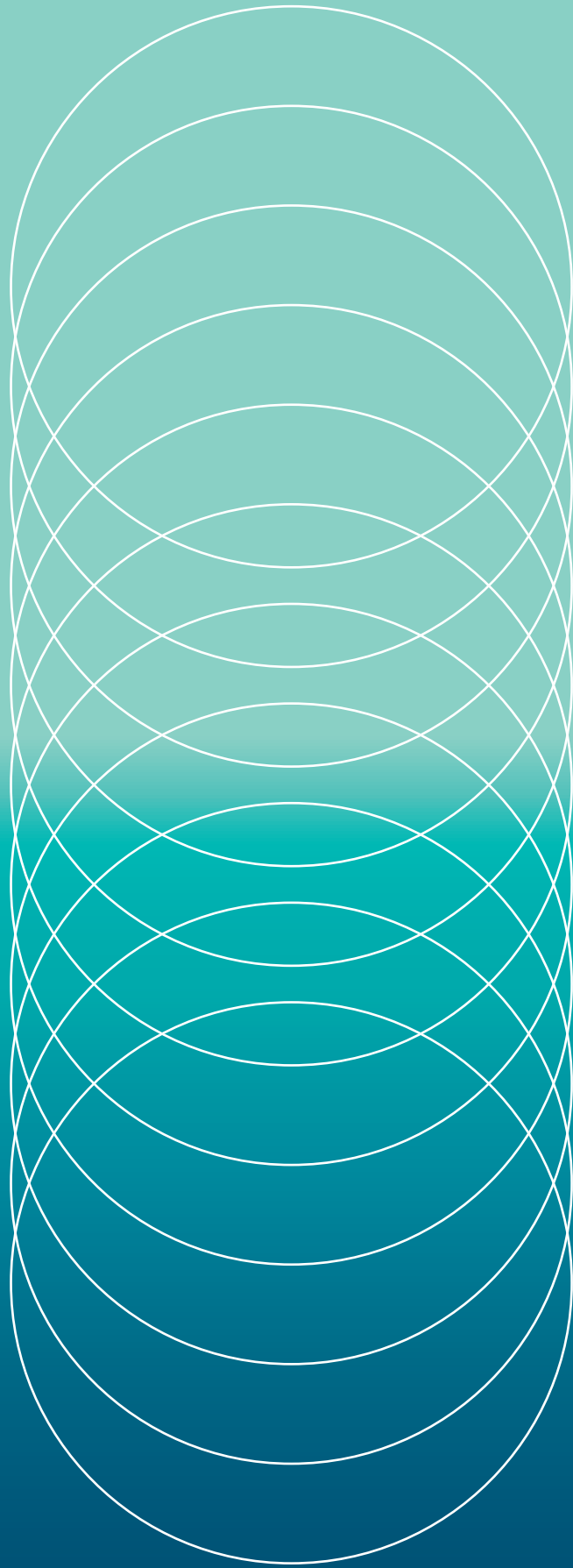




—  
2022  
Review

# A year of research at Télécom Paris



**2022**

**Review**

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# Editorial



**Nicolas Glady**, President of Télécom Paris

I am delighted to introduce the latest Télécom Paris research report, which showcases our accomplishments over the past year. As an engineering school under the trusteeship of the Ministry of the Economy, Finance, and Industrial and Digital Sovereignty, the relevance of our research avenues has been further reinforced by recent global crises such as the Covid-19 pandemic and geopolitical turbulence. In addition to our telecommunication and AI expertise, our research also addresses the strategic autonomy of organizations and their inevitable environmental transformation. Looking ahead, in order to ensure the continued success of our research activities, we are constantly focusing on attracting the best doctoral candidates to our teams and providing them with the necessary resources to develop their research.

This year, we proudly highlighted our tradition of scientific excellence and our ability to anticipate and address the major challenges of our time, ranging from embedded systems to the digital economy, networks, 5G, cloud computing, cybersecurity, algorithmics, AI, big data, and quantum computing. One strategic success for our entire ecosystem has been the French government's recent approval of our Step2 ExcellenceS project with our Institut Polytechnique de Paris partners. We continue to maintain a strong scientific presence in the field of artificial intelligence and have made significant strides in the areas of cybersecurity and privacy as attested by the establishment of our C<sup>3</sup> team, the recruitment of two professors, an assistant professor, and a junior professorship. Similarly, we are proud to be one of France's leading laboratories in the field of future digital infrastructures, as demonstrated by our significant participation in the PEPR Networks project. It is also worth emphasizing the quality of our research through the recognition of one of our faculty members who has been awarded the only advanced ERC in computer science in France. Our research activities also uphold the principles of social and environmental responsibility as evidenced by our scientific publications. Our mission statement, which aligns with initiative-driven organizations, is a powerful lever for transformation, and it guides our actions towards positive social impact.

Finally, Télécom Paris remains an open laboratory where academic excellence and a culture of innovation and entrepreneurship allow us to assert our expertise in the deep tech that is essential to current and future technological and economic development. Our ability to infuse the economy and industries, both in France and abroad, with the progress of our labs, produce patents, and develop spin-offs, remains a strong asset and overarching identity of our school.

Welcome to where vision meets expertise.



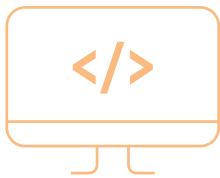
# Gather & Grow



# Key figures

## Disclaimer

This document concerns the research activity of Télécom Paris in 2022. In order to obtain the most representative figures possible, unless otherwise stated, the statistics shown in this report correspond to the activity of our research teams in 2022.



## Staff

As of December 31, 2022

**159**   
Permanent Researchers and Faculty Members

**226**   
PhD Students

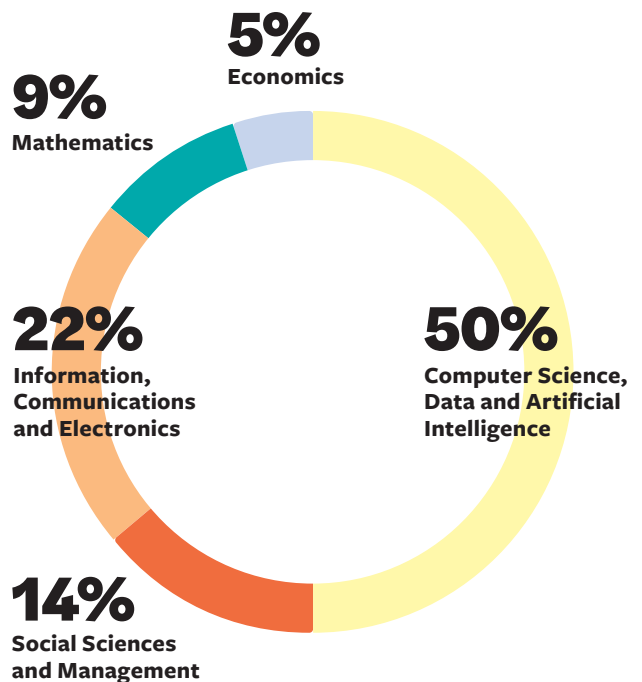
**105**   
R&D Engineers and Postdocs

**29**   
Administrative Staff

**519**  
Total Research Staff

**18**  
Research Teams

## Breakdown by Institut Polytechnique de Paris Education and Research Departments

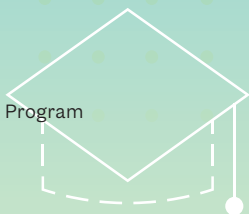




## ERC Grants

Since the beginning of the ERC Program

► [telecom-paris.fr/erc](https://telecom-paris.fr/erc)



