LABORATOIRE
JEAN KUNTZMANN
MATHÉMATIQUES APPLIQUÉES - INFORMATIQUE

LABORATOIRE JEAN KUNTZMANN

HIGHLIGHTS

FAITS MARQUANTS

[2019-2020]

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December 2020

LABORATOIRE JEAN KUNTZMANN

HIGHLIGHTS

FAITS MARQUANTS

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FOREWORD

The synergy between computer science and applied mathematics is the essence of the Jean Kuntzmann Laboratory, a joint research unit of Grenoble Alpes University, CNRS, Grenoble INP (Institute of Engineering) and Inria. This multidisciplinarity makes it a rich structure both humanly and scientifically. In a spirit of conviviality and creative enthusiasm, the success of our teams is the result of a joint investment, favoring exchanges, ethics, and scientific rigor.

The unit thus brings together more than 250 people and is composed of three services and three scientific departments, the latter comprising eighteen research teams. Our research focuses on analysis, on scientific and high-performance computing, on modeling, on exact and symbolic computation, on cybersecurity, on inverse problems, statistics and probability, on machine learning, signal and image processing, on data mining, optimization, applied geometry, graphic computing or computer vision. The versatility of the fields of application of the projects is large, ranging from mechanics to biology, or from image and cryptology to economics and finance.

This new edition of the highlights of the Laboratory compiles two years of research, with the second one largely impacted by the heath crisis. We nonetheless are happy to present here many new projects and successes of these past two years. Among them, we highlight here many scientific developments, that are at the heart of our activities, as well as three portraits of colleagues.

Our results range from theoretical studies to computational modeling and simulation. We point out a novel classification of regular convex cones, the optimization of large-scale learning, as well as an historic project to measure the effort and to see how the human body reacts when wearing a metallic armor. We also have developed models of global systemic risks, secure algorithms outsourcing computations to the cloud, a reliable evaluation of the maintenance, for instance of steam generators of nuclear power plants, or the study of functional brain connectivity. This is illustrated by several industrial collaborations, start-ups, and the advancement of a computing platform for the coastal and regional ocean. Overall, a number of prestigious prizes were awarded to members of the LJK and we organized a dozen multidisciplinary and international events.

Finally, 2020 has also been a year of transition between the management teams and this compendium illustrates the pursuit of a common vision. We are therefore particularly mindful to gender equality, sustainable development, quality of business life, and we work together for technological innovation and the exploration of the limits of knowledge.

We wish you a pleasant and fruitful journey with us!

Stéphane Labbé and Jean-Guillaume Dumas

PART 1

PORTRAITS

Ludovic Métivier

› EDP team

Ludovic Métivier is a CNRS researcher in applied mathematics at LJK. He is currently leading the high resolution seismic imaging project SEISCOPE together with Romain Brossier, assistant professor in the Earth Sciences Institute of Grenoble Alpes University (ISTerre).

He obtained his PhD degree in 2009, carried out between the French Petroleum Institute (IFP) and the applied mathematics laboratory of Paris XIII University, under the supervision of Laurence Halpern. After two years of post-doc in CEA Saclay, Ludovic joined the SEISCOPE project in 2011 as a post-doc and became a CNRS researcher in 2012. In 2016, he undertook the management of the SEISCOPE project. He obtained his Habilitation à Diriger des recherches in 2017 and received a CNRS Bronze medal in 2019.

The main particularity of Ludovic's research is the strong interaction he has developed along the years with the geophysicists of ISTerre. His main field of study is the propagation of mechanical waves within the subsurface, both from a theoretical and a numerical modeling perspective, and how to use these waves to image the Earth, that is inferring its mechanical properties from partial measurement of the wavefield which propagates within it. With the SEISCOPE project, he develops concepts and methods which are implemented in computer codes deployed at the national supercomputer level, and applied to industrial field data, to go beyond proof of concepts towards data geophysicists actually deal with.

Recently, Ludovic has worked on the introduction of optimal transport distances within the high resolution seismic imaging method named full waveform inversion. This method is based on the iterative minimization of a misfit function measuring the distance between field and simulated data. When conventional least-square distances are employed, the misfit function is non-convex, rendering the full waveform inversion method difficult to apply without a good enough initial guess of the solution. To remedy this problem, Ludovic has shown how optimal transport distances, inherited from the work of mathematicians in the field of geometry and analysis, can be used to render the misfit function more convex. This work has strong implications and impact in the geophysicists community and has been at the origin of his bronze medal in 2019.

Sophie Thery

› AirSea team

I joined the laboratory in 2017 as a PhD student in the AIRSEA team under the supervision of Eric Blayo and Florian Lemarié. The research world has been attractive to me for a long time. After high school, I decided to pursue at the university driven by my curiosity about the universe of scientific research and attracted by the work autonomy it offered. For me, studying Mathematics was obvious and I particularly appreciated the contact with mathematics teachers, especially for their originality. At the same time, I maintained a teaching activity for high school students that has become a real professional activity since I was 17 years old until my master's degree. After my bachelor's degree in fundamental mathematics I started a master's degree in applied mathematics both at Grenoble University.

My research internship ultimately led to a PhD thesis "Numerical study of ocean-atmosphere coupling algorithms taking into account turbulent boundaries layers". Initially, I chose this subject for its application to physics close to PDEs which interested me and for its originality that appealed to me. But clearly, the opportunity to combine my tendency for the questions related to ecology with mathematics attracted me. I naturally took a step back on the subject by trying to answer open-questions: what are we "really" showing? Does this match with what we expect? What is the concrete meaning of our results? With such an approach, I hope to make the project progress in a meaningful way. During my thesis, I also had the pleasure to teach entire classes. Teaching keeps me to constantly question my knowledge and renews my interest for mathematics, and I really appreciate combining teaching and research.

The work environment during the thesis particularly appealed to me. I liked having autonomy in my work and taking the time to fully explore a subject. I was very well integrated into the team and the laboratory where I met researchers and other PhD students. Of course, the employment condition with a stable situation for 3 years allowed me to work with serenity. Despite all these positive points, I should say that my last year as a PhD student in 2020 was a bit disappointing. Due to the pandemic, I haven't had the opportunity to attend conferences, which prevented me to discuss with my colleagues from around the world and to develop my network. This will not impact my motivation to keep going in academic research and my defense in February 2021 should open the doors for the next steps.

PART 1

PORTRAITS

Vincent Brault

› SVH team

Vincent Brault joined the LJK in 2016 as an Associate Professor. His work focuses mainly on unsupervised classification and segmentation, especially when these two phenomena are applied to both the rows and columns of a matrix (co-classification and bisegmentation in particular). He appreciates to start from a concrete case, to propose an adapted modeling and estimation procedures whose theoretical properties he studies. He then proposes an implementation, often in an R package, trying to limit the computational time as much as possible by looking at the problem often from another angle.

Interested in interdisciplinarity, he has participated in several projects such as the detection of dysgraphic children (CEA and LPNC collaboration), the identification of the structure of electrical networks from meter readings (Odit-E), the classification of students following the SELF test (UGA Language Department) or, more recently, the use of pooling for Covid (Université Sorbonne Nord, Université Aix Marseille, and TURING center), the detection of bias in recruitment algorithms (CERAG), and is part of the MIAI Chair "High-dimensional Inference by Convex Optimization".

Involved in the scientific community, in particular in statistics, he has been president of the young group of the French Statistical Society, he is in charge of the Informatics Unit and has recently been elected in the board of the association. At the LJK, he is elected as substitute to the laboratory council and is part of the scientific animation commission. In the STID department where he teaches, he is responsible for the Big Data professional license.

