department, department which was not the most natural for her, coming from the stochastic community. Nevertheless Clémentine is the kind of personality who is not afraid by challenges. She has successfully faced this one: introducing randomness in the deterministic community. She has deployed an incredible energy and amount of work to integrate the community of uncertainty quantification and climate modeling. She has been in charge of the national GDR MascotNum, developing numerous industrial collaborations and multidisciplinary projects in a very dynamic way. She has co-supervised 7 PhD students since her arrival in Grenoble, all of them at the interface of the deterministic and the stochastic approaches, thus enriching the interactions between the two communities.

From these experiences and to answer questions from her collaborators, she has invested new themes such as model reduction, sensitivity analysis or extremes theory in environment and climate. She is now a pillar of the INRIA team AIRSEA. Her point of view has led to new approaches and new questions in the projects of AIRSEA, especially in the field of uncertainty quantification and sensitivity analysis. She is now a leading researcher in this domain.

To conclude, Clémentine is a very energetic person, involved in an incredible amount of projects covering an impressive large palette of applied mathematics. She has been recently awarded by the Prix Blaise Pascal, proving once again her leadership at the national and international level.

## Jean-Charles Quinton

Jean-Charles Quinton joined the LJK as an assistant professor in 2015. As a member of the Statistics for Life Sciences and Humanities team (SVH), he interacts heavily with colleagues from psychology and neuroscience. Before arriving in Grenoble, he did a PhD in artificial intelligence, worked in various labs on computational neuroscience and robotics (France, Japan, UK, and Italy), and was then recruited as an assistant professor at the interface between computer vision, robotics, and psychology in Clermont-Ferrand in 2011.

Interdisciplinarity may best characterize his activities, with a commitment to cognitive sciences. His approach is to craft intelligent systems to better study the principles driving cognition in living systems. While he participates(ed) in the co-supervision of 9 PhD students on seemingly various projects and disciplines, all subjects revolve around predictive (unsupervised) learning; how agents may extract and exploit regularities in their environment, and how predictions may themselves continuously drive interactions (e.g. active learning and active perception).

Such predictions may take many different forms in Jean-Charles's work depending on the level of abstraction and applicative domain: 1) pure neural or sensorimotor adaptation (e.g. tracking through eye movements), 2) dynamic decision-making in complex situations (e.g. risk-taking in driving situations), 3) planning of future actions while taking into accounts local constraints (e.g. co-articulation in manipulation), 4) influence of regularities observed in our social environment over the years (e.g. implicit stereotypes on math not being made for women, simply due to observed frequencies), 5) reasoning about the expectations of others (e.g. desirability bias in human interactions).

In practice, experimental data are analyzed statistically, and complex dynamical systems simulated. For instance, the dynamic neural field framework approximates the brain activity with integro-differential equations. Decisions may then be characterized by attractors, and behaviors as trajectories passing through heteroclinic channels.

Whether it be for computer science or statistics, teaching requires the assimilation and manipulation of concepts by students. Jean-Charles therefore works on the interactivity of pedagogical platforms, trying to facilitate the learning of regularities in equations, visual representations, numbers, and empirical observations. This loops back with predictive learning, connecting teaching and research...

[1] **A unified neural field model of the dynamics of goal-directed eye movements.** J.-C. Quinton and L. Goffart. *Connection Science*, 30(1), 20-52 (2018).

[2] **Tracking and Simulating Dynamics of Implicit Stereotypes: A Situated Social Cognition Perspective.** A. Smeding, J-C Quinton, K. Lauer, L. Barca, and G. Pezzulo. *Journal of Personality and Social Psychology: Attitudes and Social Cognition*, 111 (6), 817-834 (2016).

[3] **The cat is on the mat. Or is it a dog? Dynamic competition in perceptual decision making.** J.-C. Quinton, N. Catenacci, L. Barca, and G. Pezzulo. *IEEE Transactions on Systems, Man and Cybernetics: Systems*, 44, 539-551 (2014).



$$\begin{cases} \tau \frac{\partial A}{\partial t} = -A - w_1 \phi(B) + S_A \\ \tau \frac{\partial B}{\partial t} = -B - w_1 \phi(A) + S_B \end{cases}$$

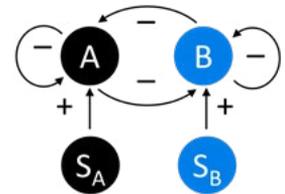


Illustration and equations of the mutual inhibition model (dynamic decision in two-alternative forced choice tasks).

$$\tau \frac{\partial u(x)}{\partial t} = -u(x) + \int_X w(x, x') \phi(u(x')) dx' + \sum_k s_k(x)$$

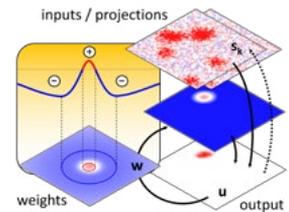


Illustration of a dynamic neural field model with an adaptation of the classical integro-differential equation (decisions in continuous spaces).



## Julyan Arbel

Julyan Arbel started a research position at Inria in 2016. Prior to that, he worked at Insee where he completed a PhD in statistics (CREST and Paris Dauphine) and then did a postdoc at Collegio Carlo Alberto (Turin) and Bocconi (Milan). He also worked abroad for one- to three-month periods during his studies at Ecole Polytechnique and Ensaie and during his early career, including at University of Liverpool, Universitat de València and University of Texas at Austin.

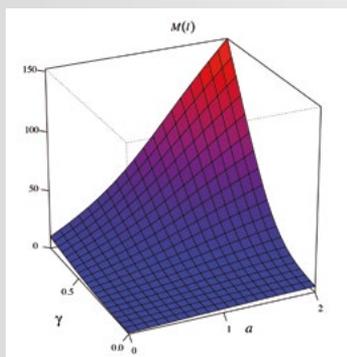
His research within statistics focusses on the Bayesian paradigm, thus called after Thomas Bayes and his eponym formula, which models parameters as random variables and turns data into useful quantities. Julyan works on nonparametric models, that are highly flexible models which adapt to data complexity by allowing for an infinite number of parameters. The flexibility of these models comes at a computational and technical price. In this context, Julyan's research contributes to better understanding and justifying Bayesian inference in high-dimensional models and data, and proposes feasible and scalable algorithms in a background of data analysis in neuroscience, ecology and astrophysics.

During his Ph.D., Julyan identified a class of prior distributions with optimal and adaptive behaviour for increasing data size. He also proposed a platform for modelling partially replicated data which alleviates the need for empirical data. This has been used in ecology to derive toxicology recommendations of a fuel spill region in Antarctica. Addressing computational issues, Julyan focusses since then on approximations of models, obtaining algorithms which scale with large sample size, while maintaining low error rates, and being able to measure them. Tools employed include discovery probabilities, point processes (Fig 1), while techniques include Laplace approximations, moment matching methods (Fig 2), concentration inequalities...

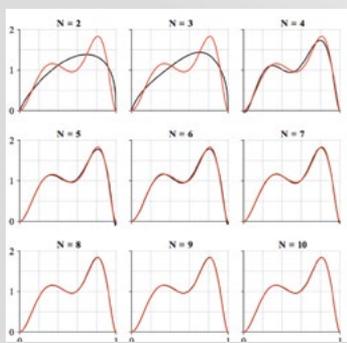
Julyan also loves popularizing science: he writes about his research on the collaborative blog *Statisfaction*, is a member of the board of *Variances.eu*, the webzine of Ensaie, is an R enthusiast involved in the Grenoble R User Group and author of R packages (eg. *momentify*, Fig 2), and used to interact with MATH.en.JEANS teams in Italy and the International Mathematics Competition team of Polytechnique. He launched the monthly reading group Bayes in Grenoble (<https://sites.google.com/view/bigseminar/>), and co-organises the Stat4Astro summer school in 2017, the Bayesian learning theory workshop in 2018, and Statlearn 2019. With more than 60 talks since the start of his PhD, Julyan is a passionate traveler to conferences and seminars.

<http://www.julyanarbel.com/>

<https://statisfaction.wordpress.com/>



Number of jumps required to achieve a given precision level in a point process called generalized gamma process.



Bimodal density approximated with the knowledge of an increasing number,  $N$ , of its moments by using the *momentify* R package.