### Gaël Richard

ERC Advanced Grant 2021

### Mansoor Yousefi

ERC Starting Grant 2018

### Michèle Wigger

ERC Starting Grant 2016

### Yanlei Diao

ERC Consolidator Grant 2016

### Alexandre Gramfort

ERC Starting Grant 2015

## Transfer and innovation

5-year consolidated figures

Spinoff creation

1

Maturing projects

21

Registered patents

84

Registered software

13

Registered know-how

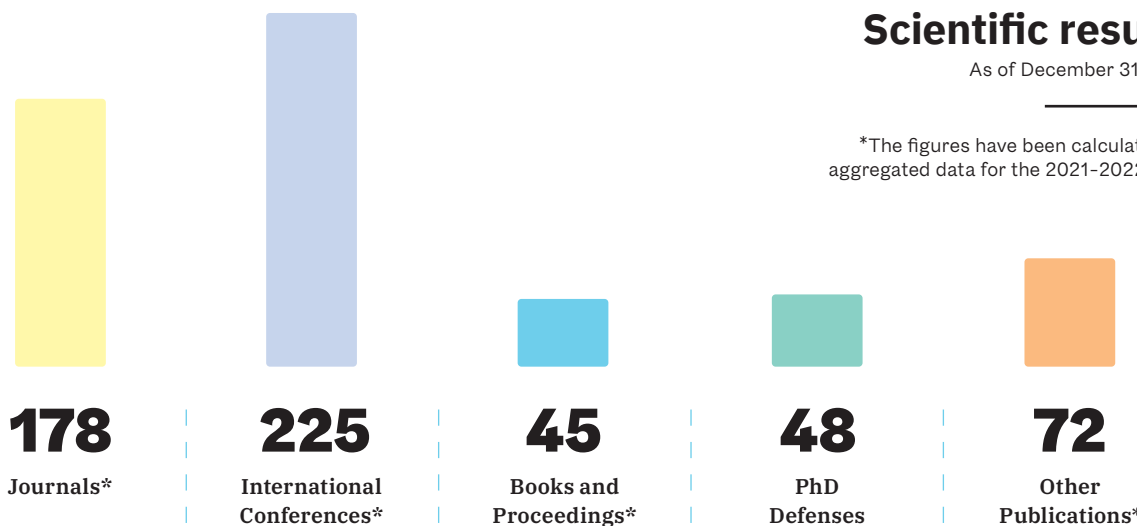
1



## Scientific results

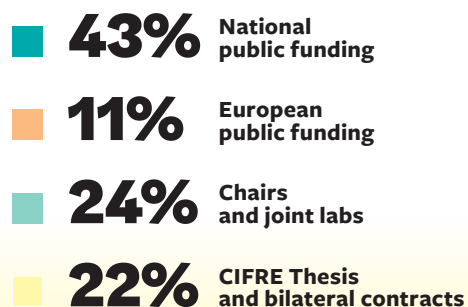
As of December 31, 2022

\*The figures have been calculated with aggregated data for the 2021-2022 period



## Research Funding

As of December 31, 2022



# Highlights

February 2022 **16**

## Télécom Paris became an associate member of the Open Infrastructure Foundation

The Open Infrastructure Foundation, created in 2012 to manage the governance of the Openstack project, supports the development of open source projects and communities in the fields of free software infrastructure, mainly on cloud technologies.

Télécom Paris uses and teaches these technologies, and therefore joins the foundation as an associate member, alongside CERN or Inria, for example.

*“Open Infrastructure is one of the building blocks of our future in a digital world”, said Nicolas Glady, Dean and President of Télécom Paris. “At Télécom Paris, we rely on this infrastructure everyday and build on it our research and teaching. By becoming an associate member, we will strengthen our bond with the community. More generally, we share the values of open source development and have made a specific objective of enabling open source as a critical public infrastructure component ensuring both technological strategic autonomy and open science.”*



**Jean-Claude Dufourd** and **Jean Le Feuvre (MM)** were rewarded by the Emmy® Awards Academy for their work on the MP4 and MPEG-DASH formats. This award is twofold: in 2021, at the 72<sup>nd</sup> Annual Technology & Engineering Emmy® Awards Ceremony, in the Standardization of the ISO Base Media File Format category; in 2022, at the 73<sup>rd</sup> Ceremony, for MPEG-DASH.

This is the recognition of long-standing editions and contributions, from the very beginning of these two formats (1998 and 2010).

February 2022 **21**

## Télécom Paris set up its mission statement committee

In 2019, Télécom Paris became the first French engineering school to adopt a mission statement: *“To shape, envision, and design models, technologies, and digital solutions that serve a society and economy mindful of people and the environment.”* The following years were an opportunity to implement ambitious projects in line with this statement: more than 80 hours of teaching on the social and ecological transition have now been incorporated into the training of 1<sup>st</sup> and 2<sup>nd</sup> year students; an overall transformative strategy to meet the challenges of digital transition and innovation is shaping the entire school.

In 2022, Télécom Paris takes a new step in its transformation by setting up a committee within its School Council to monitor the implementation of this core mission. Three qualified individuals from outside the School Council joined the committee: Ms. Clara Chappaz, Director of the French Tech mission, Ms. Agnès van Zanten, Director of Research at the CNRS, Mr. Jean-Marc Jancovici, President of the Shift Project.

The French Government is supporting seven new projects to build a sovereign offer for industrial 5G, for a total investment of €47 million, including €19 million of public funding under the France 2030 program.

One of these projects, Kapteos’ TopTen, developed in partnership with CEA-Leti and Télécom Paris aims to develop a breakthrough solution for antenna testing via an open platform covering all the needs of industry, from research to production, without requiring anechoic chambers, multiple sensors, or constant recalibration.

► See also page 56.

April 2022



**Gaël Richard (S2A)** was awarded an advanced ERC grant of the European Union for his project, HI-Audio. This initiative aims to develop hybrid approaches that combine signal processing with deep machine learning for the purpose of understanding and analyzing sound, it is the only advanced ERC grant in computer science in France.

Scientific Co-Director of Hi! PARIS—the Interdisciplinary Center on Data Analytics and Artificial Intelligence for Science, Business and Society created by Institut Polytechnique de Paris and HEC Paris, Gaël Richard is the Vice-chair of the IEEE Audio and Acoustic Signal Processing Technical Committee.

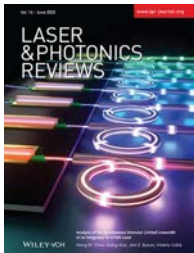


## June 2022

Télécom Paris (C2M chair) was involved in two research projects funded under the call “Exposure to electromagnetic fields (EMF) and health” (HORIZON-HLTH-2021-ENVHLTH-02-01): SEAWave and GOLIAT. These projects started in June 2022 and will last 3 and 4 years respectively.

## June 2022

The works of **Frédéric Grillot (GTO)** were featured in the June 2022 issue of the scientific journal *Laser & Photonics Reviews*.



The photograph chosen for the cover shows integrated micro-resonators that carry data in an integrated photonic circuit and relates to

article [1] in the journal. Frédéric Grillot, in collaboration with an international team of researchers, describes a laser theory, beyond the customary quasi-mode approximation for treating resonator out-coupling, for understanding the physics underlying spectral narrowing to Hz-level, spontaneous-emission limited lasing linewidth. This theory will serve as an analytical tool for parametric studies to produce timely results in engineering design.

► [1] W. W. Chow, Y. Wan, J. E. Bowers, and **F. Grillot**, “Analysis of the Spontaneous Emission Limited Linewidth of an Integrated III–V/SiN Laser,” *Laser & Photonics Reviews*, vol. 16, no. 6, p. 2100620, 2022.

## Progress in university rankings

From 2022 onwards, Télécom Paris has been recognized by several World University Rankings as a school and founding member of Institut Polytechnique de Paris (IP Paris), and individual international rankings are no longer available as such. This improves overall ranking and confirms the relevance of the 5 prestigious French engineering schools—École Polytechnique, ENSTA Paris, ENSAE Paris, Télécom Paris, Télécom SudParis—to join forces within IP Paris.

For its first participation, IP Paris made a strong entry, up to the 43rd place in the Times Higher Education (THE) 2022 world’s most international universities ranking. It is the first and only French institution in the Top 50. In terms of international co-authorships, IP Paris is among the Top 40 of the THE 2022 most international universities. IP Paris also ranks 6<sup>th</sup> in the 2022 Times Higher Education Young University Rankings that list the world’s best institutions which are 50 years old or younger.

For its second ranking of QS World University Rankings 2023, IP Paris has progressed to the 48<sup>th</sup> position. It is also ranked 12<sup>th</sup> worldwide—1<sup>st</sup> in France — for the specific Graduate Employability Ranking, and 14<sup>th</sup> for the QS World University Rankings by Subject—1<sup>st</sup> in France.

On a national basis, Télécom Paris was ranked 1<sup>st</sup> Engineering school in digital, computer science and mathematics, and 2<sup>nd</sup> among the “Grandes écoles d’excellence”. It is also the 2<sup>nd</sup> engineering school with the best employer recognition according to tutors and recruiters.

These rankings reflect the school’s excellence, confirming our position as France’s leading engineering school for digital technology. They also reflect the validity of the Télécom Paris model, which trains engineers and PhDs in the theoretical, technological and sociological aspects of digital technology using a unique interdisciplinary approach.