Committed to popularization, he is part of the association MATh.en.JEANS where he animates a club in Morestel and organized with Catriona Maclean of the Institut Fourier the 28th and 30th congresses in Grenoble. He also participated in "100 parrains 100 classes" set up by the UGA and is regularly present at the science days. He was also interviewed in local newspapers for the article on pooling for COVID.

As he believes that a pleasant and benevolent environment favors work in research, he was a member of the QWL commission of the laboratory and the building. In these capacities, he has organized laser games, Mario Kart tournaments, killer games, quizzes...

PART 2

MULTI-DISCIPLINARY INTERACTIONS

Measuring athletes' performance through the ages: a 3D motion study of XVIth armored locomotion with the MarchAlp project

› CVGI team

Textured and wire models of armored warriors.

1515? Marignano! This is one of the most famous dates in the history of France when Francis I of France set out to fight the Swiss mercenaries for the Duchy of Milan. What is perhaps less well known is that the preparations for this battle gave rise to a logistical and human exploit with the crossing of the Alps by an army of about 60,000 men via the Argentière pass in 5 days, guided in particular by the famous knight Pierre Terrail de Bayard.

The athletic performance is all the more remarkable because Francis I, fearing a surprise encounter with the Swiss mercenaries, had imposed that the knights remain in armor during this march in order to ward off any eventuality.

A correspondence with his mother, Louise of Savoy, states that he found it "very unpleasant to have to keep the armor on".

500 years later, Stéphane Gal of the LARHRA laboratory at UGA wanted to question in a very concrete way what this "very unpleasant" could mean in terms of athletic performance through an experimental anthropological approach.

The MarchAlp project allowed three subjects to test locomotion in armor, in the mountains as in the time of Francis I, but also beforehand in the laboratory to quantify the physical performance that this effort represents thanks to the participation of the Gipsa-lab and LJK laboratories. Within the LJK, Lionel Reveret worked on a method to measure kinematic parameters when walking in armor by relying on the 3D temporal meshes provided by the Kinovis platform.

As metal armors are reflective, it proved to be complex to analyze the subjects with classical systems of motion analysis using optical markers. A geometric analysis approach of the 3D meshes over time has allowed to identify fundamental kinematic parameters of the walk such as stride length, foot poses, both with and without armor. It appeared that these parameters did not happen to be significantly different in walking speed and efficiency with and without an armor, despite a real overweight of 20 to 40 kg. This result suggests that the architecture of the armors (replicated as faithfully as possible compared to the models of the 16th century) does not hinder the normal walking but however induces an energetic over cost that experiments carried out at Gipsa-lab have sought to highlight.

More information

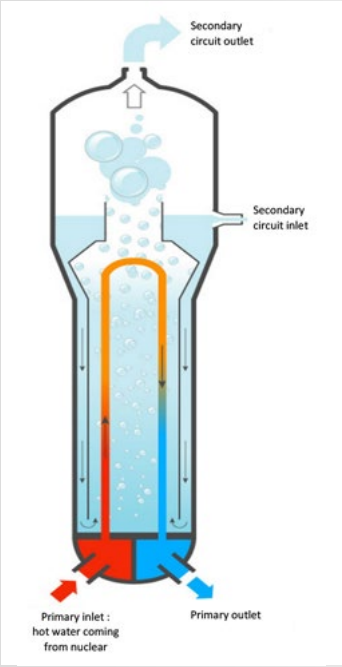
https://www.megapixailes.com/docu-chevaliers-dans-la-montagne/

PART 2

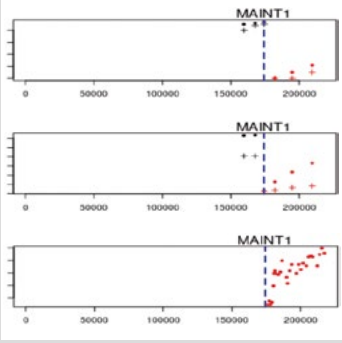
MULTI-DISCIPLINARY INTERACTIONS

AMORE-MIO - Advanced MethOds for Reliability and maintenance Evaluation: Models, Inference, Optimization

› ASAR team



Blueprint of a steam generator of nuclear power plant.



Example of the corresponding measurements of the three degradation indicators and of the maintenance effect on one steam generator.

AMORE-MIO is a collaborative research team, supported by Persyval-lab, between LJK and GIPSA-lab laboratories at UGA and two industrial partners, EDF R&D and GRTGaz. AMORE-MIO focuses on technological or industrial equipment that are subject to degradation because of intrinsic wear, usage imposed by operating conditions or exposure to environmental factors. For such repairable industrial equipment, an issue consists in maintaining the system in working order conditions in accordance with safety, availability and cost constraints. Nowadays, the generalization of sensors or modern monitoring techniques allows to access a wide range of heterogeneous information on systems and opens new research perspectives. This project aims at developing approaches to optimally manage the health state of deteriorating systems based on this diversity of available information, and resorting to a wide range of possible actions from optimal control of the operating conditions to maintenance actions.

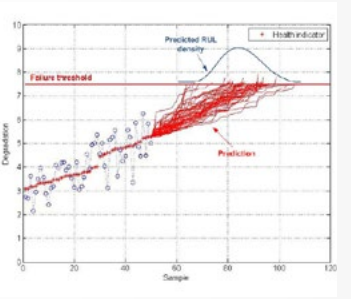
For example, the steam generator of EDF nuclear power plants can serve as an illustrative use case. A steam generator is composed of thousands of reverse U tubes. The radioactive water of the primary circuit circulates into the tubes and the non-radioactive water of the secondary circuit circulates along the tubes while heating and boiling.

The clogging, which consists in an accumulation of deposits, that hampers the flow inside the steam generator, is one of the degradation phenomena that is carefully monitored. Televisual camera inspection is the most informative but also the most expensive way to measure the clogging indicator, and consequently there is only a small number of such measures.

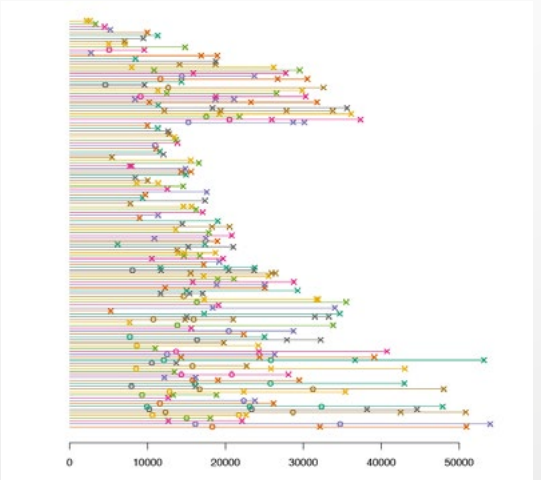
A second indicator, based on Eddy currents, can be measured more frequently but with less accuracy than televisual inspection. Finally, a third indicator based on a constant monitoring of the pressure within the system can be measured very regularly, but corresponds to an indirect vision of the clogging. In addition, preventive maintenance actions can be planned. The steam generator can be cleaned using chemical solvents. These operations are very expensive (more than several million of euros) and must be foreseen many years before. The first challenging issue is to propose integrated models considering both multivariate dependent degradations and the effect of maintenances and covariates. Then, statistical estimation procedures have to be developed in agreement with database characteristics. A final issue is to take into account the fact that the different degradation indicators are more or less informative and can be more or less regularly measured. In particular, an optimum has to be found between the information contained in an indicator and its measurement cost.