# MULTI-DISCIPLINARY INTERACTIONS



## Conference - debate series « Understanding & Acting »

› Team STEEP - Scientific mediation

*Saving Civilization is not a spectator sport.  
(Lester Brown)*

Following a dynamics of exponential growth in a finite world, humanity today faces a number of unprecedented and tightly interlinked challenges. With a growing number of environmental limits being largely and irreversibly exceeded (GHG concentrations in the atmosphere, biodiversity loss, soil erosion, freshwater shortages...), social, economic, geopolitical, humanitarian (etc.) consequences are becoming more urgent than ever to address, while the threat of an uncontrolled global collapse is now more than a prospect. It is urgent to initiate deep, structural, socioeconomic changes on virtually all aspects of our increasingly global societies (economics, industrial and agricultural production, consumption, education, all requiring major new local and global policies).

In view of these facts, the STEEP research team has initiated in 2016 a series of conferences-debates entitled "Understanding & Acting" (« Comprendre et agir ») that examines these issues in order to help researchers and citizens to increase their awareness of the various issues at stake in order to initiate relevant individual and collective actions. From now on, the scientific community at large must realize that its duty also lies in helping citizens to better understand these issues. If the fraction of people in society whose privilege is to be paid to think about society's problems do not seize this opportunity in the critical times we face, who will? Researchers must become more involved in the search of socioeconomic alternatives and help citizens to implement them. The interactions between researchers and citizens must also be reinvented.

The presentations of this series of conferences typically last between 30 to 45 minutes; they are followed by a 45 minute public debate with the audience. The presentations are captured on video and then made directly accessible on the YouTube Channel "Comprendre et Agir". At the end of 2017 the YouTube channel counts more than 40,000 views with a rate of integral viewings remaining at above 25%.



*Examples of conferences given in 2015-2016:*

**“Reinventing agriculture and food in the 21st century?”**  
by Gilles Billen, CNRS.

**“Limiting climate change: Why do we not do it?”**  
by Denis Dupré, University Grenoble Alpes.

[www.youtube.com/channel/UC7AzblwnTStA6oTkm87tkLg](http://www.youtube.com/channel/UC7AzblwnTStA6oTkm87tkLg)

<https://team.inria.fr/steep/seminars/les-conferences-debats-comprendre-et-agir/>



# MULTI-DISCIPLINARY INTERACTIONS

## PERSYVACT2

› Team SVH

Persyvact2 is a collaborative research team that aims at developing cutting edge data science methodologies to analyze large biomedical data. Persyvact2 consists of about 20 researchers from GIPSAIab, LJK and TIMC-IMAG. Coming from different fields related to data science (statistics, machine learning, image and signal processing), members of Persyvact2 analyze biomedical data generated from neuroscience, genomics, and clinical trial research. The key structures of biomedical data that Persyvact2 exploit consist of graph structures, repeated experiments and their intrinsic lower dimensional representation.

The aim of Persyvact2 is to perform collaborative research and to bring together researchers of different scientific fields interested by data science. Persyvact2 seeks to enhance the international visibility of data science in Grenoble. Persyvact2 has provided funding for 2 PhD about biostatistical analysis of large-scale biomedical data.

pcadapt is an R package to look for footprints of natural selection in human genomes. The package implements cutting-edge data science method to extract information from high dimensional genomic data. It has been applied to a large human genomic dataset to find genes involved in adaptation. Another R package to process large genomic data is under construction (<https://github.com/privefl/bigsnpr>) and should be delivered in 2017.

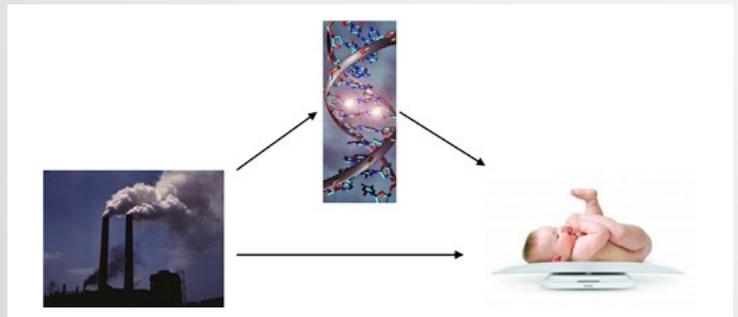
In neuroscience, we constructed a new graph metrics entitled the "hub disruption index". This metric allows to show that stroke induces a network-wide pattern of reorganization in the contralesional hemisphere.

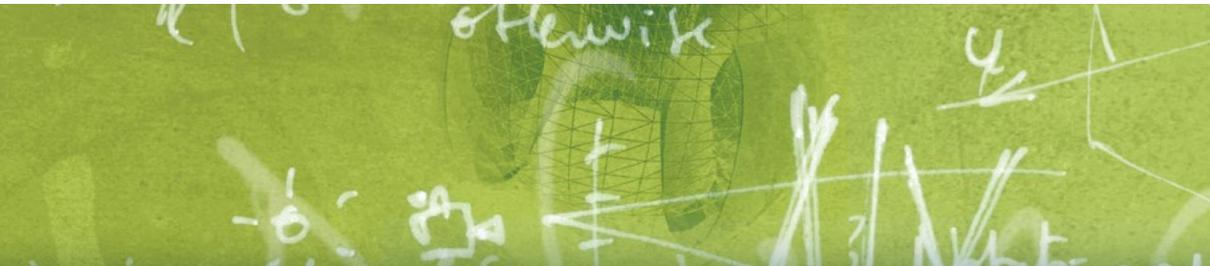
Persyvact has organized the statlearn 2015 workshop about statistical machine learning. Around 150 participants attended to the workshop. Persyvact2 has organized the journées MAS (about stochastic processes and statistics) in Grenoble in 2016.

### Future

Collaboration with epidemiologists from the Institute for Advanced Biosciences IAB initiated by the Epigenetic & High-Dimension Mediation Data Challenge (June 7-9 2017, Aussois), which is organized by Persyvact2. The objective is to understand if epigenetic mediates the effect of environmental exposures (air pollution) on child health.

*Epigenetics: a mediator between air pollution and birth weight.*





In neuroscience, we anticipate that graph modeling and metrics such as the "hub disruption index" can become a useful tool for clinical applications.

Applications of cutting data-science to biomedical data is the focus of a work package of the Cross Disciplinary Research project DATA@UGA funded by the IDEX Université Grenoble Alpes (2017-2020). A 3-year junior chair whose research concerns data-science applied to biomedical data will be recruited.

#### Coordinators

Pierre-Olivier Amblard, GIPSA-lab  
Michael Blum, TIMC-IMAG  
Adeline Leclercq-Samson, LJK

#### [1] Detecting Genomic Signatures of Natural Selection with Principal Component Analysis: Application to the 1000 Genomes Data.

N. Duforet-Frebourg, K. Luu, E. Bazin, and M. GB Blum (2016). *Molecular Biology and Evolution*, 33, 1082-1093 (2016)

#### [2] A SAEM Algorithm for Fused Lasso Penalized Non Linear Mixed Effect Models: Application to Group Comparison in Pharmacokinetic.

E. Ollier, A. Samson, X. Delavenne, and V. Viallon. *Computational Statistics and Data Analysis*, 96, 207-221 (2016)

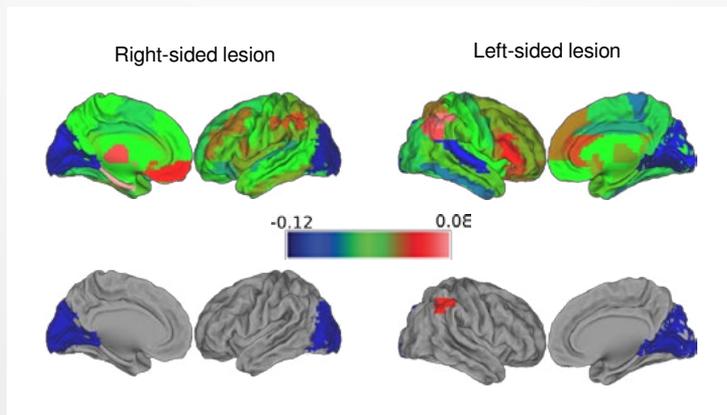
#### [3] Reliability of graph analysis of resting state fMRI using test-retest dataset from the human connectome project. M. Termenon, C. Delon-Martin, A. Jaillard, and S. Achard, *Neuroimage*, 142, 172-187 (2016)

#### Websites

<https://persyval-lab.org/en/sites/persyvact2>

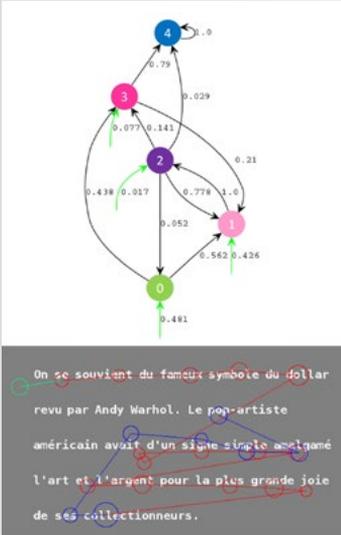
PCADAPT:

<https://cran.r-project.org/web/packages/pcadapt/index.html>

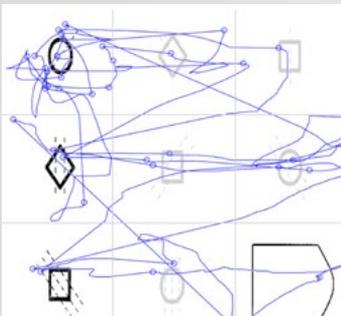


Brain connectivity efficiency disruption in stroke patients.