June 28  
2022

## June 2022

**Valérie Fernandez (NOS)** was appointed to the multidisciplinary scientific committee of Arcom, the French regulatory authority for audiovisual and digital communication.

A specialist in digital economy issues, Valérie Fernandez is scientific coordinator and member of the Executive Committee of the CNRS Interdisciplinary Innovation Institute research (i3) unit, co-holder of the Responsibility for Digital Identity Chair, and head of the Sciences Po Master 2 Digital Innovation program in partnership with Télécom Paris.

The work of **Olivier Spitz (GTO)**, a post-doctoral fellow from 2020 to 2021, was selected as one of the top contributions of the 2020-2021 period in the selective journal *Advanced Photonics*.



Published in October 2020, Olivier Spitz’s paper, written under the supervision of **Frédéric Grillot**, and in collaboration with other international researchers, describes the exhibition of extreme pulses in quantum cascade lasers [1].

► [1] **O. Spitz**, J. Wu, A. Herdt, G. Maisons, M. Carras, W. E. Elsässer, et al., “Extreme events in quantum cascade lasers,” *Advanced Photonics*, vol. 2, no. 6, p. 066001, 2020.

July  
2022

01

The graduation ceremony for doctoral students of the Institut Polytechnique de Paris rewarded three PhD students from Télécom Paris with a first prize: **Kamélia Daudel (S2A)**, **Bozhang Dong (GTO)** and **Kimia Najjahi (S2A)**.

July  
2022

19

A paper written by Subhankar Banerjee under the supervision of **Marceau Coupechoux (RMS)**, received an Excellent Paper Award at the ICUFN 2022. Subhankar Banerjee was a student in the Advanced Communication Network (ACN) Master's program previously offered by Télécom Paris, and is now at the University of Maryland. The results are the outcome of a collaboration with Nokia Bell Labs and the Indian Institute of Technology in Madras.

► S. Banerjee, C. Shue Chen, **M. Coupechoux**, and A. Sinha, "Joint Power and Subcarrier Allocation in Multi-Cell Multi-Carrier NOMA," in *2022 Thirteenth International Conference on Ubiquitous and Future Networks (ICUFN)*, 2022, pp. 180–185.

July  
2022

22

**Frédéric Grillot (GTO)** and **Michèle Wigger (ComNum)** were honored as "Distinguished Lecturers" respectively by the IEEE Photonics Society and the IEEE Information Theory Society for their high-quality scientific contributions.

Within the optics-photonics community, this prestigious distinction has been awarded since 1984 to nearly 130 researchers, and Frédéric Grillot is the fourth French researcher to receive it.

The ITSoc community distinguished Michèle Wigger for her research in multi-terminal information theory, in particular in distributed source coding and hypothesis testing, and the capacities of communication networks.

## July 2022

**Leonardo Linguaglossa (RMS)** was awarded a four-year JCJC (Young Researcher) 230k€ grant by the French National Research Agency (ANR), for his project IONOS-DX on "Inference of networks characteristics via non-invasive data exploration". Starting in February 2023, the project brings together Nokia Bell Labs, Politecnico di Bari, University College London, University of Wuezburg, Norwegian Institute of Science and Technology, and Universiteit van Amsterdam with Télécom Paris.

July  
2022

29

**Fabian Suchanek (DIG)** was awarded one of the 2022 Open Science Research Data Awards in the "jury's special prize" category, for his software YAGO, supported by the French Ministry of Higher Education, Research and Innovation, Ministère de l'Enseignement supérieur et de la Recherche.

► See also page 66.

 **Ouvrir  
la science !**



## July 2022

The **IMAGES** team was rewarded twice during the keynote conferences.

**Emanuele Dalsasso** was awarded Best Student Paper (2<sup>nd</sup> place) at EUSAR 2022, the 14<sup>th</sup> European Conference on Synthetic Aperture Radar and the world leading international conference dedicated to SAR techniques, technology and applications. 300+ papers were presented at this conference.

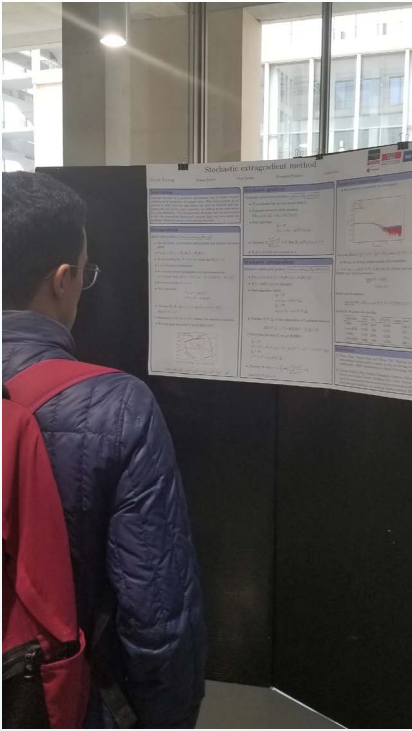
**Emanuele Dalsasso**, Inès Meraoumia, Loïc Denis and **Florence Tupin** received the 2021 IEEE GRSS Symposium Prize Paper Award during IGARSS 2022 (International Geoscience and Remote Sensing Symposium), the flagship conference of the IEEE Geoscience and Remote Sensing Society. Their paper was selected among the 2,000+ papers presented at the conference.

► See also page 51.



# Highlights





## October 2022

**Stefano Zacchiroli (ACES)** and **Davide Rossi (University of Bologna)** were selected to receive the Google Award for Inclusion Research Program for their proposal “What Causes the Lack of Diversity in Open Source?”.

Launched in 2020 by Google, the Award for Inclusion Research Program recognizes and supports academic research in computing and technology that addresses the needs of historically marginalized groups globally. It represents an ongoing effort to support innovative research and professors working to create positive societal impact.

► See also page 66.

► <https://research.google/outreach/air-program/>

October 2022 **14**

### Annual research day

The annual day is an opportunity for teams to exchange views, through keynotes, demonstrations and a poster session. Works leading to spin-offs or industrial partnership were presented: **Ghaya Rekaya-Ben Othman (ComNum)** gave a talk on “Space-Division Multiplexing on the fiber: from idea to innovation” and **Petr Kuznetsov (ACES, TrustShare Chair)**, **Fabian Suchanek (DIG, NoRDF Chair)** and **Pavlo Mozharovskiy (S2A, DSAIDIS Chair)** gave insight into research conducted in their respective Chair. Artificial Intelligence was a central topic for several projects, as in “MinConvNets: A New Class of Multiplier-less Neural Networks for Edge AI” by **Sumanta Chaudhuri (SSH)** and “Deep learning for face image editing” by **Alasdair Newson (IMAGES)**.

In addition to these specific research projects, **Henri Maître (IMAGES)** presented the scientific integrity rules in place at the Institut Mines-Télécom, **Raphaël Granier de Cassagnac** gave insight into a future IP Paris Interdisciplinary Center on Art and Sciences, and **David Filliat** presented the third call for projects of the Interdisciplinary Centre for Defence and Security (CIEDS) at IP Paris.

December 2022 **08**

### Annual innovation day

This day, dedicated to entrepreneurship in all its forms, offered a succession of keynotes, round tables, testimonials from former students who created their company thanks to the school, and pitch competitions for business projects created by students and entrepreneurs, watched by the day’s sponsors: Michel Paulin (Télécom Paris 1986 graduate), CEO of OVH, and François Paulus (Télécom Paris 1989 graduate), founder of Breega.



## November 2022

### Free-space optical transmission record

**Pierre Didier**, PhD student under the supervision of **Frédéric Grillot (GTO)**, demonstrated a 31-m long high bit-rate data transmission in the 8µm to 14µm thermal atmospheric window at a gross rate of 30Gbit/s, using a full set of inter-subband quantum devices. This work is a key step toward the realization of a real-field mid-infrared FSO system.

The results were published in *Advanced Photonics*, and selected by *Optics & Photonics News* which lists in its December issue the 20-30 best results of the year 2022 in optics.

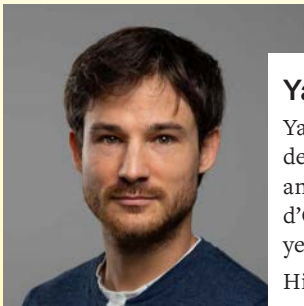
► **P. Didier**, H. Dely, T. Bonazzi, **O. Spitz**, **E. Awwad**, E. Rodriguez, A. Vasanelli, C. Sirtori, and **F. Grillot**, “High-capacity free-space optical link in the midinfrared thermal atmospheric windows using unipolar quantum devices,” *Advanced Photonics*, vol. 4, no. 5, p.056004, 2022.