A second illustrative example, issued from GRTGaz, is the case of natural gas pressure reducing units. The global system modeling is created with predictive stochastic Petri nets. Petri models are used for decision making to define an optimized maintenance policy. But, the relevance of the decision making is conditioned by an accurate modeling of the characteristics of nodes and edges of the net, that is to say of the different components of the pressure reducing units. Feedback databases are then used to determine accurate models for components successive stochastic failure times and maintenance effects. The VAM R-package, developed by the ASAR team of LJK, has already been used to select accurate models and estimate their parameters values. However, existing models and estimation procedures are not sufficiently general with respect to the complexity of equipments. The problem is to be able to take into account competitive failure modes and different corrective maintenance types. Another problematic issue from the GRTGaz database is due to the presence of left censoring.

To consider these types of issues, two disconnected approaches have been used in the reliability literature. One is based on recurrent event models (GRTGaz example) and is centered on the probabilistic lifetime modeling of the successive discrete event times and types. For instance, the Arithmetic Reduction of Age models, proposed by the ASAR team, are models of this kind. The other one (EDF R&D example) considers stochastic processes representing continuously time varying degradation (such as Wiener or gamma processes), in which failures correspond to the first time a given threshold is reached. We are convinced that closing the gap between these two "modeling worlds", that describe the same reality from different points of view and using different tools, can be fruitful, but requires to solve several difficulties that we aim at addressing in this project.



Sketch of an estimation method on a degradation model and of the issue of prediction of the Residual Useful Life (RUL).



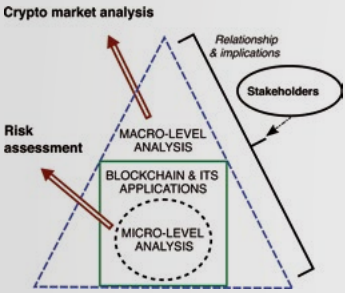
Example of successive corrective (crosses) and preventive (circles) maintenance times for 141 independent and identical Brazilian off-road mining trucks that can be represented with recurrent events model.

PART 2

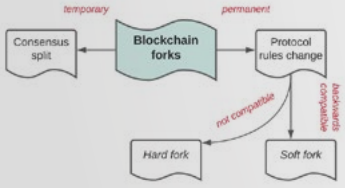
MULTI-DISCIPLINARY INTERACTIONS

Risk-driven Blockchain optimization: Impact for financial markets and firms

› CAS^{3}C^3 team



Multilevel model of analysis.



Fork classification.

A cryptocurrency is a digital asset for which individual coin ownership records are stored in a chained distributed ledger, a blockchain. A blockchain is a new technology combining a public list of transactions (that are linked together using cryptographic hash functions and electronic signatures) and a peer-to-peer network managing this list, the ledger, in a duplicated and distributed manner.

In Florentina Şoiman's thesis under the direction of S. Jimenez Garces and J.-G. Dumas, the idea is to explore the links between the technological characteristics of the blockchain and the financial characteristics of cryptocurrencies, as assessed by investors, such as the return, the risk, the volatility, or the firm performance.

This resulted first in a detailed risk assessment of the cryptomarket. We took into consideration technological issues, such as consensus, network, cryptographic primitives, quantum and smart contract attacks, together with economic and financial concerns such as market, information, liquidity, supply, reputation and environmental risks. Vulnerabilities are analyzed both at the micro-level with empirical demonstrations and at the macro-level, taking into account its stakeholders and their implication. We were then able to identify a continuity between the technological risks and financial ones as well as a long-term profitability of the stakeholders strategy/position within the market [1].

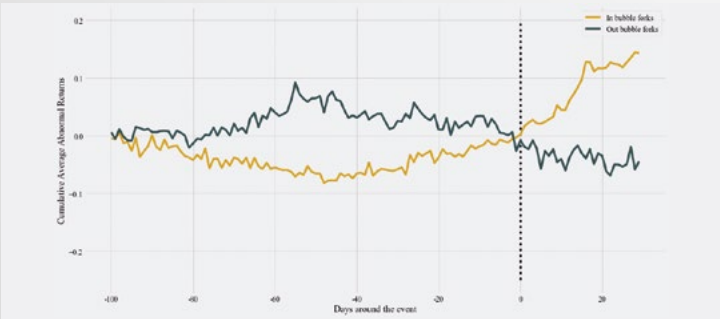
A second result of this collaboration is the detection of a "forking effect" on the characteristics of cryptocurrencies around bubbles: before, after or during bubbles the effect of a fork on the parent and the forked coins can be diametrically opposed [2]. More precisely, we have found that the forked coins show higher illiquidity, value-at-risk and and volatility, as well as worse efficiency than their parent, for multiple time horizons. Further, our results show that the value-at-risk, volatility, illiquidity and efficiency are worse for the recent forks when compared to early ones.

[1] ***Blockchain technology and the cryptomarket: vulnerabilities and risk assessment****. J.-G. Dumas, S. Jimenez-Garces, and F. Şoiman. In 12th International Conference on Complexity, Informatics and Cybernetics, pages 30–37, Orlando, USA, 9–12 March 2021.*

[2] ***The forking effect****. F. Şoiman, M. Mourey, J.-G. Dumas, and S. Jimenez Garces. Research report. hal-03216121, May 2021.*

https://www.cerag.org/vie-scientifique/cross-discplinary-program-cdp/cybersecurity-institute/zoom-these-florentina-Şoiman

Cumulative Average Abnormal Returns.



Statistical network analysis, application to brain connectivity

› STATIFY team

The brain is the most complex organ of the human body. It is composed of around a hundred billion neurons that are interconnected with each other. It is nowadays possible to measure the activity of the brain while functioning using neuroimagery such as ElectroEncephalography (EEG), MagnetoEncephalograpy (MEG) or functional Magnetic Resonance Imaging (fMRI). Neuroimaging facilities are now available in most hospitals to make observations of the brain during task or resting-states. These has brought new perspectives for understanding the evolution of pathologies such as neurodegenerative diseases of consciousness disorders, especially at the subject level [1]. From a statistical point of view, neuroimaging provides many datasets with both spatial and temporal scales. For example, fMRI consists of a set of voxels (i.e. cubes) covering the whole volume of the brain for each time point. The side of one voxel is usually around 2 to 3 millimeters and one volume is acquired every 1 to 2 seconds. It is then needed to summarise these complex datasets to give a comprehensive model of the brain. Using these spatio-temporal datasets, a current goal is to infer brain networks, where one node of the network corresponds to a region of the brain and one edge corresponds to a connection or link between a pair of regions. The challenge is to define an accurate and interpretable measure of a connection between two regions. Indeed, neuroimaging provides a massive amount of data that can be difficult to process and analyse adequately to obtain reproducible results [2].

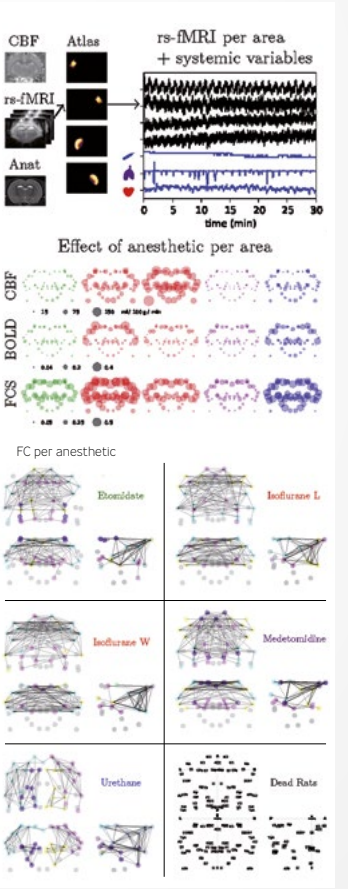
Our objective is to develop methods for robust and statistically consistent estimation of networks using functional data analysis for multivariate datasets such as those observed in neuroimaging. We already obtained reliable results using wavelet correlations (FC) for both dead and anesthetized rats [3]. The idea is to combine accurate correlations estimations for long memory time series and correction for multiple testing. We are currently working on using spatio-temporal characteristics of the datasets to exploit densities of correlations as a novel tool for quantile-based network construction. This work is partly funded by a joint NSF-ANR project between Grenoble (France) and Santa Barbara (USA).