# MULTI-DISCIPLINARY INTERACTIONS



Example of a segmentation of a scanpath (right-hand side) into cognitive phases estimated by an HMM including 5 types of cognitive phases. The interpretation of the phases in the transition graph (right-hand side) is: 0 / initialization of reading process, 1 / careful reading, 2 / speed reading, 3 / normal reading, 4 / confirmation (absorbing state).



IQ test item (Raven's matrix), where the goal is to deduce the missing piece by inferring rules from the others. Depending on the experimental condition, the user had to click on a computer interface to choose a limited number of visible pieces (here illustrated through shading). Measures to study resolution strategies included both mouse movements (superimposed in blue) and eye movements.

## Oculo Nimbus

> Teams MISTIS and SVH

### New statistical models to understand and predict oculometric data

The PERSYVAL-Lab Oculo Nimbus project-team focuses on characterizing human-environment interactions through eye movements. Indeed, these reflect dynamic exploration of visual regions of interest. This project aims at developing new statistical tools for eye-movement analysis, potentially augmented with multimodal data (electroencephalography - EEG - or mouse tracking). Such models are dedicated to: (i) the segmentation of spatiotemporal data of visual exploration into cognitive phases, (ii) the analysis of spatiotemporal dependencies in fixation prediction, (iii) the analysis of ocular fixations with a higher spatial resolution for understanding the functional roles of microsaccades (miniature eye movements during multistable perception) in visual perception. The main specificity of the project is to capture information from eye movements at different scales: spatio-temporal scale from saccades to microsaccades, cognitive scale from low-level information extraction to high level tasks and usages, in a multimodality context.

(i) EEGs and eye movements were recorded during some press review tasks, in which reading and decision making are intertwined. Hidden Markov models (HMMs) were used to segment the sequence into reading strategies, each having well statistically identified eye-movement properties. We are extending such HMMs to jointly analyze eye movements and EEGs. Similarly, Markovian models were used to analyze eye and hand movements (computer mouse) during the resolution of IQ test items, to distinguish resolution stages and strategies.

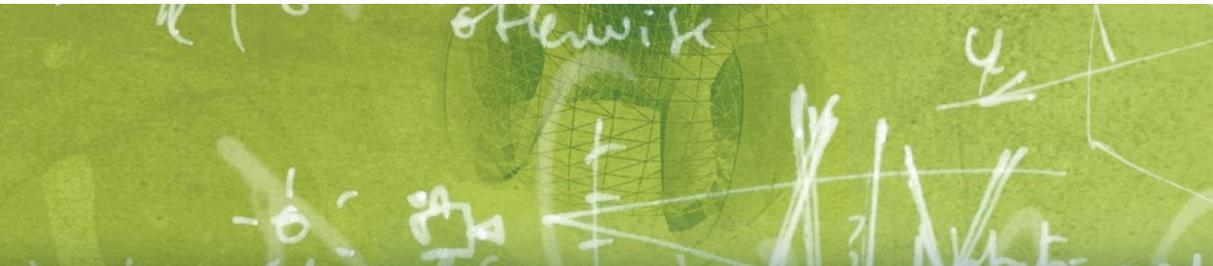
(ii) As far as image exploration is concerned, two approaches were developed: firstly, sparse semi-parametric spatial point processes with covariates were used to predict the sequence of fixations on images in tasks of visual exploration. Secondly, the dependence between chromatic and luminance information in images and the effect of the associated information redundancy on eye movements was analyzed.

(iii) At a finer spatio-temporal scale, ocular micro-movements (microsaccades occurring during eye fixations) have been identified as a noise factor facilitating decision making processes during perception. Theoretical models based on stochastic resonance allow for an improvement in the prediction process of decision making. Ongoing work focuses on explanatory models of these perceptual phenomena in the framework of multistable perception.

[1] **Regularization and a General Linear Model for Event-Related Potential Estimation.** E. Kristensen, A. Guérin-Dugué, and B. Rivet, *Behavior Research Methods*, 49(6), 2255-2274 (2017).

[2] **A unified dynamic neural field model of goal directed eye-movements.** J.-C. Quinton and L. Goffart, *Connection Science*, 30(1), 20-52 (2018).

[3] **How redundant are luminance and chrominance information in natural scenes?** C. Breuil, S. Barthelmé, and N. Guyader, *Visual Society Conference, VSS2017, Florida* (2017).



## The Jean Kuntzmann Prize

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Professor Joachim Weickert, from Saarland University, is the second recipient of the Jean-Kuntzmann Prize, and has been awarded on April 14th 2016 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.

Joachim Weickert is professor of mathematics and computer science at Saarland University where he has been the leader of the Mathematical Image Analysis Group since 2001. He received a diploma and a Ph.D. degree in mathematics from the University of Kaiserslautern (1991, 1996), and a habilitation degree in computer science from the University of Mannheim (2001). He worked as research assistant at the University of Kaiserslautern, as post-doctoral researcher at the universities of Utrecht and Copenhagen, and as assistant professor at the University of Mannheim.

Joachim Weickert performs research in image processing, computer vision and scientific computing, focusing on techniques based on partial differential equations, variational principles, wavelets, morphological and nonlocal methods. He has developed mathematical models and efficient numerical algorithms for image restoration, enhancement, segmentation, compression, optic flow computation, stereo reconstruction, shape from shading, as well as signal processing methods for tensor fields. These ideas have entered a number of applications in industry, biomedical image analysis and other fields.

Joachim Weickert has received 32 research, teaching and reviewing awards, including a Gottfried Wilhelm Leibniz Prize. In 2017 he has been awarded an ERC advanced Grand. He is elected member of the Academia Europaea - The Academy of Europe.

During his stay in Grenoble, Joachim Weickert gave a series of talks on Variational Models for Motion Estimation in Videos, Osmosis in Visual Computing, and Cyclic Schemes for PDE-Based Image Analysis. He also gave during his award ceremony a public lecture entitled "Image Compression with Differential Equations".