December 2022 **13**

This year, 40 second year students participated in the “Doctoral School of IP Paris Best Poster Award” during which they presented their thesis subject in six categories. Nine students won the contest, three of them being Télécom Paris PhD students: **Simon Delarue** (“Enriched graph models and algorithms for transparent machine learning”—Computing, Data and AI), **Mélanie Gornet** (“Ethics and regulation of machine learning systems: building operational requirements for image recognition algorithms”—Economy, Management & Social Sciences), and **Arnaud Varillon** (“Deep Learning for Embedded Cybersecurity”—Information, Communication, Electronics).

# New joiners

## in 2022



📍 ▶ Joined the **S2A** team on September 1, 2022.

### **Yann Issartel Associate professor**

Yann Issartel graduated in 2016 with an engineering degree from École Polytechnique and a master's degree in Mathematics from the Université Paris-Cité. He completed his PhD in Mathematical Statistics and Learning, "Inference on random networks", at Paris-Saclay University, Institut de Mathématiques d'Orsay, under the supervision of Christophe Giraud and Nicolas Verzelen, in 2020. He then spent two years at CREST-ENSAE as a post-doctoral researcher on data privacy, working with Cristina Butucea.

His research topics are mainly in the fields of statistics and mathematical learning, especially random networks, latent position models, link prediction, sequential learning, bandits, data privacy and generative adversarial network. He has published for prestigious conferences (NeurIPS) and scientific reviews (Journal of Machine Learning Research).

📍 ▶ Joined the **S2A** team on September 1, 2022.

### **Charlotte Laclau Associate professor**

Charlotte Laclau completed her PhD, "Hard and fuzzy block clustering algorithms for high dimensional data", in Computer Science, with a specialization in Data Science, at Paris Sorbonne Cité University, in the Machine Learning for Data Science team in 2016. She was a visiting PhD student at the Universidade Federal de Pernambuco (Brazil) in 2014 and at the University of Ottawa (Canada) in 2015. She then held a post-doctoral position until 2018 at the Grenoble computer science laboratory, AMA team, working on ranking models for recommendation systems.

Charlotte Laclau was Associate professor at Télécom Saint-Étienne/Hubert Curien Laboratory in the Data Intelligence team until 2022, where she has been an active member for the creation of the International Emerging Actions (IAE) between the Data Intelligence Team and the Alberta Machine Intelligence Institute (AMII).

Her main line of research is in machine learning. Her research focus includes representation learning for complex data, game theory and deep learning, fairness in machine learning for relational data and unsupervised learning for high-dimensional data. She has published 11 articles in international peer-reviewed conferences and 5 articles in peer-reviewed journals. She was vice-president of the French Association on Machine Learning (SSFAM) until 2021, and Co-head of the ATLAS research group, GdR MADICS, on Machine Learning applied to healthcare problems.





🕒 ▶ Joined the **IMAGES** team on September 1, 2022.

**Loïc Le Folgoc Associate professor**

In 2015, Loïc Le Folgoc obtained his PhD, “Statistical learning for image-based personalization of cardiac models”, at INRIA. In the Asclepios team of Nicholas Ayache and Hervé Delingette, he explored robust and efficient Bayesian approaches to model the deformation of organs, as observed in temporal sequences of 3D medical images, such as the motion of the heart throughout the cardiac cycle. He was then a postdoctoral fellow at Microsoft Research Cambridge with Antonio Criminisi and Aditya Nori; and a Research Associate at Imperial College London in the BioMedIA group of Daniel Rueckert and Ben Glocker until 2022.

His research focuses on biomedical data analysis at the intersection of Artificial Intelligence and image processing. His current research interests include probabilistic deep learning, uncertainty quantification, generalizability and robustness of AI methods, and inference from biased, imperfect and limited data. He is working on tools for quantitative medical image analysis, to help experts take more accurate, better informed and faster decisions.



🕒 ▶ Joined the **MM** team on October 1, 2022.

**Jhony Giraldo Associate professor**

Jhony Giraldo received a Bachelor in Electronics Engineering and a Master of Science degree with honors from the Universidad de Antioquia, Colombia, in 2016 and 2018, respectively. He spent 15 months at the University of Delaware, USA, working on Graph Signal Processing between 2018 and 2019. Jhony was a visiting scholar at the Università degli Studi di Napoli Parthenope, Italy, working at the CVPR Lab “Alfredo Petrosino” in 2021. He was also a visiting PhD student at Centre de Vision Numérique (CVN), Inria OPIS, CentraleSupélec, Université Paris-Saclay, France, in 2022.

He defended his PhD in Applied Mathematics, “Graph-based Algorithms in Computer Vision, Machine Learning, and Signal Processing”, at La Rochelle Université, France, in 2022. His research interests include the fundamentals and applications of Graph Neural Networks, Computer Vision, Machine Learning, and Graph Signal Processing. He has worked on image and video processing, supervised and semi-supervised learning, and sampling and reconstruction of graph signals.

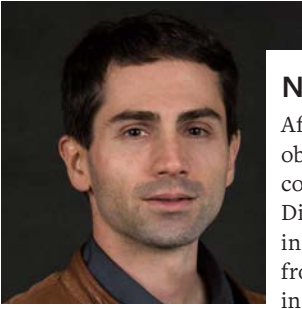
🕒 ▶ Joined the **INTERACT** team on December 1, 2022.

**Panos Mavros Associate professor**

Panos (Panagiotis) Mavros received his training as a graduate architect engineer from the School of Architecture of the National Technical University of Athens (NTUA, Greece), and obtained a Master of Research in Digital Media and Culture by the University of Edinburgh. In 2019, he completed his PhD, “Measuring the emotional experience of pedestrian navigation: the development of a research approach for mobile psychophysiological experiments”, in Advanced Spatial Analysis from University College London (UCL). Between 2016 and 2022, he worked as a research coordinator and postdoctoral researcher at Future Cities Laboratory (FCL), Singapore, in the “Cognition Perception and Behaviour in Urban Environments” group and the “Architectural Cognition in Practice” group. At FCL, he has developed several projects on the experience and spatial cognition of high density cities, as well as on the use of digital tools such as virtual reality in the design process of architectural projects.

His research focuses on the integration of digital tools in the study of user experience, behavior and cognition, the interaction between humans and digital and spatial information, and the translation of spatial cognition research into design and policy.





🕒 ▶ Joined the **GTO** team on December 1, 2022.

### Nicolas Fabre Associate professor

After the obtention of the *agrégation de physique* at ENS Paris-Saclay and a Master 2 in quantum physics obtained in 2017 at ENS Paris, Nicolas Fabre defended his PhD, “Quantum information in time-frequency continuous variables”, at the joint research unit Quantum Materials and Phenomena of Université Paris Diderot (now Université Paris Cité) and CNRS under the supervision of Pérola Milman and Arne Keller in 2020. This theoretical thesis was written in collaboration with the experimentalists led by Sara Ducci from Quantum Information and Technologies group (QITE). He then became a post-doctoral researcher in quantum optics at the Centre of New Technologies in Warsaw in 2021 in Konrad Banaszek’s group, and at the Universidad Complutense de Madrid in 2022 in the group of Luis Sanchez Soto.

Nicolas Fabre’s research interests span time-frequency quantum information processing, with a particular emphasis on quantum metrology, quantum pulse light sculpting, and spectral tomography. He is also interested in a group theoretical approach to quantum optics.

🕒 ▶ Joined the **DIG** team on December 1, 2022.



### Mehwish Alam Associate professor

Mehwish Alam obtained a PhD, “Interactive Knowledge Discovery over the Web of Data”, at LORIA, Inria, in 2015. Before that, she was a candidate for the prestigious Erasmus Mundus Masters in Language Communication & Technology where she completed the first year of her Masters at the University of Groningen, the Netherlands, and the second year of Masters at the University of Lorraine, Nancy, France.

Mehwish Alam’s research areas are at the intersection of Machine Learning, Knowledge Graphs, Graph Mining, and Natural Language Processing. She held several post-doctoral positions since 2016, first at the LIPN, University of Paris 13, Paris, then at the National Research Center (CNR) in Rome, Italy, in Prof. Dr. Aldo Gangemi’s group, where she also collaborated with the University of Bologna, Italy, until 2019. During her last post-doctoral stay at Karlsruhe Institute of Technology and FIZ-Karlsruhe, Leibniz Institute for Information Infrastructure, Germany, she was leading a sub-team on Machine Learning, and Knowledge Graphs with three PhD students specifically on the topic of Knowledge Graph Completion using Embeddings along with Multilinguality.