Joint work of Sophie Achard, Hanâ Lbath, Lucrezia Carboni, Florence Forbes, Guillaume Becq, and Emmanuel Barbier

*[1] **Graph analysis of functional brain networks: practical issues in translational neuroscience**. F. De Vico Fallani, J. Richiardi, M. Chavez, and S. Achard. Philosophical Transactions of the Royal Society B: Biological Sciences, 369(1653):20130521, 2014.*

*[2] **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(15):172–187, 2016.*

*[3] **Functional connectivity is preserved but reorganized across several anesthetic regimes**. G. Becq, T. Habet, N. Collomb, M. Faucher, C. Delon-Martin, V. Coizet, S. Achard, and E. L Barbier. NeuroImage 219:116945, 2020.*



Example of the pipeline to process fMRI data. This figure is taken from [3]. The group of dead rats is considered as a null model where no connections are expected. Data are freely available, see reference within publication [3].

CBF=Cerebral Blood Flow; BOLD = Blood Oxygeneated Level Dependent; rs-fMRI= resting-state fMRI.

PART 2

MULTI-DISCIPLINARY INTERACTIONS

MIAI Chairs

MIAI Grenoble Alpes (Multidisciplinary Institute in Artificial Intelligence) aims to conduct research in artificial intelligence at the highest level, to offer attractive courses for students and professionals of all levels, to support innovation in companies and to inform and interact with citizens on all aspects of Artificial Intelligence (AI). Two main research themes are addressed: (i) future AI systems and (ii) AI for human beings and the environnement and seven axes have been identified. At the initiation of the project in 2019, five chairs have been assigned to LJK members and a sixth chair joined us later. Far beyond this, the selected research directions federate many colleagues in the corresponding research teams.

The first axis of MIAI is devoted to Machine learning and reasoning, among which Machine learning models :
- Sophie Achard (STATIFY team) chairs the « Towards Robust and Understandable Neuromorphic Systems » together with Martial Mermillod (Laboratoire de Psychologie et Neurocognition)
- Julien Mairal (THOTH team) heads the « Towards More Data Efficiency in Machine Learning » chair

Statistics and optimization
- Anatoli Juditsky (DAO team) « High dimensional inference by Convex Optimization » together with Arkadi Nemirovski (Georgia Institute of Technology)
- Jérôme Malick (DAO team) « Optimization & Learning » together with Yurii Nesterov (University of Louvain)

The third axis of MIAI deals with Perception & Interaction, among which Robotics
- Xavier Alameda-Pineda & Radu Horaud (PERCEPTION team) « Audio-visual machine perception and interaction for companion robots ».

Computer vision
- Edmond Boyer « Data Driven 3D Vision »

https://miai.univ-grenoble-alpes.fr/research/chairs/machine-learning-and-reasoning/towards-robust-and-understandable-neuromorphic-systems-849763.htm?RH=6499588038450843

https://miai.univ-grenoble-alpes.fr/research/chairs/machine-learning-and-reasoning/towards-more-data-efficiency-in-machine-learning-851347.htm?RH=6499588038450843

https://miai.univ-grenoble-alpes.fr/research/chairs/machine-learning-and-reasoning/high-dimensional-inference-by-convex-optimisation-860831.htm?RH=6499588038450843

https://miai.univ-grenoble-alpes.fr/research/chairs/machine-learning-and-reasoning/optimisation-learning-851213.htm?RH=6499588038450843

https://project.inria.fr/avbot/

https://miai.univ-grenoble-alpes.fr/research/chairs/perception-interaction/data-driven-3d-vision-edmond-boyer-851217.htm?RH=6499588038450843

PART 3

SCIENTIFIC RESULTS OF THE TEAMS

Global Systemic Risk

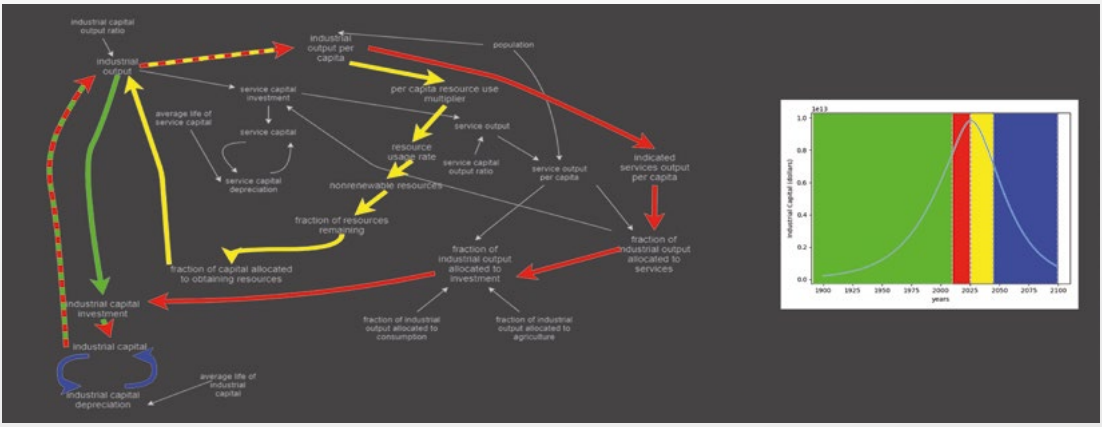
› STEEP team

In 2019, the STEEP team started a new research focus on Global Systemic Risk (GSR). Our modern industrial societies are characterized by the very high degree of interconnection linking the different sectors that make them up. The intersecting dynamics of these sectors, as well as the consequences of our human activities in terms of environmental destruction, are the bearers of intrinsic destabilization risks, called systemic risks. They are rooted in all the existing feedbacks between the socio-environmental components of this global system, and represent serious threats, growing with the increase of the complexity of our societies, and which can go as far as the collapse of all or part of our socio-ecosystems.

STEEP team works on the two major families of systemic risks: the long-term trend risks (decades) and the short-term systemic contagion risks (months or years) which are more random in nature than the previous ones. In particular, in the context of the first family of risks, the team has undertaken work to analyze the validity and robustness of the World 3 model [1], an emblematic and even unique model predicting a risk of global societal collapse between the 2020s and 2070s if business-as-usual policies were continued. A potential issue is the possibility of discerning trend collapse risks in the short term (pre-2050) or further out in time (post-2050), both of which involve different mitigation and adaptation strategies that need to be properly anticipated.

The team is also working on the second family of risks. In particular, the team is now developing a model of the interconnections between energy, food security, logistics, and finance. Here, the primary objective is not to obtain precise quantitative evaluations, but to draw fine qualitative and semi-quantitative understanding of the dynamics of crisis contagions. To carry out this work, the main tasks are to identify the most important feedback loops of the coupled energy/agro-food/logistics/finance system, to identify the most fragile links in the supply chain, and to assess the likelihood of this type of risk, and, if necessary, define mitigation strategies.