*Professor Joachim Weickert*

# SCIENTIFIC RESULTS OF THE TEAMS

## Ageing and Maintenance in reliability: Modeling and Statistical Inference (AMMSI)

› Team FIGAL

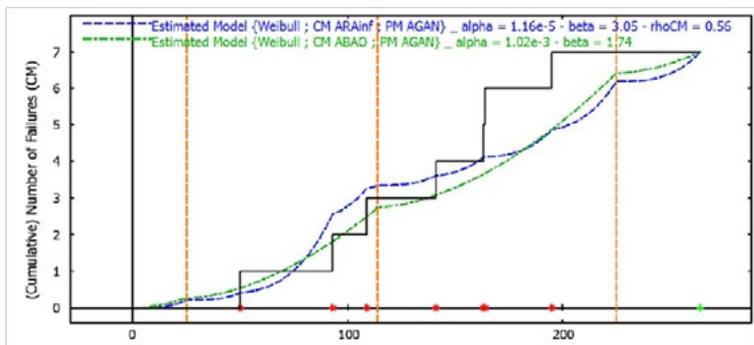
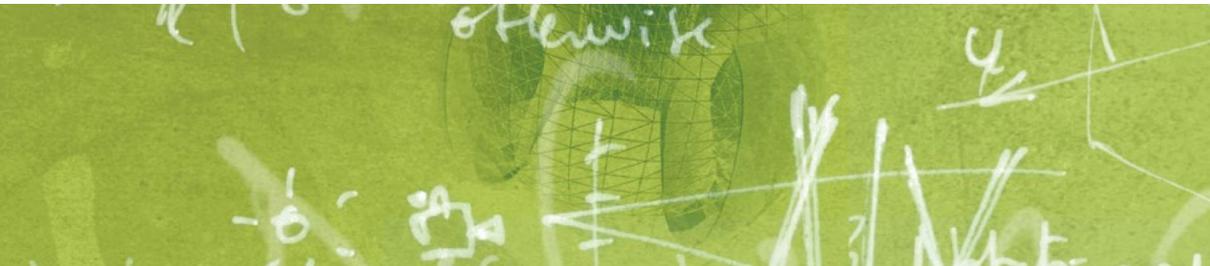
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Managing the reliability of industrial equipment is a major economic and societal issue. This requires to better control the ageing of these systems, to adapt the maintenance strategy, and to accurately estimate their residual life, while respecting safety, regulation and operational performance. Depending on the occurred events and monitoring devices, the aging of a material can be undetectable before its failure, or result in an observable degradation. Moreover, the aging can be slowed by the effect of maintenance actions, either corrective or preventive. Therefore, the impact of maintenance on aging has to be assessed, and maintenance has to be planned optimally. This goal can be achieved by the proposal of probabilistic models of degradation, failure and maintenance, and the development of appropriate statistical analysis methods.

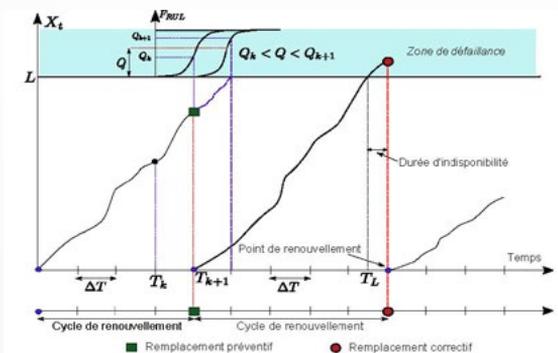
To that aim, the AMMSI project was funded by ANR from 2012 to 2016. Coordinated by LJK for Grenoble INP, the other members were Université de Pau et des Pays de l'Adour, Université de Franche Comté, Université de Technologie de Troyes, EDF and SNCF Réseau. Gathering complementary academic and industrial partners, AMMSI resulted in a successful coupling between basic and industrial research.

From the academic point of view, the work done during the project allowed to propose, on one hand, new stochastic models for the degradation, failure and maintenance of complex systems, and on another hand, new statistical methods for analyzing experience feedback data, such as estimation methods and goodness-of-fit tests. From the application point of view, the industrial partners now can use an expanded range of models and analytical methods adapted to a wide variety of possible operational situations. They can also use decision making tools for the industrial implementation of these methods. Thus, the results of the project contribute to improve the management of industrial assets, to assess more precisely the reliability of equipment, and to optimize their maintenance. The work done has been published in a hundred of papers in the best refereed journals and international conferences of this field of research. It also led to the development of two packages of the statistical software environment R, EWGoF and VAM.

<https://www-ljk.imag.fr/AMMSI/>



Observed and estimated cumulative number of failures for a system submitted to corrective and preventive maintenances.



Trajectory of a degradation process.

# SCIENTIFIC RESULTS OF THE TEAMS

## GeoSpec strike force

› Team CVGI

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The mathematical theory of complexity is that of classifying objects or problems based on how difficult they are to apprehend or to solve. It is a well known research subject in applied mathematics for example in Numerical Analysis or Combinatorics where estimating the number of steps needed to compute a quantity is crucial in the perspective of a computer implementation. In more fundamental mathematics, for example in Geometry or Dynamical Systems, the exact geometry of an object is rarely known with sufficient accuracy: for instance it may be altered with time, as is the case of many mechanical parts, or simply because it is a priori unknown, such as the structure of the Universe. For these reasons, the features of an object are often appraised in terms of associated algebraic or analytic quantities (for instance, the decay rate of the solution of a Partial Differential Equation, etc.), which pave the way to a measure of their complexity.

The purpose of the present project is to develop a synergy between fundamental and applied mathematicians in order to study important problems related to the complexity of two-dimensional objects (such as surfaces) and initiate investigations in higher dimension where the situation is, for most problems, widely unknown. In this project we aim at studying the complexity of the geometry of a mathematical object (e.g. a manifold) through three different aspects: its metric (that is, the way distances are measured on the object), its dynamics (i.e. the trajectories followed by particles moving on it) and its spectrum (i.e. its resonance frequencies). More specifically, we intend to study extremal manifolds for invariants describing this complexity in each of the above items.

We illustrate below one of our first results obtained by the synergy provided by this enthusiastic group of researchers. This new approach aims to identify "opposite" points of a given location on a surface. More precisely, we define the set of "opposite points" as the points for which it exists at least two different shortest paths connecting the point and the location. On a sphere for instance, every point has one and only one opposite point which is precisely its antipodal point. On a general surface, the set of opposite points is called the cut locus of the location and may have a huge topological complexity. The following pictures show examples of approximation of cut loci for different topological surfaces.

<http://ljk.imag.fr/GeoSpec/>



Approximation of cut locus on four surfaces of different genus.

### People

Gérard Besson (coordinator), Institut Fourier, CNRS-Université Grenoble Alpes

Édouard Oudet (coordinator), LJK, Université Grenoble Alpes

Dorin Bucur, Lama, IUF-Université Savoie Mont Blanc

Charles Dapogny, LJK, CNRS-Université Grenoble Alpes

Pierre Dehornoy, Institut Fourier, Université Grenoble Alpes

Erwan Lanneau, Institut Fourier, Université Grenoble Alpes

Emmanuel Russ, Institut Fourier, Université Grenoble Alpes

Boris Thibert, LJK, Université Grenoble Alpes

Bozhidar Velichkov, LJK, Université Grenoble Alpes

François Générault, LJK, Université Grenoble Alpes

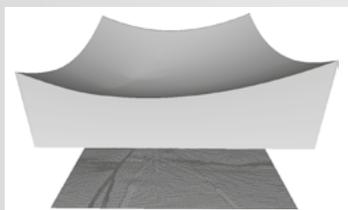
Baptiste Trey, Institut Fourier/LJK, Université Grenoble Alpes

# SCIENTIFIC RESULTS OF THE TEAMS

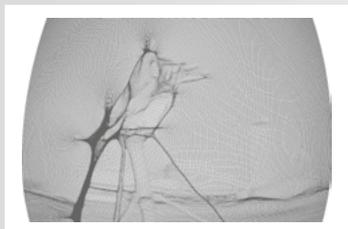
## Numerical optimal transport and inverse problems in optics

› Team CVGI

*Mirror that reflects a point light source (located inside the mirror)*



*Vertical rays are emitted by the light source supported on the plane and traverse the lens.*



*Surface of the lens.*



*Forward simulation on a wall with raytracing.*

The field of non-imaging optics consists in designing optical components whose goal is to transfer the radiation emitted by a light source to a prescribed target in an optimal way. This question is at the heart of many applications where one wants to optimize the use of light energy by decreasing light loss or light pollution, such as car headlamp design, public lighting, solar ovens and hydroponic agriculture. In the last years, we have considered the design of different kind of lenses or mirrors that satisfy some light energy constraints. To be a bit more specific, given a light source and a desired illumination (target) after reflection or refraction, the goal is to design the geometry of a mirror or a lens which optimally transports the energy emitted by the source onto the target. Note that these mirror or lens design problems can be regarded as inverse problems, where the forward one would be to simulate, for instance by raytracing, the target illumination from the description of the light source and the geometry of the mirror or lens.

In many settings these problems amount to solving a generalized Monge-Ampère equation on the plane or on the sphere which is equivalent to an optimal transport problem. In collaboration with Q. Mérigot and J. Kitagawa, we proposed a Newton algorithm to efficiently solve optimal transport problems and proved its convergence for general cost functions. We also developed a code able to solve optimal transport problems accurately for a target discretization up to one million points and applied it to the design of eight different lenses or mirrors. We also collaborated with the company Optics, together with the Gipsa-Lab, for the automatic realization of car light beams.