She serves at the editorial board of the Semantic Web Journal as well as the Journal on Neurosymbolic Artificial Intelligence. She has been part of the organizing committee of several conferences such as European Semantic Web Conference, Semantics. She has recently co-organized a workshop on deep learning and knowledge graph at ISWC 2022.



🕒 ▶ Joined the **ACES** team on December 1, 2022.

### Théo Zimmermann Associate professor

Théo Zimmermann graduated from École Normale Supérieure in 2016 and defended his PhD, “Challenges in the collaborative evolution of a proof language and its ecosystem”, at Université de Paris (now Université Paris Cité) in 2019, where he presented the application of software engineering methods and knowledge to the development, maintenance, and evolution of Coq—an interactive proof assistant based on type theory—and its package ecosystem. He then became a post-doctoral researcher at Inria, working on the development of Coq and its associated research topics on software engineering, open collaboration, community and ecosystem issues.

Théo Zimmermann’s expertise spans empirical software engineering, software maintenance and evolution, open source and open collaboration, software ecosystems, and community management. His research focuses on understanding and enhancing how open source maintainers and contributors collaborate to maintain and evolve software projects and ecosystems. He is particularly interested in securing software supply chains, by detecting and resolving maintenance issues in open source packages used in these supply chains.

He is a member of the core development team of Coq, the lead maintainer of Coq’s documentation, the author of the bot assisting the development team in everyday’s tasks, and the founder of the Coq-community initiative for long-term package maintenance in the Coq ecosystem.





# Young talents



Web <https://perso.telecom-paristech.fr/eawwad/>

## Élie Awwad – GTO

Élie Awwad's research interests include signaling schemes and digital signal processing related to optical fiber communication systems and optical fiber sensors. He worked particularly on modulation design and DSP for MIMO communication schemes. He currently studies novel interrogation techniques of optical fiber sensors (mainly for distributed acoustic sensing (DAS) applications) and is co-supervising five PhD thesis projects dealing with mitigation of non-linear effects in fiber optic communications and monitoring optical fiber networks. Some of these projects take advantage of machine learning algorithms to complement system design and real-time monitoring, particularly with the aim of minimizing energy consumption and detecting faults in the optical network (for instance as part of the Celtic-Next AI-NET project).

His research results have been published in various leading journals and conferences (Journal of Lightwave Technology, Photonic Technology Letters, Optics Letters and Optics Express), and have produced nine patents. Élie Awwad is also a regular reviewer for several scientific journals and serves as a TPC member of the IEEE/Optica European Conference on Optical Communications since 2022 (Basel, Switzerland in September 2022 and Glasgow, Scotland in September 2023).

In 2022, he organized two events for students, in collaboration with colleagues and PhD students from Université Paris-Saclay and IP Paris, funded by the Labex Digicosme. The spring school on emerging and future communication networks in April 2022 and the junior conference on wireless and optical communications in October 2022 gathered more than 50 participants each.

### CV

- ▶ M.Eng. degree from the Lebanese University and Télécom Paris, 2011
- ▶ PhD in communications and electronics from Télécom Paris, 2015
- ▶ Research Scientist at Nokia Bell Labs from 2015 to 2019
- ▶ Associate professor at Télécom Paris (**GTO team**) since October 2019

Web <https://perso.telecom-paristech.fr/linguaglossa/>

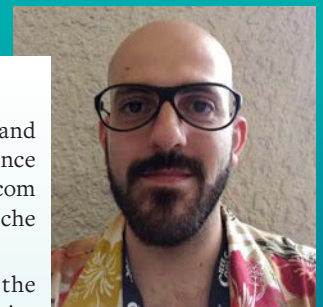
## Leonardo Linguaglossa – RMS

Leonardo Linguaglossa's current research topics span AI-enhanced high-speed networks, design and evaluation of novel architectures for data processing in edge/cloud systems and energy performance tradeoffs in high-speed cloud networks. Previously he was part of the NewNet Cisco's Chair at Télécom Paris, worked at CNIT (Italy), University of Catania (Italy), and was guest scientist at Technische Universität München (TUM, Germany).

Leonardo Linguaglossa was awarded a four-year JCJC (Young Researcher) 230k€ grant by the French National Research Agency (ANR), on the subject of "Inference of networks characteristics via non-invasive data exploration" in 2022. In this project (acronym IONOS-DX), he explores the "data uncertainty principle" in the context of data acquisition and analysis in Network Functions Virtualization (NFV) networks. In such high-performance critical environments, each measurement will inevitably alter the state of the measured system (hence the name), which makes it impossible to detect an accurate depiction of the real state of the system with current technologies. Leonardo develops a novel approach based on non-invasive data collection and the integration of compact machine learning techniques in standard commercial off-the-shelf equipment, with the objective to provide a new methodology to infer the system's behavior with a limited impact. Through the exploration of previously hidden data, this approach will provide a more accurate description of the system analyzed.

### CV

- ▶ MSc degree in Telecommunication Engineering, University of Catania, Italy in 2012
- ▶ PhD in Computer Networks, Université Paris Diderot, INRIA, Nokia Bell Labs, France, 2016
- ▶ Post-doctoral researcher at Télécom Paris, co-leading the project AI4P (Artificial Intelligence for Performance), 2018-2019
- ▶ Associate professor at Télécom Paris (**RMS team**) since April 2020





## Pavlo Mozharovskyi – S2A

Pavlo Mozharovskyi's main research interests lie in the areas of machine learning, computational statistics, robust statistics, with a focus on data depth, anomaly/novelty detection, missing values, multivariate/functional data analysis, data envelopment analysis and explainable AI.

He is co-responsible for second research theme—Exploiting Large Scale, Heterogeneous, Partially Labeled Data—of the DSAIDIS Chair. In this context, in 2022, he facilitated a two-part tutorial on multivariate and functional anomaly detection. He is also part of the academic team of the French National Agency of Research (ANR) PRCE 2020 collaborative research project with IDEMIA, “Leveraging Interpretable Machines for Performance Improvement and Decision”, (LIMPID, see page 63). He is a reviewer of several journals in machine learning and statistics.

In 2021, Pavlo Mozharovskyi was awarded a JCJC (Young Researcher) 3-year grant by the ANR, for a project on “Large-scale data depth: computation and applications”, starting in April 2022. Data depth measures the centrality of an observation with respect to data. Being non-parametric, robust, and possessing attractive invariance properties, it substitutes density and quantiles in numerous applications. However, its large-scale applications are impeded by its computational infeasibility. This project addresses this question in a systematic way. The main objective is for a link between statistical and computational properties of depth to be established. Further, gradient-based optimization technique for smoothed data depth shall be developed with corresponding statistical guarantees. A Python library shall implement the obtained results. This will be used in applications: statistical analysis of the diffusion-tensor brain images and multivariate spectra of construction materials.

He defended his habilitation thesis, “Data depth: computation, applications, and beyond”, in July 2022.

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### CV

- ▶ PhD, University of Cologne, 2014
- ▶ Post-doctoral researcher at the University of Cologne, 2014-2015
- ▶ Post-doctoral researcher at Lebesgue Center of Mathematics Agrocampus Ouest, Rennes, 2015-2016
- ▶ Accredited to supervise research (HDR) from Institut Polytechnique de Paris, 2022
- ▶ Associate professor at Télécom Paris (**S2A team**) since September 2018

## Samuel Huron – INTERACT

Samuel Huron is an information designer and associate professor in Design of information technologies. He is part of the Codesign Lab at Télécom Paris, and in charge of developing the Studio Design, a multipurpose workplace that is both design oriented and entrepreneurship focused. Before doing research, he was engaged in new media art where he collaborated with video art label on art installation, video mixing and live performances. He presented and performed some of these works in various places including art museums, parties, and festivals. For his work on Constructive Visualization, he received the 2015 best doctoral dissertation award from IEEE VGTC Pioneer Group.

His research mostly focuses on the design process of visual representation of data and design methods that apply to research and computer human interaction. This spans how humans create visual and physical representations of abstract information to think, collaborate, learn, analyze, explore, and design new data representations, systems and information artefacts. His approach is grounded in fifteen years of experience in industry with interactive media industries where he worked for a broad range of civic, cultural and corporate clients.