*[1] **The Limits to Growth: The 30-year Update**. D. H. Meadows, J. Randers, and D. L. Meadows. 3rd edition. Chelsea Green Publishing, 2004.*



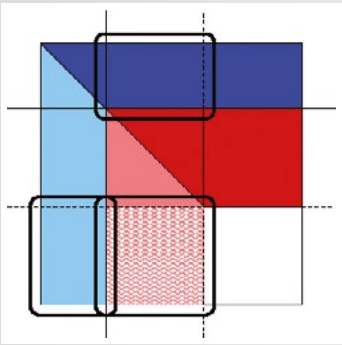
Example of results of loop dominance analysis for the capital and resource sector of the World 3 model. The curve on the right shows the evolution of the world's industrial capital between 1900 and 2100 (BAU scenario). 4 phases can be identified (exponential growth in green, slowdown in growth in red, first phase of collapse in yellow, then decline in blue). The diagram on the left shows the dominant loops associated with each of these phases (correspondence via color). This analysis allows to understand the mechanisms inducing the model dynamics, in particular that the loop modeling the growth of the industrial capital is responsible for the instability in the sector and that the lack of resources forces to invest less in the capital and is responsible for the decline.

PART 3

SCIENTIFIC RESULTS OF THE TEAMS

LU factorization with errors

› CAS^{3}C^3 team



Representation of a block recursive variant of the Crout LU decomposition algorithm.

The development of cloud computing led to an increasing trend of outsourcing data storage and computation in the cloud. Nonetheless, externalizing computations yields new challenges regarding the security, the confidentiality and the trust in data manipulated by infrastructures no longer managed by the user or his working group. Several fields contribute to defining algorithms and protocols to restore trust in outsourced computing infrastructures, by providing guaranties on the correctness of the results and on the confidentiality of the data manipulated. These include for instance

• **Fault tolerance**, based on error correcting codes, allowing to support failure or malicious corruption of a bounded share of the outsourced resources;

• **Interactive Proof Protocols**, applied to the certification of results;

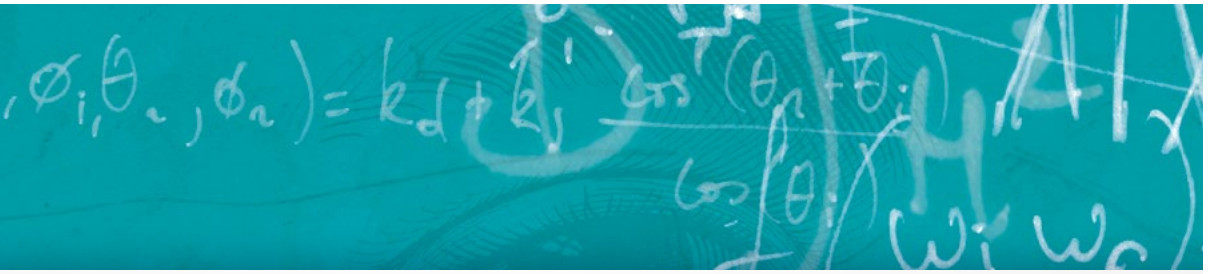
• **Secure Multiparty Computation**, orchestrating computation between players while ensuring the privacy of their data.

The CAS^{3}C^3 group is working on these three angles with a special focus on dedicated protocols, exploiting the inner algebraic structure of the problems, to reach a good practical efficiency where the existing generic solutions are most often much too costly in practice (despite being asymptotically optimal). We present a recent contribution [1] dealing with fault tolerant Gaussian elimination.

Fault tolerance, is about detecting faults or silent errors occurring in a computation but also to correct them whenever it is possible. The coding theory approach makes it possible by introducing redundancy. We focus here on an alternative approach, with no added redundancy except the one resulting from the algebraic relations between the input and the expected output. These techniques, previously developed by [2] for matrix multiplication rely on probabilistic matrix equality tests and sparse polynomial interpolation. We proposed in [1] an algorithm detecting and correcting errors in the LU decomposition of a matrix. It does not require any other information than the input matrix and the possibly erroneous triangular factors L and U. Contrarily to the coding theoretic approach, the efficiency is not measured by correction capacity, since this algorithm is able to correct any number of errors, but instead the cost overhead for performing the correction. Our algorithm requires $t+\min(nk, k^{\omega-2}\, n^{4-\omega})$ field operations to correct k errors in the LU decomposition of an $n \times n$ matrix with t non-zero coefficients. This algorithm relies on sparse polynomial interpolation combined within a recursive Crout LU factorization algorithm.

*[1] **LU factorization with errors**. J.-G. Dumas, J. van der Hoeven, C. Pernet, and D. S. Roche. In Proceedings of the 44th International Symposium on Symbolic and Algebraic Computation, ISSAC'19, pages 131–138, New York, NY, USA, ACM, 2019.*

*[2] **Efficiently correcting matrix products**. L. Gasieniec, C. Levcopoulos, A. Lingas, R. Pagh, and T. Tokuyama. Algorithmica, 79(2):428–443, 2017.*



STROLL — Harnessing Structure in Optimization for Data Science

› DAO team

Many problems in data science (regression, classification, clustering, etc.) lead to the minimization of some risk function that measures the adequation between a model and the data. However, when the number of parameters of the model becomes large and the difficulty of the problem increases, the risk minimization gets harder and the stability of the obtained model is degraded.

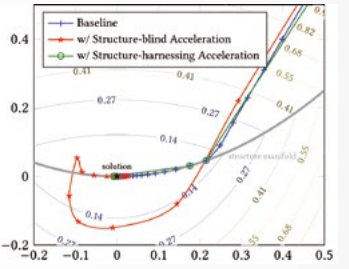
In order to overcome this issue, a popular solution is to introduce a prior on the structure of the model. For instance, we may want the obtained model to be sparse or low-rank so that the number of (non-null) parameters of the model is not too large. This low-complexity often corresponds to useful practical information; for instance, the support of a model obtained with a sparsity prior usually indicates the most important features for the task at hand. Moreover, the obtained low-complexity pattern is often stable to small perturbations of the data which is helpful in terms of generalization to new data.

Mathematically, while the fit of the model to the data is usually measured by a smooth function, the structure priors are enforced by adding a nonsmooth function to the objective. Indeed, there is a strong link between non-differentiability and structure stability which made the use of nonsmooth regularizers ubiquitous in machine learning and signal processing for the appealing recovery or consistency properties that they induce.

However, to the contrary of general nonsmooth optimization problems, the points of non-differentiability of these regularized objectives follow a known structure (this is our prior), and the properties of the problem (smoothness, conditioning) are improved when restricted to the optimum's structure [1].

In this project, we study how certain optimization methods can produce iterates that recover partially or exactly this structure. Then, we show how this information can be harnessed to numerically accelerate these algorithms [2]. For instance, once some structure, typically modeled as a manifold, has been identified (eg. some coordinates are null), there is some hope that it will be stable for subsequent iterations (the coordinates will remain null). It is thus natural to update preferentially along this manifold (the non-null coordinates) [3].

This project received the funding of ANR through the JCJC grant STROLL (ANR-19-CE23-0008).



Harnessing the nonsmooth structure of the function can boost optimization methods.