### People

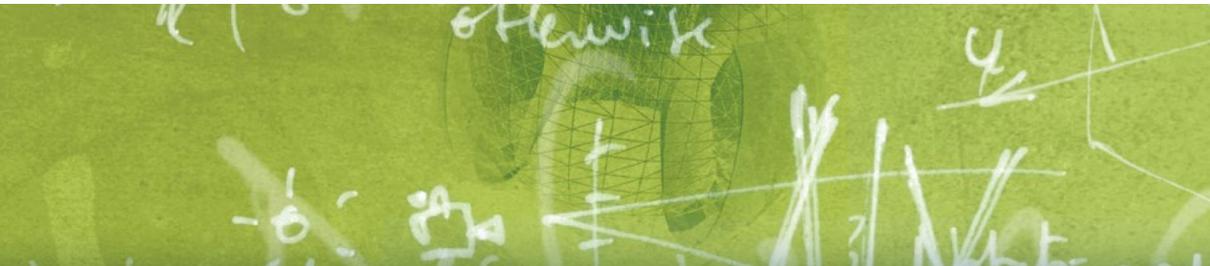
Jocelyn Meyron, Gipsa-Lab and LJK  
Boris Thibert, LJK

[1] *An algorithm for optimal transport between a simplex soup and a point cloud.* Q. Mérigot, J. Meyron, and B. Thibert, accepted to SIAM Journal on Imaging Sciences.

[2] *Convergence of a Newton algorithm for semi-discrete optimal transport.* J. Kitagawa, Q. Mérigot, and B. Thibert, Journal of the European Mathematical Society (JEMS), accepted.

[3] *Far-field reflector problem and intersection of paraboloids.* P. Machado Manhães de Castro, Q. Mérigot, and B. Thibert, Numerische Mathematik, 134, 389-411 (2016).

[4] *Far-field reflector problem under design constraints.* J. André, D. Attali, Q. Mérigot, B. Thibert, International Journal of Computational Geometry and Applications, 25(2), 143-163 (2015).



## Continuity Editing for 3D Animation

› Team IMAGINE

We propose a continuity editing model for 3D animations that provides a general solution to the automated creation of cinematographic sequences. Our model encodes the continuity editing process as a search for the optimal path through an editing graph. In this editing graph, a node represents a time-step (a temporal fragment of a shot), and an arc represents a transition between two cameras, going from a camera to either the same camera (no cut) or another camera (cut).

Our optimization uses dynamic programming to minimize, under a semi-Markovian hypothesis, the errors made along three criteria: the quality of the shots (with respect to the unfolding actions), the respect of continuity editing rules and the respect of a well-founded model of film editing rhythm (cutting pace). Semi-Markov models have been used before in the context of information extraction, speech generation and computer vision. To the best of our knowledge, this is the first time they are suggested as a computational model for film editing.

To validate our approach, we recreated the animation of a well-known scene from Robert Zemeckis' movie "Back to the future" with four main characters, all engaging in a variety of actions, including two-way and three-way dialogues, physical contacts, and everyday activities such as sweeping the floor and serving food. All animations were manually annotated to provide (subject; verb; object) descriptions at the right time-codes and twenty-five cameras were manually placed for the whole duration of the sequence. We performed a subjective evaluation of our method by designing a perceptual user-study, demonstrating that editing has an impact on the perceived quality of the observed video stimulus; that each of the three terms in our cost function has a positive impact on perceived quality; and that the perceived quality of our version was not significantly lower than the version done by an expert film editor.

Our model is currently limited to the case of linear editing, where the chronology of events is maintained. In future work, we would like to allow temporal ellipses and re-ordering of events, and we are investigating higher-order Markov models and context-free grammars to overcome this limitation.

[1] **Continuity Editing for 3D Animation.** Q. Galvane, R. Ronfard, C. Lino, and M. Christie, AAI Conference on Artificial Intelligence, Jan 2015, Austin, Texas, United States. AAAI Press (2015).



We compute the visibility of all actors in all cameras then choose cameras according to Hitchcock's principle that the size of a character should be proportional to its narrative importance in the story.

# SCIENTIFIC RESULTS OF THE TEAMS

## Diffraction effects in material reflectance models

› Team MAVERICK

Photorealism is a long-term goal in image synthesis. We aim at creating pictures of a virtual world that looks, as much as possible, like a photograph. It is especially useful in special effects for motion pictures, where the transition from real pictures to computer-generated imagery must be as seamless as possible.

In recent years, research on photorealism focuses on material models, how an object reflects illumination. The micro-facet model is highly popular in both research and industry. In this model, the visual aspect of a material is determined by the surface roughness, through its micro-geometry.



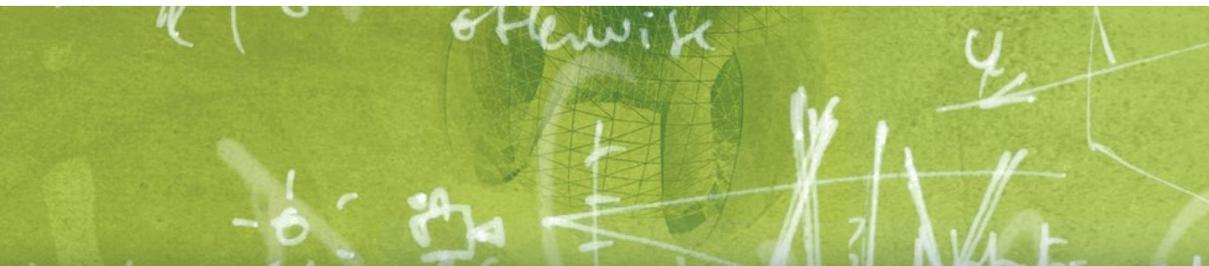
In this model, the surface micro-geometry is made of micro-facets, and that we have a probability distribution function describing the orientation of their normals. We can then express the overall material reflectance as an integral of the micro-facet reflectance multiplied this probability distribution.

If we assume the micro-facets are specular, their reflectance is a Dirac and the integral collapses into a simple expression. The micro-facet model gives a connection between material aspect and surface roughness. It is relatively close to the measured reflectance.

But there are still differences between measured reflectance and what this model predicts: we observe that the reflectance dependence on wavelength is more complex than expected; also, on some materials, we observe a slope rupture, as if there were two different phenomena.

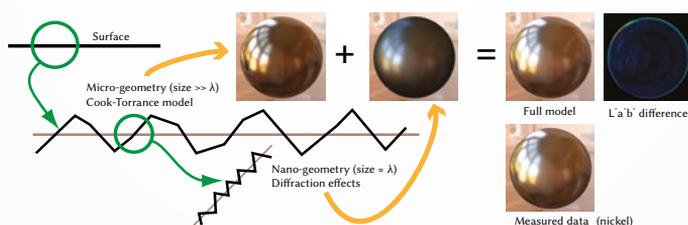
To go further, we need to question the assumptions of the micro-facet model. The main assumption is that we can use the rules of geometrical optics, because micro-facet geometry is larger than light wavelength. In the model, light moves in a straight line, independently of its color.

Our key idea is that this assumption is unlikely to hold: first, the wavelength of visible light ( $\approx 0,1 \mu\text{m}$ ) is large enough that some surface details will have similar dimensions. Second, there is no reason for surface details to stop at a certain threshold. If there are surface details whose dimension is close to the visible light wavelength, the incoming light will also be diffracted as it bounces on the surface. The equation connecting material reflectance and micro-geometry becomes more complex.



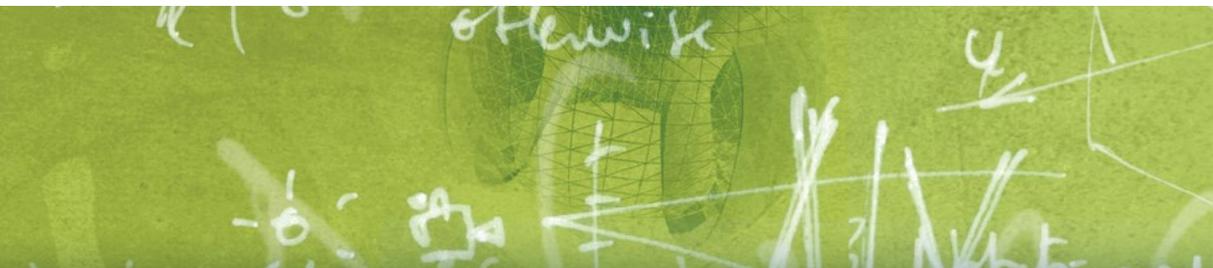
To make it simpler, we introduced a two-scale model, where the geometry that diffracts (whose size is comparable to the wavelength) is laid on top of a larger-scale geometry. We end up with a usable equation, with two different behaviors that add up: the reflectance predicted by the micro-facet model and a second lobe, corresponding to the diffraction effects, which we express using a convolution.