Samuel Huron is currently working on the design of two of the eight protolabs—DesignLab and VirtualLab—within “La Factory”, a new project for the Interdisciplinary Center of the Institut Polytechnique de Paris on arts, sciences and citizens. The DesignLab will be dedicated to sketching techniques, combining several dimensions—drawing on paper, digital sketching and prototyping—whereas the VirtualLab will contribute to the democratization of AR/VR applications for the general public, industry, museums and the arts, and study the representation, creation, transmission and rendering of interactive and animated 3D graphic content, human-machine or human-robot interaction.

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### CV

- ▶ Master in New Media Art in Paris 1 Panthéon-Sorbonne, 2009
- ▶ PhD from the University Paris Saclay in collaboration with Inria, 2014
- ▶ Post-doctoral researcher at the University of Calgary in the Innovis group, 2015
- ▶ Associate professor at Télécom Paris (**INTERACT**) since November 2015



## Ada Diaconescu – ACES

Ada Diaconescu works mainly on complex autonomic systems. Her interests include self-adaptive (autonomic), self-organizing (organic) and self-aware computing systems; complex systems engineering; multi-level control systems; multi-scale feedback systems; multi-agent systems; middleware and distributed, component- and service-oriented applications; artificial life; self-integration of socio-cyber-physical systems; and the impact of technology on socio-technical systems. Her targeted domain applications are smart grids, smart cities, smart homes, data-mediation frameworks and autonomous vehicle networks.

Before joining Télécom Paris, she worked at Inria, Orange Labs and Université de Grenoble. She also took a sabbatical leave in 2016 and 2017 at Leibniz University, in the Systems Research and Architecture group with Prof. Dr. Ing. Christian Müller-Schloer.

She co-authored several books on Autonomic Computing, Organic Computing Systems and Self-Aware Computing Systems and has published more than 100 articles in various leading journals and conferences (ACSOS, ICAC, SASO, TAAS, ALife).

Ada Diaconescu was re-elected in 2022, for a three-year mandate, as co-chair of the steering committee of the IEEE International Conference on Autonomic Computing and Self-Organizing Systems (ACSOS), a merger of the IEEE International Conference on Autonomic Computing (ICAC) and the IEEE International Conference on Self-Adaptive and Self-Organizing Systems (SASO). The goal of ACSOS is to provide a forum for sharing the latest research results, ideas and experiences in autonomic computing, self-adaptation, and self-organization. She has also served on the editorial board of ACM Transactions on Autonomous and Adaptive Systems, from 2018 to 2022.

She is the Head of the ACES (Autonomous Critical Embedded Systems) team since August, 2022.



### CV

- ▶ MSc in Computer and Software Engineering, University Politehnica of Timisoara, Romania, 2000
- ▶ PhD from Dublin City University, 2006
- ▶ Post-doctoral researcher at Orange Labs, 2006-2007
- ▶ Post-doctoral researcher at Grenoble-Alpes University, 2007-2009
- ▶ Associate professor at Télécom Paris (**ACES team**) since October 2009

### For more details on their work

▶ C. Dorize, S. Guerrier, **E. Awwad**, H. Mardoyan, J. Renaudier, “From Coherent Systems Technology to Advanced Fiber Sensing for Smart Network Monitoring”, IEEE Journal of Lightwave Technology, 2022.

▶ A. May, **E. Awwad**, P. Ciblat, P. Ramantanis, “Receiver-Based Localization and Estimation of Polarization Dependent Loss”, IEEE OptoElectronics and Communications Conference (OECC), 2022.

▶ C. Dorize, S. Guerrier, **E. Awwad**, K. Benyahya, H. Mardoyan, and J. Renaudier, “Advanced Fiber Sensing Leveraging Coherent Systems Technology for Smart Network Monitoring,” in 2022 Optical Fiber Communications Conference and Exhibition (OFC), 2022.

▶ C. Shelbourne, **L. Linguaglossa**, T. Zhang, and A. Lipani, “Inference of Virtual Network Functions’ State via Analysis of the CPU Behavior,” presented at the International Teletraffic Congress, Avignon, France, Aug. 2021.

▶ T. Zhang, H. Qiu, **L. Linguaglossa**, W. Ceroni, and P. Giaccone, “NFV Platforms: Taxonomy, Design Choices and Future Challenges,” IEEE Transactions on Network and Service Management, vol. 18, no. 1, pp. 30–48, 2021.

▶ G. Staerman, E. Adjakossa, **P. Mozharovskyi**, V. Hofer, J. Sen Gupta, and S. Cléménçon, “Functional anomaly detection: a benchmark study,” International Journal of Data Science and Analytics, Oct. 2022.

▶ M. Goibert, S. Cléménçon, E. Irurozki, and **P. Mozharovskyi**, “Statistical Depth Functions for Ranking Distributions: Definitions, Statistical Learning and Applications,” 25<sup>th</sup> International Conference on Artificial Intelligence and Statistics AISTATS, Valence, Spain, Mar. 2022.

▶ K. Mosler and **P. Mozharovskyi**, “Choosing Among Notions of Multivariate Depth Statistics,” Statistical Science, vol. 37, no. 3, pp. 348–368, 2022.

▶ Webinar Anomaly Detection: **P. Mozharovskyi**, “Anomaly detection using data depth: multivariate case”, Nov. 2022. [youtu.be/4SICUyFd8L8](https://youtu.be/4SICUyFd8L8)

▶ T. Hogan, U. Hinrichs, **S. Huron**, J. Alexander, and Y. Jansen, “Data Physicalization,” IEEE Computer Graphics and Applications, vol. 40, no. 6, pp. 21–24, 2020. “Data Physicalization—Part II,” IEEE Computer Graphics and Applications, vol. 41, no. 1, pp. 63–64, 2021.

▶ H. Djavaherpour, F. Samavati, AMahdavi-Amiri, F. Yazdanbakhsh, **S. Huron**, R. Levy, et al., “Data to Physicalization: A Survey of

the Physical Rendering Process,” Computer Graphics Forum, vol. 40, no. 3, pp. 569–598, 2021.

▶ S. Bae, C. Zheng, M. E. West, E. Yi-Luen Do, **S. Huron**, and D. Albers Szafrir, “Making Data Tangible: A Cross-disciplinary Design Space for Data Physicalization,” in *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA: Association for Computing Machinery, 2022.

▶ **A. Diaconescu**, L. J. D. Felice, and P. Mellodge, “Exogenous Coordination in Multi-Scale Systems: How Information Flows and Timing Affect System Properties,” Future Generation Computer Systems, vol. 114, pp. 403–426, 2021.

▶ J. Garbiso, **A. Diaconescu**, M. Coupechoux, and B. Leroy, “Fair Self-Adaptive Clustering for Hybrid Cellular-Vehicular Networks,” IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 2, pp. 1225–1236, Feb. 2021.

▶ É. Houzé, J.-L. Dessalles, **A. Diaconescu**, and D. Menga, “What Should I Notice? Using Algorithmic Information Theory to Evaluate the Memorability of Events in Smart Homes,” Entropy, vol. 24, no. 3, p. 346, Mar. 2022.

# International cooperation



International cooperation at Télécom Paris takes many forms, including research partnerships, research visits and sabbatical exchanges, joint workshops and seminars, and also joint PhD supervision that can lead to a double degree PhD diploma. It also gives rise to numerous publications in major scientific journals and conferences and other joint results. We highlight some of our international cooperation projects in these pages.

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## Quantum collaborations

Since it was created, the IQA Team, now QURIOSITY (or QTY, see page 25), has maintained an active network of international collaborations with several teams along all its research themes.

In Canada, the team conducts research activity with the Polyquantique group started at Polytechnique Montreal, and with the Institute for Quantum Computing, Waterloo. Collaborations in the USA span the University of Arizona, the Oak Ridge National Laboratory, MIT and the University of Houston. The team has a collaboration history with the Center for Quantum Technologies in Singapore.

In Europe, outside of France, the team has a long-term collaboration with ID Quantique and GAP Optique, both in Geneva and with the Austrian Institute of Technology in Vienna, strong connections with the York Center for Quantum Technologies (University of York) and with the University of Cambridge, and ongoing collaborations with the members at the Complutense University of Madrid, and the Institute for Quantum Optics and Quantum Information in Vienna.