[1] ***Nonsmoothness in Machine Learning: specific structure, proximal identification, and applications****.F. Iutzeler and J. Malick. Set-Valued and Variational Analysis, 28(4): 661–678, 2020.*

[2] ***On the Interplay between Acceleration and Identification for the Proximal Gradient algorithm****.G. Bareilles and F. Iutzeler.Computational Optimization and Applications, 77(2:)351–378, 2020.*

[3] ***Newton acceleration on manifolds identified by proximal-gradient methods****.G. Bareilles, F. Iutzeler, and J. Malick.Research report. arXiv:2012.12936, 2020.*

PART 3

SCIENTIFIC RESULTS OF THE TEAMS

Self-associated cones

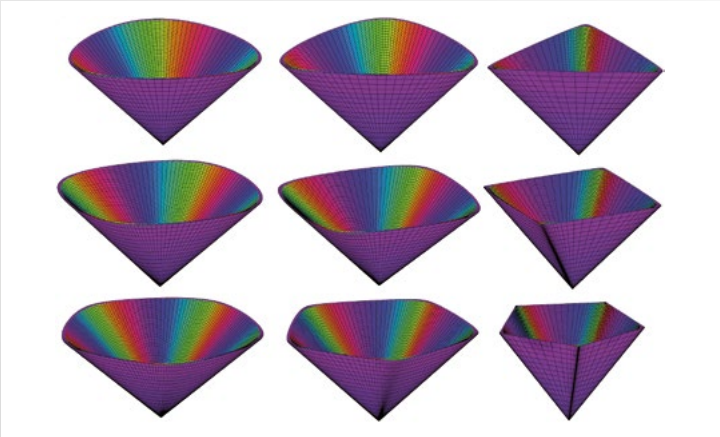
› DAO team

Conic programs are a widely used standard form of optimization problems. Besides trivial linear equality constraints and a linear cost function they contain only a single non-trivial constraint, namely the inclusion of the design variable into a convex cone. In order to numerically solve a conic program one uses a so-called self-concordant barrier, which is a smooth function defined on the interior of the cone. Solvability of a conic program hence crucially depends on the availability of a computable self-concordant barrier.

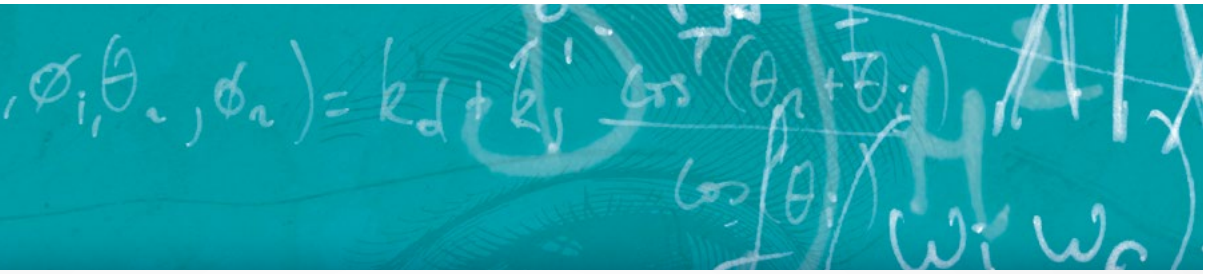
To date there exist three universal constructions of self-concordant barriers on arbitrary regular convex cones, the universal, entropic, and canonical barrier. All three are difficult to compute in general, but possess advantageous theoretical properties. All constructions are invariant with respect to automorphisms of the cone, but in addition the canonical barrier is equivariant with respect to duality, leading not only to a better computational accessibility, but to the possibility of making use of more advanced mathematics.

This comes especially into play when considering 3-dimensional cones. In this case the level sets of the canonical barrier are 2D surfaces, and can be interpreted as domains in the complex plane carrying a special mathematical object, the so-called holomorphic cubic form. The duality symmetry manifests itself as a multiplication of this cubic form by -1. One may then generalize this property and ask when the symmetry extends to multiplication of the cubic form by arbitrary complex numbers of unit norm. This leads to a special class of convex 3D cones, which we call self-associated cones and which possess a hidden continuous symmetry generalizing the usual discrete duality symmetry.

Among these cones are families which continuously interpolate between the ellipsoidal Lorentz cone and the polyhedral cone defined over the regular n-gon. In the limit one obtains computable canonical barriers which possess the same complexity independent of the number n of vertices in the polygon, and extending even to 3D cones with infinitely many planar faces. This allows to take into account an arbitrary number of linear constraints while keeping the complexity of the conic program bounded.



Members of the interpolating families of self-associated cones along with a level surface of the canonical barrier. The color code and grid on the surface depict the action of the continuous symmetry which generalizes duality.



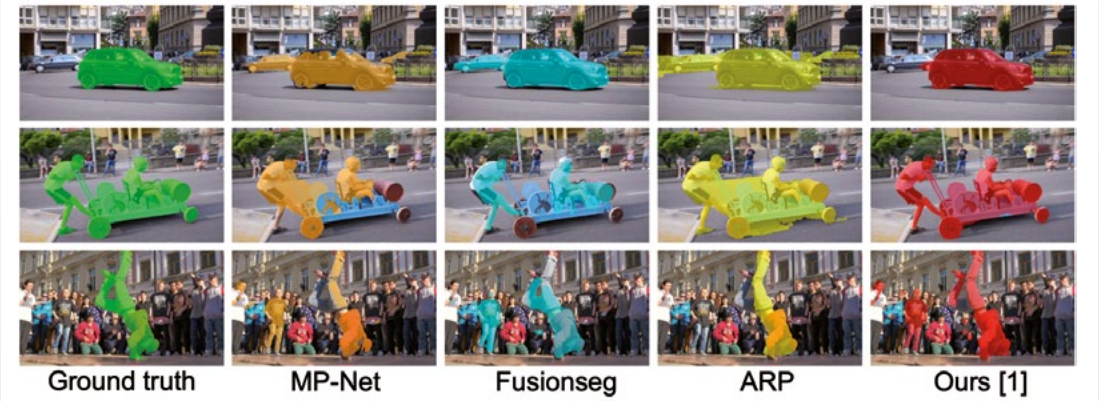
Segmenting Objects in Motion

› THOTH team

Video object segmentation is the task of extracting spatio-temporal regions that correspond to object(s) moving in at least one frame in the video sequence. Several top-performing methods for this problem rely on handcrafted features and do not leverage a learned video representation, despite the impressive results achieved by convolutional neural networks (CNNs) for other computer vision tasks, e.g., image segmentation, object detection. There have been attempts to build CNNs for video object segmentation. Yet, they suffer from various drawbacks. For example, a few approaches rely on a manually-segmented subset of frames (typically the first frame of the video sequence) to guide the segmentation pipeline. Some others do not require manual annotations, but remain frame-based, failing to exploit temporal consistency in videos. Furthermore, these methods have no mechanism to memorize relevant features of objects in a scene. In our work published in the International Journal of Computer Vision [1], we propose a novel framework to address these issues.

We formulate the task of segmenting all the objects that exhibit independent motion in at least one frame as a learning problem and design our framework with three cues: (i) independent object motion between a pair of frames, which complements object recognition, (ii) object appearance, which helps to correct errors in motion estimation, and (iii) temporal consistency, which imposes additional constraints on the segmentation. The framework is a two-stream neural network with an explicit memory module. The two streams encode appearance and motion cues in a video sequence respectively, while the memory module captures the evolution of objects over time, exploiting the temporal consistency. The motion stream is a CNN trained on synthetic videos to segment independently moving objects in the optical flow field. The module to build a "visual memory" in video, i.e., a joint representation of all the video frames, is realized with a convolutional recurrent unit learned from a small number of training video sequences. This unit encodes the spatio-temporal evolution of object(s) in the input video. Sample results of our approach and along with those of other popular methods are shown in the Figure.

*[1] **Learning to Segment Moving Objects**. P. Tokmakov, C. Schmid, and K. Alahari. International Journal of Computer Vision, 127(3), 282-301, 2019.*



Results of our approach ("Ours [1]") on a few examples from the DAVIS dataset, along ground-truth annotations and comparisons to popular methods.

PART 4

COMPUTING PLATFORMS AND VALORIZATION

Creation of the TerriFlux company

› STEEP team

How to reduce soybean imports and increase oilseed production in France? How is the wood industry organized in Savoie? What material flows are associated with animal feed? Can Bourgogne-Franche-Comté structure a straw industry for construction?