All the odd behaviors in the micro-facet model disappear when we introduced diffraction effects. The new model is surprisingly good at predicting material behavior, with almost no differences between model and measures. Diffraction effects are relatively subtle, but important for the visual aspect of the material.



*Combining the micro-facet model and diffraction effects.*





**[1] NOLB: Nonlinear Rigid Block Normal Mode Analysis Method.**

A. Hoffmann and S. Grudinin, *Journal of Chemical Theory and Computation*, 13(5), 2123-2134 (2017).

**[2] Automatic molecular structure perception for the universal force field.**

S. Artemova, L. Jaillet, and S. Redon, *Journal of Computational Chemistry*, 37(13), 1191-1205 (2016).

**[3] Adaptively Restrained Particle Simulations.**

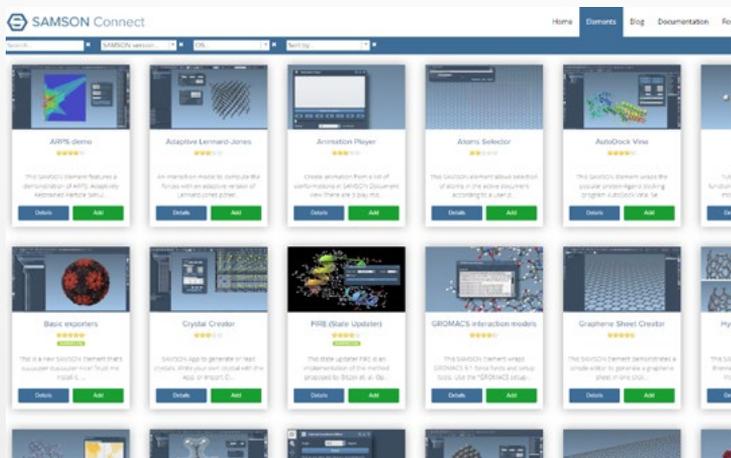
S. Artemova and S. Redon, *Physical Review Letters*, 109 (19), 190201:1-5 (2012).

**[4] Molecular Propensity as a Driver for Explorative Reactivity Studies.**

A. Vaucher and M. Reiher, *Journal of Chemical Information and Modeling*, 56 (8), 1470-1478 (2016).

**[5] Multiscale Visualization and Scale-Adaptive Modification of DNA Nanostructures.**

H. Miao, E. De Llano, J. Sorger, Y. Ahmadi, T. Kekic, T. Isenberg, M.E. Gröller, I. Barišić, and I. Viola, *IEEE Transactions on Visualization and Computer Graphics*, 24(1), 1014-1024 (2017).



SAMSON Elements available on SAMSON Connect.



Pixyl

› Team MISTIS

**Pixyl Brain Analysis, Unlock Neuroimaging Data**

Pixyl is a spinout of the Mistis team at Inria Grenoble Rhone-Alpes, LJK and INSERM, leveraging Hidden Markov Random Field modeling, statistical analysis and machine learning methods developed in these laboratories to provide quantitative imaging biomarkers, thereby helping clinicians achieve greater insight and value in the healthcare domain.

**NEUROIMAGING BIOMARKER EXTRACTION FOR NEURODEGENERATIVE DISEASES.**

Pixyl team is developing an automatic brain segmentation software: Pixyl.Neuro. It delivers automatic neuroimaging biomarker extraction for enhanced clinical insight, and streamlining of the clinical workflow. The software is engineered for specific pathologies, and solutions are available for Stroke, Multiple Sclerosis, Traumatic Brain Injuries and Neurodegenerative diseases.

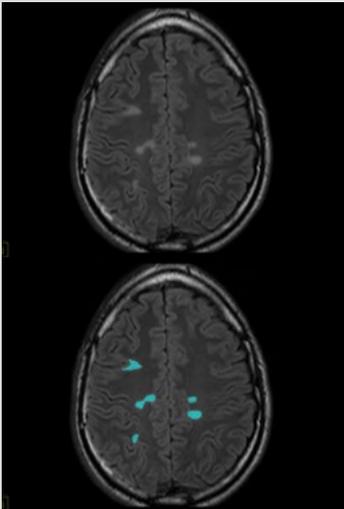
**EASE OF USE****NEUROIMAGING EXPERTS**

Our R&D team has a solid background in neuroimaging research, and is continually expanding our portfolio of biomarkers. Today the software is used in clinical studies investigating MS, TBI, and Stroke, working closely with medical professionals, performing extensive testing and validation to ensure the highest quality analyses.

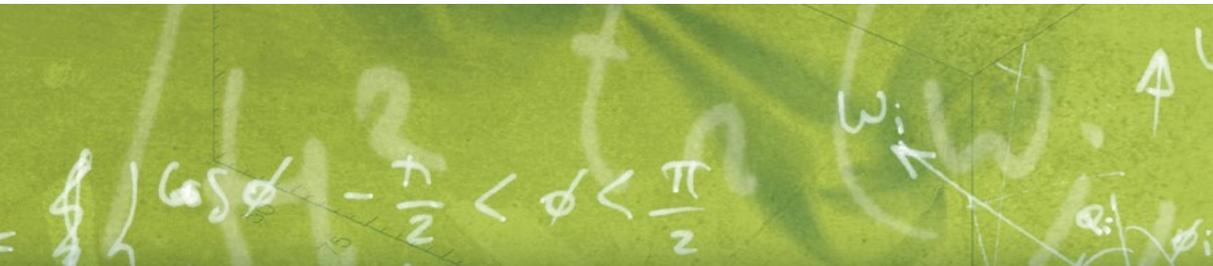
- In Neuroscience, Pixyl.Neuro increases publication confidence, thanks to a reliable monitoring (repeatable and reproducible measurements allow for the reliable monitoring of disease evolution). It also accelerates the pace of research and allowed to discover new imaging biomarkers.
- For a clinical use, Pixyl.Neuro helps to improve decision making and simplifies workflow.

The software optimizes imaging endpoint costs (removing the burden of manual delineation improves human resource management, with associated economic and time benefits). It gets confident insight into disease evolution and diagnosis (reducing reviewer variability ensures greater confidence in the reported biomarkers, and their evolution in time).

[www.pixylmedical.com](http://www.pixylmedical.com)



Automatic neuroimaging biomarker extraction.



## Anatoscope - Straight from Imaging to CAD

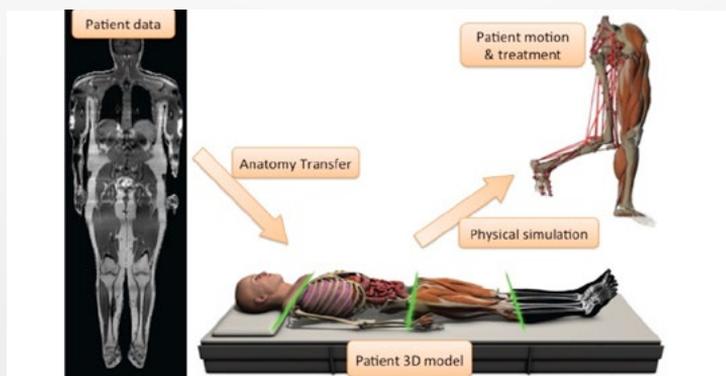
› Team IMAGINE



Would you board a plane that has never been tested? Nowadays, no prototype would take off before careful numerical modeling, testing, optimization using computer simulation. At Anatoscope, a young spin-off company from France's CNRS and INRIA research institutes, we believe that this digital pipeline will become a must in medicine, especially in orthopedics. Biomechanical simulation is mature enough to numerically optimize each personalized treatment before its application to the real person. What was still missing is the patient's personalized model. Anatoscope lifts the last obstacle on the way to personalized orthopedics, by automatically computing every patient's digital twin based on imaging.

A digital twin is to patient imaging what an architectural design is to pictures of a building: simplified but editable shapes, with additional information on materials and connections between the parts. Turned in digital twins, static imaging becomes virtual anatomy that can be processed to simulate motion and deformations in reaction to treatments. Until now, creating personalized digital twins based on imaging took weeks of highly skilled work, making time and delays incompatible with standard healthcare pipelines, and CAD advantages unsuitable to patients. Now, thanks to the Anatomy Transfer technology developed by Anatoscope based on LJK-INRIA technology, the digital twins are generated automatically by numerically warping a generic 3D avatar to patient imaging. Simulation can then be performed using a variety of standard or specialized softwares. This framework is adapted to each application by Anatoscope engineers, based on the type of imaging and simulation at hand. Anatoscope thus bridges the gap between imaging and biomechanical simulation, opening a new era in medicine!