### Award for YAGO, a Max Planck Institute for Informatics and Télécom Paris collaboration

Resulting from 15 years of collaboration between two institutions, the Max Planck Institute for Informatics (Saarbrücken, Germany) and Télécom Paris, the “YAGO knowledge base” project is now a reference on the Semantic Web. It is one of the three winners in the “jury’s special prize” category awarded for the first time in 2022 by the French Committee for Open Science, for ideas and a project that are exemplary in terms of opening or sharing data.

### Collaboration with the Indian Institute of Technology in Madras

As part of a collaboration with Nokia Bell Labs and the Indian Institute of Technology in Madras, a paper written by **Subhankar Banerjee**, a former student in the Advanced Communication Network (ACN) Master’s program previously offered by Télécom Paris, under the supervision of **Marceau Coupechoux (RMS)**, has received an Excellent Paper Award at the ICUFN 2022.

Subhankar Banerjee’s paper details the research conducted around a global optimal algorithm for joint power and subcarrier allocation for the NOMA system in a multi-cell scenario. Non-orthogonal multiple access (NOMA) is a technology proposed for next generation cellular networks because of its high spectral efficiency and enhanced user connectivity. However, in the literature the optimal joint power and sub-carrier allocation for NOMA has been proposed for single cell only. Consequently, joint allocation in multi-cell scenario was still an open problem that the authors tried to solve with a polyblock optimization based algorithm. Numerical studies have shown the effectiveness of the solution obtained.

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► S. Banerjee, C. Shue Chen, **M. Coupechoux**, and A. Sinha, “Joint Power and Subcarrier Allocation in Multi-Cell Multi-Carrier NOMA,” in 2022 *Thirteenth International Conference on Ubiquitous and Future Networks (ICUFN)*, 2022, pp. 180–185.





## International MOBI-Kids study on the risk of brain tumors in young people

Published in December 2021, MOBI-Kids, a 14-country (Australia, Austria, Canada, France, Germany, Greece, India, Israel, Italy, Japan, Korea, the Netherlands, New Zealand, Spain) case-control study conducted over five years showed that there is no evidence of a causal link between cell phone use among young people and the development of brain tumors, [1]. At Télécom Paris, this work was carried out as part of the Modeling, Characterization and Control of Exposures (C2M) Chair (see page 56).

Since the beginning of mobile telephony, the risk of developing brain tumors linked to electromagnetic waves has been a major concern, particularly given the considerable increase in the use of mobile communicating devices by young people. MOBI-Kids was conducted to evaluate whether wireless phone use (and particularly resulting exposure to radiofrequency and extremely low frequency electromagnetic fields) increases risk of brain tumors in young people. Between 2010 and 2015, the study recruited 899 people with brain tumors aged 10 to 24 years old and 1,910 controls (operated for appendicitis) matched to the cases on date of diagnosis, study region and age. Parents were also asked to complete a questionnaire regarding exposures that might have occurred prior to conception, during pregnancy, and in the first year of life of the participant.

Exposure levels were estimated using algorithms developed during the study. Tumor location was assessed by one neuroradiologist in each country who reviewed the diagnosing MRI (or CT if MRI was not available) of the cases and marked the location of the tumors on a 3D Grid, using the XGridMaster software developed by Télécom Paris (see [2]), an adaptation of the software used in a previous international study (INTERPHONE study, 2011). To validate reported mobile phone use, two validation studies were also conducted. In the second study, MOBI-Expo, controls and general population volunteers were asked to install a software application, XMobiSense, developed by Télécom Paris, on their phone to record their phone use over four weeks.

► [1] G. Castaño-Vinyals, S. Sadetzki, R. Vermeulen, F. Momoli, M. Kundi, F. Merletti, et al., “Wireless phone use in childhood and adolescence and neuroepithelial brain tumours: Results from the international MOBI-Kids study,” *Environment International*, vol. 160, p. 107069, 2022.

► [2] C. Calderón, G. Castaño-Vinyals, M. Maslanyj, J. Wiart, A.-K. Lee, M. Taki, et al., “Estimation of RF and ELF dose by anatomical location in the brain from wireless phones in the MOBI-Kids study,” *Environment International*, vol. 163, p. 107189, 2022.

## Electromagnetic fields (EMF) and Health Cluster

The European Research Cluster on EMF and Health (CLUE-H) was officially launched on September 22, 2022, with a kick-off meeting in Thessaloniki, Greece. The cluster involves more than 70 European research organizations in four research consortia—ETAİN, GOLIAT, NextGEM, SEAWave—with additional contribution from research teams in the USA, Korea and Japan. The C2M Chair at Télécom Paris is part of the consortium for two of the four Horizon Europe projects selected for funding from the HORIZON-HLTH-2021-ENVHLTH-02-01 call “Exposure to electromagnetic fields (EMF) and health”: SEAWave and GOLIAT. These projects, started in June 2022, will last 3 and 4 years respectively. CLUE-H aims at optimizing synergies, to avoid overlaps and increase the impact of each projects.

GOLIAT will monitor exposure to 5G and other sources of radiofrequency EMF in order to study its potential effects on human health, and to understand how exposure and risk are perceived and best communicated using citizen engagement. GOLIAT is coordinated by the Barcelona Institute for Global Health.

► <https://projectgoliat.eu/>

SEAWave will address major knowledge gaps: the differences in exposure between 2G-4G and 5G networks; measuring exposure using new local networks operating in high frequency bands (5G FR2); adaptation of instrumentation and procedures; investigation on the human skin, health risk studies and the potential (co-)carcinogenicity of FR2 exposure of the skin; the assessment of end user devices; and citizens’ perception and how to communicate the exposure and risk of FR2. It will disseminate its results to all stakeholders, ranging from citizens and national regulators, to standardization bodies and the industry. SEAWave is coordinated by the Aristotle University of Thessaloniki, Greece, and is co-funded by Horizon Europe and SERI (Switzerland).

► <https://seawave-project.eu/>





## Selection of international events sponsored by Télécom Paris

August  
2022

# 24-30

### PhD students trained in international scientific mediation

From June 27 to July 1, **Bethany Cagnol**, **Sinead Namur**, and **Melania Burgelis**, of the Languages and Cultures Department, welcomed to Télécom Paris about thirty international doctoral students from various European higher-education establishments for a unique training program, “Mediating International and Scientific Communication”, as part of the Project IDEAL “European soft skills for PhD: enhancing transversal skills through innovative doctoral courses”.

In this highly interactive course, participants had the opportunity to explore various mediation pathways for sharing and relaying their own cultural experience and scientific knowledge. The first half of the course covered a range of popular and modern intercultural communication models to be used to foster collaborative interaction, encourage conceptual dialogue, and facilitate a multicultural space.

Participants then used these intercultural foundations to gain hands-on experience showcasing their scientific work to professional peers, the general public, and the media. They gained key takeaways for adapting one’s language to break down complex information, facilitating communication in delicate situations, mediating Q&A sessions, and adapting their message in media interviews.

Project IDEAL is being carried out in the ATHENS Network, and has been funded by the Erasmus+ Strategic Partnerships program 2019. As stated by the partners, “it consists in designing and providing high-level doctoral training to address the challenges faced by European researchers today: being better prepared to face the growing complexity of their jobs and increasing the economic and societal impact of their work; questioning the relevance of their research activities, while renewing the attractiveness of Doctoral Education for new generations of talents.” The consortium of ten partners includes six French Engineering Schools (AgroParisTech, Arts et Métiers ParisTech, Chimie ParisTech, Mines Paris – PSL, ENSTA, and Télécom Paris) and four European Universities of Science and Technology (Politecnico di Milano – Italy, Universidad Politécnica de Madrid – Spain, Instituto Superior Técnico/Universidade de Lisboa – Portugal and Istanbul Technical University – Turkey).

► <https://ideal-phd-project.eu/>

### IACR-VIASM Summer School on Cryptography

**Duong Hieu Phan**, head of the **C<sup>2</sup> team**, was Chair and Lecturer at the IACR-VIASM Summer School held at the Vietnam Institute for Advanced Study in Mathematics (VIASM) in Hanoi, Vietnam. The school was addressed to advanced undergraduate and master/PhD students in Vietnam and in south-east Asia countries but students from all around the world were welcomed.

The aim of the summer school is to promote cryptography research in Vietnam and neighboring countries, after the success of VietCrypt 2006, IACR (International Association for Cryptologic Research) ASIACRYPT 2016 and IACR-SEAMS School 2016. This is a great opportunity for raising students’ interest in cryptography and drawing the attention of mathematicians and computer science researchers to its applied mathematical problems.