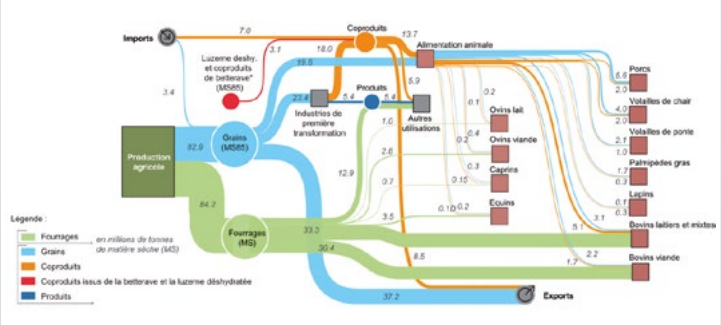
A methodology and two software programs have been developed in the STEEP team to help communities, interprofessions, technical institutes and companies that are asking these questions. From 2017 to 2019, an ADEME project validated the operationality of the tools for the wood and plant sectors: integration of the results on the wood sector in the regional biomass plan, a planning document, in AURA and Bourgogne-Franche-Comté, and collaboration with the GIS Avenir Elevages to quantify the raw materials intended for animal feed. A new step was taken in 2020 with the incubation of the TerriFlux company in the Inria Startup Studio. TerriFlux's objective is to industrialize the two software programs, AF Filières and OpenSankey, and to disseminate them on a large scale in order to support the bioeconomy strategies at work in the context of the energy transition.

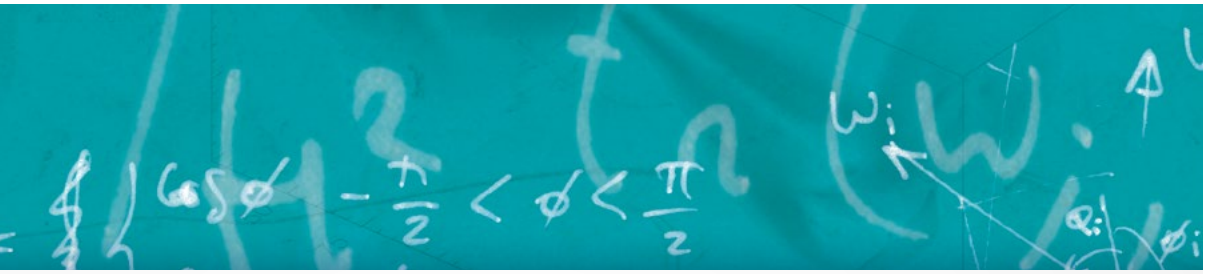
Applied to the value chains, the AF Filières methodology makes it possible to model them and to reconcile incomplete and inconsistent data. The method models products, sectors, and the flows that can exist between these products and sectors. The estimated material flows can be coupled with indicators of environmental pressure along the value chain and allow to compare the production footprint and the consumption footprint of the territories. Data reconciliation is a constrained optimization operation: the aim is to minimize the difference between the model input and output data. The system of equations being ill-posed, the method returns solution intervals. The methodology is multi-scale. It is first applied at the national scale, where the data are the most reliable, then at a multi-regional level, and then at a multi-departmental level.

The OpenSankey software is an online editor of Sankey diagrams (flow diagrams) particularly adapted to the representation of material flows within a supply chain. Once produced, these diagrams can be put online and visualized dynamically through filters that allow to understand different aspects of the value chain.

***Analysis of raw material flows in animal feed in France**. GIS Avenir Elevages. 6 pages, GIS Avenir Elevages, 2020.*

https://terriflux.fr/





CROCO — Coastal and Regional OCean Community model, a software for the numerical modelling of the oceanic circulation

› AirSea team

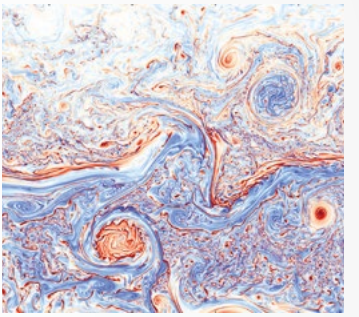
CROCO was born in 2017 and is supported by several French institutions: CNRS, IFREMER, Inria, IRD, SHOM and Université Toulouse. CROCO aims at simulating in three dimensions oceanic currents, sea level, and thermodynamic variables (temperature and salinity). An important objective for CROCO is to resolve very fine scales (especially in the coastal area), and their interactions with larger scales.

CROCO is also conceived as the oceanic component of a coupled system with many components: atmosphere, waves, sedimentary transport and morphodynamics, biogeochemistry and up to the End-to-End model concept established in the fisheries research community. The applications are thus numerous from marine pollution to fisheries management through extreme events (e.g., cyclones) and Defence.

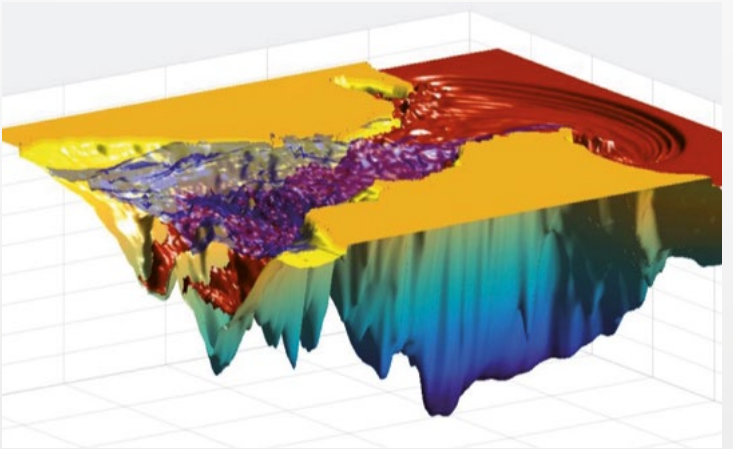
These capabilities are nowadays fundamental in assessing the local impact of climate change on the coastal and littoral oceans and in aiming at studying its socio-economic implications.

Another current exciting challenge of CROCO relies in accurate simulations of oceanic sound waves and their interactions with the ocean floor. Sound waves can be generated by a series of local phenomena like tsunamis. Their extremely fast propagation speed (much faster than surface waves) and their possible detection using hydrophones render them keys for early warning systems.

The AIRSEA team of the LJK laboratory is strongly involved in the development of CROCO including numerical methods, data assimilation algorithms and ocean atmosphere coupling related issues. The complex geometry of the coastlines is handled through multiresolution tools also maintained by AIRSEA team members.



Surface vorticity field in the Gulf Stream after separation from the western boundary. (Courtesy of J. Gula, IFREMER).



Solitons of the Strait of Gibraltar modelled by CROCO. Density surfaces reveal the propagation of a solitary wave in the Mediterranean Sea (Courtesy of L. Bordois, SHOM)

PART 4

COMPUTING PLATFORMS AND VALORIZATION

LaTeX-Workshop for Visual Studio Code

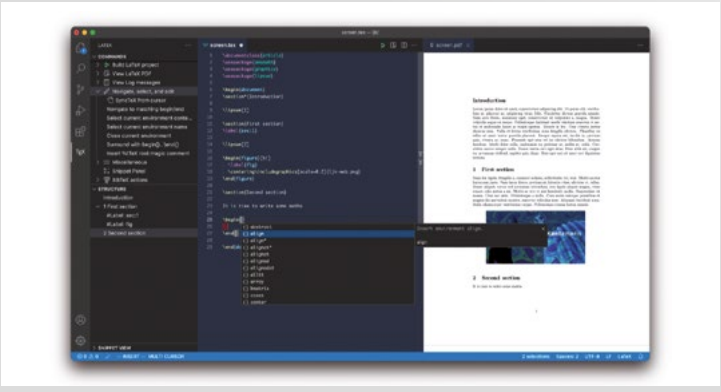
› DAO team

Visual Studio Code (VS Code) is a new generation open-source cross-platform editor developed by Microsoft. It is based on the Electron technology, which is also at the core of the Chrome web browser. VS Code relies on a powerful ecosystem of extensions to support a wide variety of programming languages and tools. For instance, we can cite C/C++, HTML/CSS, Julia, LaTeX, Markdown, Python, R, CMake, Git, GitHub and many more. These extensions are maintained by a large community of developers. Here, we will focus on the LaTeX-Workshop extension (https://github.com/James-Yu/LaTeX-Workshop/), which provides full support for LaTeX users and has 10 million downloads. LaTeX-Workshop is mainly developed and maintained by Takashi Tamura from Osaka University and Jérôme Lelong from the LJK DAO team.