Anatoscope has already attracted major partners in radiology including EOS Imaging, to complement their reconstruction with full anatomy for applications ranging from diagnostic to device design. Anatoscope also offers fast segmentation tools and prepares applications on per-operative tumor tracking using Augmented Reality. Finally, Anatoscope offers a fully digital production pipeline for personalized healthcare devices, from imaging to 3D printing. This no-plaster framework has been adopted by various businesses such as Thuasne for the production of knee braces, or Biotech Dental for dental prosthetics.



*Anatoscope pipeline from imaging to virtual patient to biomechanical simulation and CAD.*

# COMPUTING PLATFORMS AND VALORIZATION

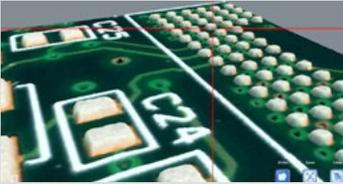
## FUI project Vi4.2 : Industry 4.0, AI and the PCB industry

› Team MISTIS

Vision 4.0 (in short Vi4.2) is one of the 8 projects labeled by Minalogic, the digital technology competitiveness cluster in Auvergne-Rhône-Alpes, that has been selected for the Industry 4.0 topic in 2016, as part of the 22nd call for projects of the FUI-Régions. This 3 year project involves 2 companies Vi-Technology (coordinator), ACTIA, and two laboratories, G-SCOP and Inria (Team Mistis from LJK), for a total budget of 3.4 MD.

Today, in the printed circuits boards (PCB) assembly industry, the assembly of electronic cards is a succession of ultra automated steps. Manufacturers, in constant quest for productivity, face sensitive and complex adjustments to reach ever higher levels of quality. Project Vi4.2 proposes to build an innovative software solution to facilitate these adjustments, from images and measures obtained in automatic optical inspection (AOI). The idea is - from a centralized station for all the assembly line devices - to analyze and model the defects finely, to adjust each automatic machine, and to configure the interconnection logic between them to improve the quality.

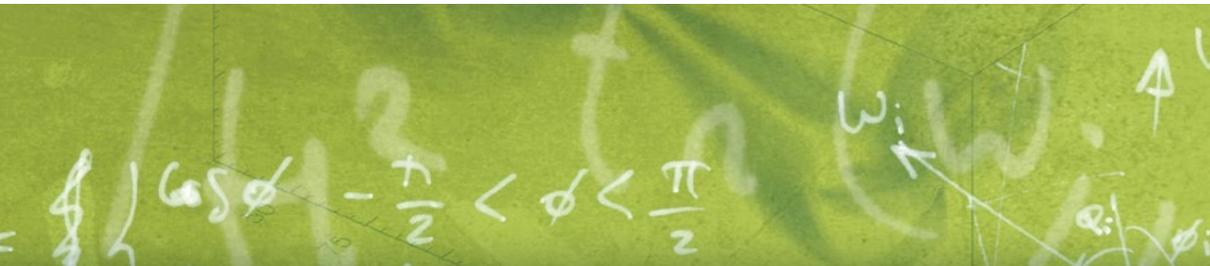
Transmitted information is essentially of statistical nature and the role of the Mistis team is to identify which statistical methods might be useful to exploit at best the large amount of data registered by AOI machines. Preliminary experiments and results on the Solder Paste Inspection (SPI) step, at the beginning of the assembly line, helped determining candidate variables and measurements to identify future defects and to discriminate between them. More generally, the idea is to analyze two databases at both ends (SPI and Component Inspection) of the assembly process so as to improve our understanding of interactions in the assembly process, find out correlations between defects and physical measures and generate accordingly proactive alarms so as to detect as early as possible departures from normality.



Printed Card Board.



Printed Card Board assembly line.

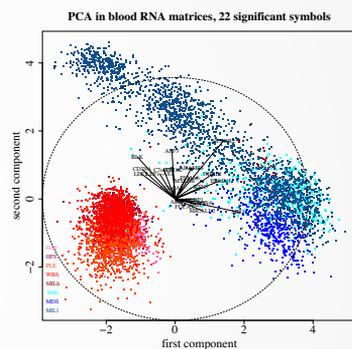


## Statistical tests for Genomics

› Team SVH

A major issue in present medical research is to reliably associate pathologies to gene expressions in patient's tissues. Genomic data are made available on the internet almost on a daily basis, thus producing an impressive mass of information that must be statistically treated. This information may consist in lists of genes known to be associated to cellular functions, pathologies, tissues, etc. It may also consist in expression data, i.e. vectors of numeric values for the whole of the 20,000 genes in the human genome. The question of integrating data from several experiments in a single statistical analysis remains largely open. The drawback of existing statistical techniques is that they do not take into account some particular phenomena, although they can be observed in all known databases. One of them is the huge variability between a small number of genes highly and often overexpressed, and the vast majority of genes, which have low expressions in general. Another phenomenon is the high correlation between expressions from two different genes, whether they are biologically related or not. Both induce a lot of spurious artefacts, which are difficult to distinguish from true biological information.

The LJK team SVH (statistics for life sciences) has been developing a collaboration with researchers in biology and medicine since 2014, particularly with the Cancerpole in Toulouse through the Labex TOUCAN (Toulouse Cancer, Jean-Jacques Fournié), and with the Institut Albert Bonniot in Grenoble (Sophie Rousseaux). Foreign collaborations include the Los Alamos National Laboratory and Georgia Institute of Technology (Philip Gerrish). Several new statistical techniques have been developed and tested on real data through these collaborations. They have been included in a new R package, STODA (Statistical Techniques for Omics Data Analysis). This package is currently under testing in Sophie Rousseaux' team. Once tested and validated, it will be transformed into a web application automatizing the statistical treatment of large omics datasets.



Separation of Acute Lymphoid Leukemia by significant genes. The expression matrices come from 7 different databases.

[1] **Checking false discovery rates on p-value plots.** B. Ycart, F. Pont, and J.-J. Fournié, *InterStat*, July#005 (2013)

[2] **Curbing false discovery rate in interpretation of genome-wide expression profiles.** B. Ycart, F. Pont, and J.-J. Fournié, *Journal of Biomedical Informatics*, 47, 58-61 (2014)

[3] **Statistical datamining for symbol associations in genomic databases.** B. Ycart, F. Pont, and J.-J. Fournié. *International Journal of Genetics and Genomics*, 2(6), 97-104 (2014)

[4] **Large scale statistical analysis of GEO datasets.** B. Ycart, K. Charmpi, S. Rousseaux, and J.-J. Fournié. *Gene Technology*, 4(1), 113, 1-9 (2014)

[5] **Weighted Kolmogorov Smirnov testing: an alternative for Gene Set Enrichment Analysis.** K. Charmpi and B. Ycart. *Statistical Applications in Genetics and Molecular Biology*, 14(3), 279-295 (2015)

## 2015

### **Ziad Sultan (LJK-LIG, PhD), Jean-Guillaume Dumas (LJK, CASYS team), and Clément Pernet (LIG)**

Distinguished paper award for their paper « Computing the rank profile matrix » at the International Symposium on Symbolic and Algebraic Computation (ISSAC 2015).

### **Clémentine Prieur (MOISE team)**

2015 Blaise Pascal Prize for Mechanical and Computer Science.

### **Navneet Dalal and Bill Triggs**

Longuet-Higgins Prize for his paper "Histograms of oriented gradients for human detection" (CVPR 2005).

## 2016

### **Jean-Baptiste Orfila, Jean-Guillaume Dumas (CASYS team), Pascal Lafourcade (LIMOS), and Maxime Puys (Verimag)**

Best Paper Award for their paper « Private Multi-party Matrix Multiplication and Trust Computations » at the International Conference on Security and Cryptography (SECRYPT 2016).

### **Antoine Deleforge (PERCEPTION team), Florence Forbes (MISTIS team), and Radu Horaud (PERCEPTION team)**

2016 Hojjat Adeli Award for Outstanding Contributions in Neural Systems for their paper « Acoustic Space Learning for Sound-Source Separation and Localization on Binaural Manifolds » published in International Journal of Neural Systems.