LaTeX-Workshop literally turns VS Code into a full featured environment for LaTeX users and developers. It obviously provides syntax highlighting for LaTeX files but also for more elaborate documents such as Rsweave (LaTeX files with dynamic R code). It features automatic building of LaTeX projects along with a built-in PDF viewer with syncing capabilities between the LaTeX and PDF files. Some parts of the LaTeX files can also be previewed before building. Hovering over a reference opens a pop-up displaying the LaTeX code associated to the label along with a direct link to the corresponding location in the PDF file. Similar features exist to preview graphics, equations and citations.

Intellisense is often mentioned as the one strength of VS Code. Indeed, we implemented in LaTeX-Workshop smart completion mechanisms to provide autocompletion for citations, references, environments and commands, which are based on the true project content. Similarly, some snippets help users insert common environments or commands such as sectioning commands or greek letters. LaTeX-Workshop can also help refactoring a LaTeX file by surrounding a selection with an environment, switching environments, promoting or demoting a section, or simply giving an overview of the project structure.

LaTeX-Workshop provides a very versatile LaTeX environment inside VS Code and makes everyday LaTeX editing much simpler and efficient. Everything LaTeX-Workshop takes care of creates an opportunity for users to focus more on the content.



PART 5

AWARDS

2019

Florian Peppon (CVGI team)

SMAI-GAMNI PhD prize for his thesis headed « Shape and topology optimization of multiphysics systems » under the supervision of Grégoire Allaire (Ecole Polytechnique Paris) and Charles Dapogny.

Ludovic Métivier (EDP team)

CNRS Bronze medal

Pixyl's IA (STATIFY team)

Winner of the data challenge at Journées Francophone de Radiologie

LJK / Ingeliance Technologies COLL'HYBRID project (EDP team)

Forum Teratec Co-Design Trophy, awarded to a group associating a the scientific competence of a laboratory and the applicative skill of a company on a scientific computing/Big Data project.

The project deals with the design and industrialization of an open-source library for fluid mechanics.

2020

Alberto Bietti (DAO team)

UGA Academic Thesis prize for his thesis on deep convolutional models through kernel methods, under the supervision of Julien Mairal.

La Grange des Maths

Jacqueline Ferrand prize, which promotes an innovating pedagogical initiative in mathematics.

Florian Peppon (CVGI team)

(European) ECCOMAS prize, following his 2019 SMAI-GAMNI prize.

PART 6

CONFERENCES & WORKSHOPS

2019

SEISCOPE Annual Meeting

April 2—4, Grenoble

STATLEARN

April 4—5, Grenoble

https://data-institute.univ-grenoble-alpes.fr/statlearn-2019-777167.htm

Applied Inverse Problems Conference (AIP 2019)

July 8—12, Grenoble

https://www.aip2019-grenoble.fr

Graphyz

October 24—25, Grenoble

https://project.inria.fr/graphyz/

Journée Histoire du Calcul

November 28, Grenoble

https://histcalcul2019.sciencesconf.org/

2020

Résidence de recherche-création « Théâtre numérique populaire »

January 27—February 19, Grenoble

https://performance.univ-grenoble-alpes.fr//actualites/toutes-les-actualites/residence-de-recherche-creation-theatre-numerique-populaire--826978.kjsp?RH=2206601420595901

6th International Conference on Event-Based Control, Communication and Signal Processing (EBCCSP 2020)

September 23—25, virtual from Krakow, Poland

https://ebccsp2020.org/

MASCOT PhD student 2020 Meeting

September 17—18, Grenoble

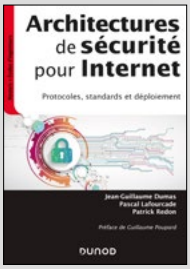
https://www.gdr-mascotnum.fr/mascotphd20.html

Workshop Psychométrie pour l'Évaluation en Langues

October 15, Grenoble

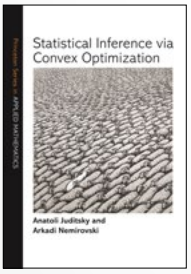
https://lidilem.univ-grenoble-alpes.fr/actualites/psychometrie-levaluation-en-langues-workshop

Books



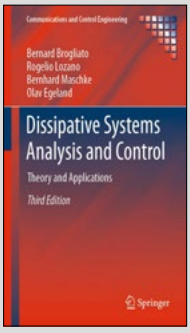
Architectures de sécurité pour Internet : protocoles, standards et déploiement.
Jean-Guillaume Dumas, Pascal Lafourcade, and Patrick Redon.

Dunod, 2020.



Statistical Inference via Convex Optimization
Anatoli Juditsky and Arkadi Nemirovski.

Princeton University Press, 2020.



Dissipative Systems Analysis and Control: Theory and Application
Bernard Brogliato, Rogelio Lozano, Bernard Maschke, and Olav Egeland.

Communication and Control Engineering series, Springer International Publishing, 2020.

Contribution to the creation of the epijournal:
Journal of Theoretical, Computational and Applied Mechanics (JTCAM)

https://jtcam.episciences.org

Some key figures for LJK

252 lab members

of which 64 professors and assistant professors

47 researchers

112 doctoral students and postdocs

29 technical and administrative staff members

and around 60 trainees each year

140 publications in peer-reviewed journals per year

3 books in 2019-2020

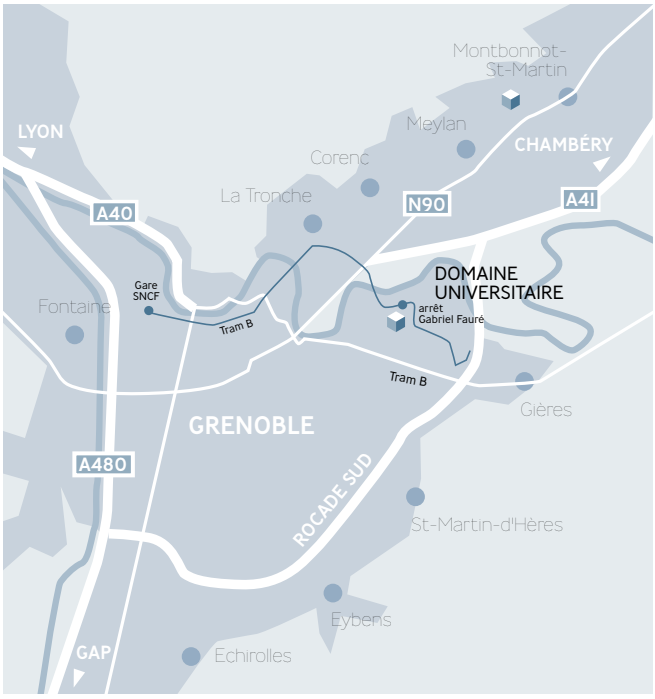
31 projects sponsored by the French ANR

7 European projects,

including 3 ERC individual grants

LABORATOIRE
JEAN KUNTZMANN
MATHÉMATIQUES APPLIQUÉES - INFORMATIQUE

ljk.imag.fr



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