### **Alexis Arnaud (MISTIS team)**

MITACS Globalink Research Award – Inria.

### **Svetlana Lazebnik, Cordelia Schmid, and Jean Ponce (THOTH team)**

Longuet-Higgins Prize for their paper "Beyond Bags of Features: Spatial Pyramid Matching for Recognizing Natural Scene Categories", CVPR 2006.

### **Cordelia Schmid (THOTH team)**

Inria - French Académie des sciences Grand Prize.

# CONFERENCES & WORKSHOPS



## 2015

### Inverse Problem Workshop

› January 27-29<sup>th</sup>, Grenoble

[www-ljk.imag.fr/membres/Faouzi.Triki/projetPbsInverses/workshopIV.html](http://www-ljk.imag.fr/membres/Faouzi.Triki/projetPbsInverses/workshopIV.html)



### 2<sup>nd</sup> SFRMBM (Société Française de résonance Magnétique en Biologie et Médecine) Congress

› March 18-20<sup>th</sup>, Grenoble

<http://sfrmbm2015.sciencesconf.org>



### STATLEARN Workshop : "Challenging problems in Statistical Learning"

› April 2-3<sup>rd</sup>, Grenoble

<http://statlearn.sfds.asso.fr/past-events/statlearn15/>



### 3<sup>rd</sup> Colloquium "Inter'Actions en Mathématiques"

› May 26-29<sup>th</sup>, Grenoble

<https://interactions15.sciencesconf.org/>

### 10<sup>th</sup> GRETSI and Gdr ISIS Summer School

› June 21-27<sup>th</sup>, Peyresq

[www-ljk.imag.fr/Actualities//1422626849166\\_/affichepeyresq2015.pdf](http://www-ljk.imag.fr/Actualities//1422626849166_/affichepeyresq2015.pdf)



# CONFERENCES & WORKSHOPS

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## R Meetings

› June 24-26<sup>th</sup>, Grenoble

<https://r2015-grenoble.sciencesconf.org/>



## IMAGINE at the EXPERIMENTA fair

› October 8-10<sup>th</sup>, Meylan

[www.atelier-arts-sciences.eu/EXPERIMENTA-2015-208](http://www.atelier-arts-sciences.eu/EXPERIMENTA-2015-208)



## 2016

### AMMSI workshop: "Ageing and Maintenance in reliability, Modelling and Statistical Inference"

› January 20<sup>th</sup>-21<sup>st</sup>, Grenoble

<https://www-ljk.imag.fr/AMMSI/Manifestations/Grenoble2016/>



### Week in honor of Professor Joachim Weickert, Jean Kuntzmann Prize recipient

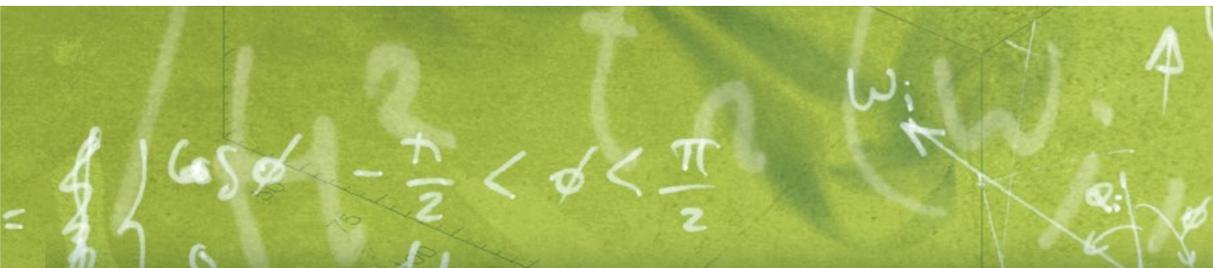
› April 11-14<sup>th</sup>, Grenoble



### PICOF (Problèmes Inverses, Contrôle et Optimisation de Formes) Congress

› June 1<sup>st</sup>-3<sup>rd</sup>, Autrans

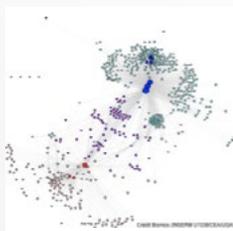
<https://picof.sciencesconf.org/>



## MAS Days « Complex and heterogeneous phenomena »

› August 29<sup>th</sup>-31<sup>st</sup>, Grenoble

<https://mas2016.sciencesconf.org/>



## IXXI-LJK Day « Networks and Patterns »

› October 18<sup>th</sup>, Grenoble

[www.ixxi.fr/agenda/seminaires/networks-and-patterns](http://www.ixxi.fr/agenda/seminaires/networks-and-patterns)



## EDP-Rhône-Alpes-Auvergne Days

› November 17-18<sup>th</sup>, Grenoble

<http://math.univ-lyon1.fr/%7Ejera/2016.html>



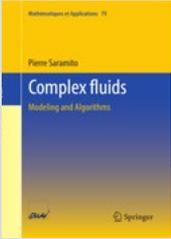
## National Colloquium on Data Assimilation

› November 30<sup>th</sup>-December 2<sup>nd</sup>, Grenoble

<https://cna-2016.sciencesconf.org/>

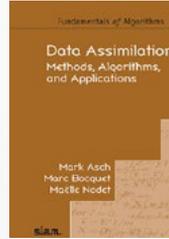
## Books

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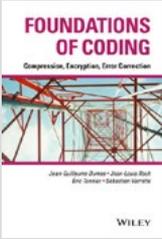
**Complex fluids: Modeling and Algorithms**  
P. Saramito

Springer, 2016.



**Data assimilation: methods, algorithms, and application (fundamentals of algorithms)**  
M. Asch, M. Bocquet, M. Nodet

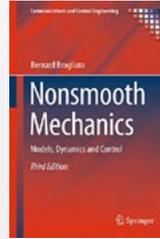
SIAM, Dec 2016



**Foundations of Coding: Compression, Encryption, Error-Correction**

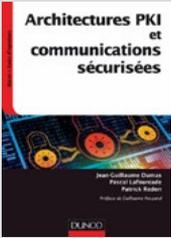
E. Tannier, J-G. Dumas, J-L. Roch, and S. Varrette

Wiley, Feb 2015.



**Nonsmooth Mechanics. Models, Dynamics and Control**  
B. Brogliato,

Springer Verlag London, Third Edition, 2016



**Architectures PKI et communications sécurisées**

J-G. Dumas, P. Lafourcade, P. Redon

Dunod, July 2015.

## Some key figures for LJK

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283 lab members  
of which 75 professors and assistant professors  
40 researchers  
127 doctoral students and postdocs  
41 technical and administrative staff members  
and around 50 trainees each year

200 publications in peer-reviewed journals per year

5 books in 2015-2016

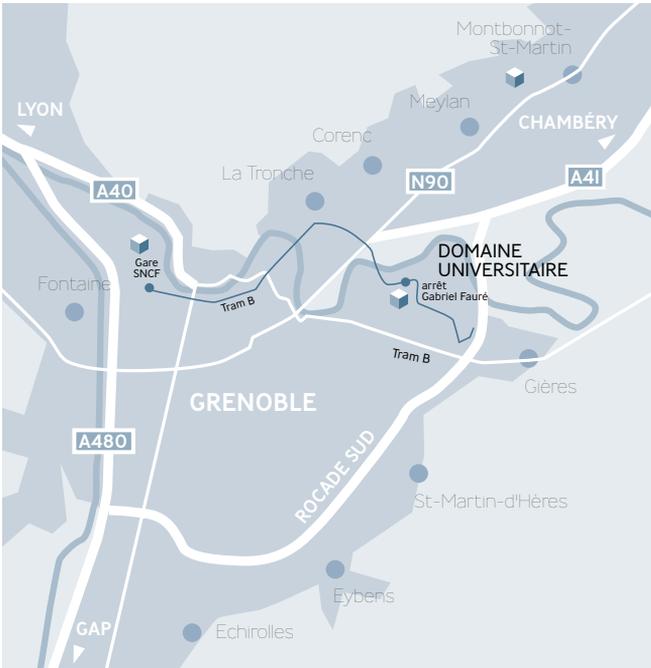
10 projects sponsored by the French ANR

5 European projects,  
including 2 ERC individual grants



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JEAN KUNTZMANN**  
MATHÉMATIQUES APPLIQUÉES - INFORMATIQUE

[ljk.imag.fr](http://ljk.imag.fr)



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