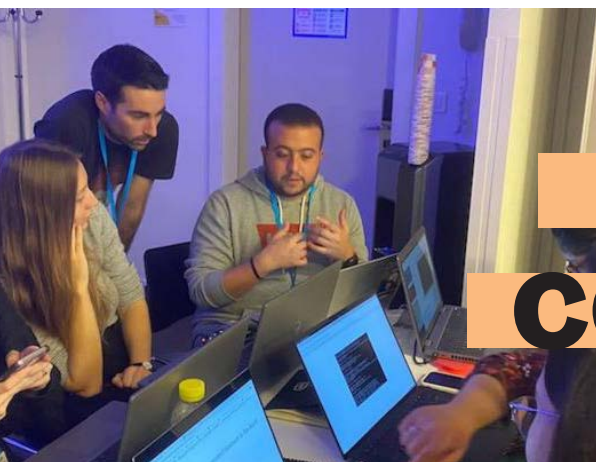
December  
2022

# 05-09

### International Winter School on Microarchitectural Security

**Maria Mushtaq** and **Ulrich Kühne (SSH)**, with the help of Karine Heydemann and Quentin L. Meunier (LIP6, Sorbonne University) organized the first IP Paris International Winter School on Microarchitectural Security (Mic-Sec). Its objective was to offer academic and industrial talks along with hands-on experience on attacks, software and hardware countermeasure techniques with a special focus on side-channel attacks. Scholars from developing countries and women were particularly welcomed. The 37 participants, including doctoral students and industrials, came from all over the world to attend the presentations of 11 international speakers, all at the forefront of their field. 18 nationalities, 13 French institutes and 10 foreign institutes were represented in what turned into an undeniable success for a first fully on-site international event after Covid.

Microarchitectural security is a vast and recent research field that started with the discovery of some vulnerabilities in almost any modern processors. Several attacks have already exploited these vulnerabilities, allowing the leakage of sensitive data. This field harnesses the knowledge of many different disciplines: Computer Architecture, Cryptography, Mathematics and Physics. Machine Learning for security and security for Machine Learning are also important topics of the field. Mic-Sec contributed to bringing together experts from around the world, to find out about each other’s concerns and approaches, expand their network and develop future collaborative research.



# International cooperation



# Research and innovation ecosystems

Institut Polytechnique de Paris

Université Paris-Saclay

HEC

EDF R&D

Thales Research and Technology

Major areas of research and innovation Ile-de-France region

- ▶ DIM RFSI
- ▶ DIM Math Innov
- ▶ DIM SIRTEC
- ▶ DIM AI4IDF

Competitiveness clusters

- ▶ Systematic
- ▶ Cap Digital

Inria

CNRS

IMT / Fondation Mines-Télécom

Institut Carnot Télécom & Société Numérique



## Institut Polytechnique de Paris

Télécom Paris is co-founder of the Institut Polytechnique de Paris (IP Paris), a world-class science and technology institute created in 2019 with the École Polytechnique, ENSTA Paris, ENSAE Paris and Télécom SudParis.

Research at IP Paris is built on the recognized expertise of its founding schools in ten major disciplines and as many departments: Biology; Chemistry and Processes; Economics; Information, Communications and Electronics; Computer Science, Data, and AI; Mathematics; Mechanics and Energetics; Physics; Humanities, Arts, Literature and Languages; Social Sciences and Management. **Bruno Thédrez (GTO)**, Professor at Télécom Paris, is head of the ICE (Information, Communications, Electronics) Department of IP Paris. And **Christian Licoppe (INTERACT)**, Professor at Télécom Paris, is Head of the SSM (Social Sciences and Management) Department of IP Paris.

IP Paris has created interdisciplinary centers on energy and climate, AI and data analysis as well as defense and cybersecurity. **Gaël Richard (S2A)** is scientific Co-Director of Hi! PARIS—the Interdisciplinary Center on Data Analytics and Artificial Intelligence for Science, Business and Society created by Institut Polytechnique de Paris and HEC Paris.

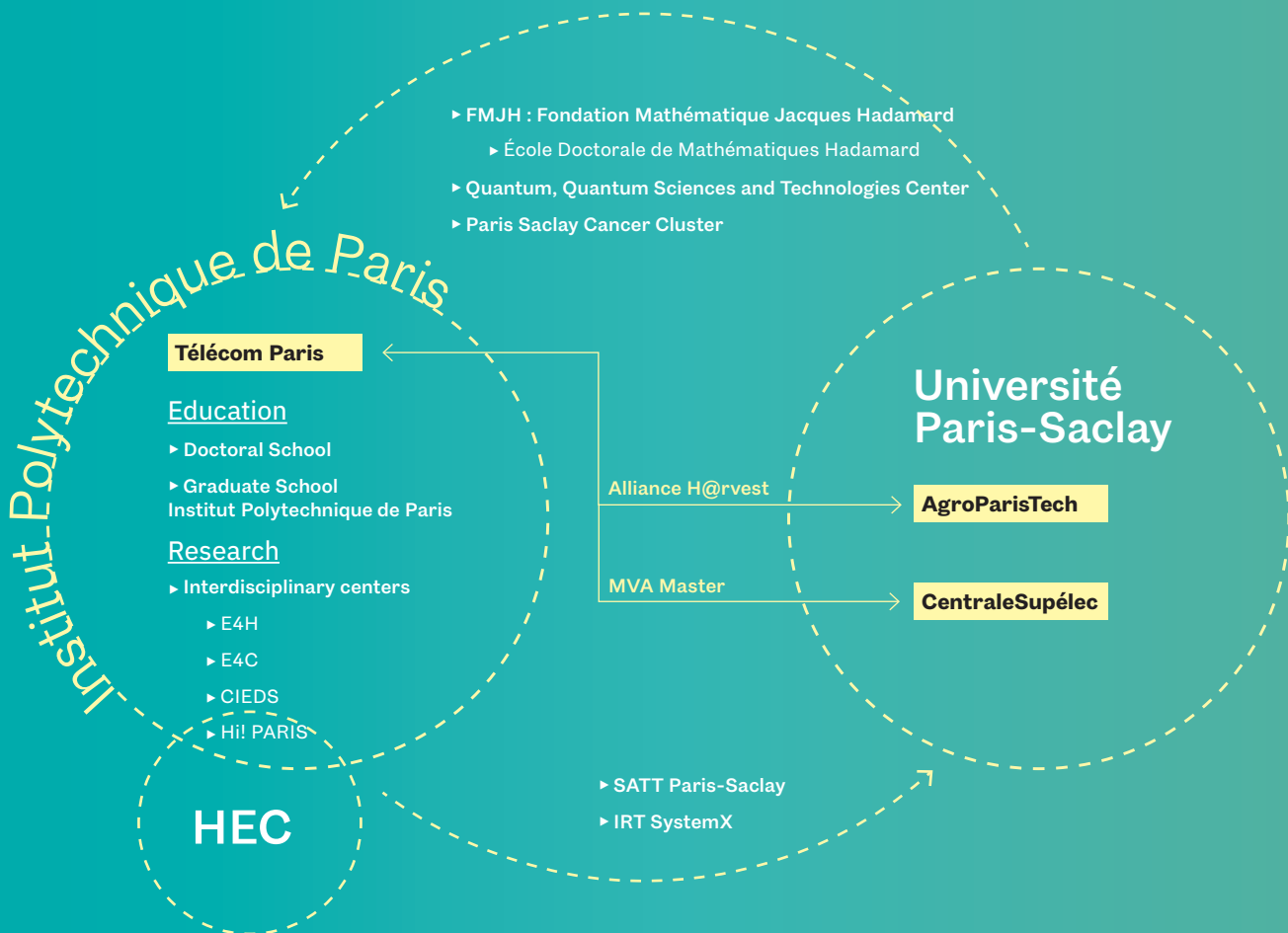
▶ [www.ip-paris.fr](http://www.ip-paris.fr)

## Energy for climate projects

Supported by the Ifker Climate Fund and led by the IP Paris interdisciplinary center Energy4Climate (E4C), XSeaO2 is a 5-year geoengineering research project in line with the objectives of combating global warming and promoting energy transition, from October 2022. It proposes a technological solution aiming at the sequestration of CO<sub>2</sub> dissolved in sea water and its valorisation as an elementary brick for the production of non-fossil fuels. The i3 laboratory and Télécom Paris are contributing to the project with a thesis, under the supervision of **Laura Draetta (INTERACT)** and Cécile Chamaret (École Polytechnique, CRG), aimed at exploring its social reception at the local and global scales and thus facilitating the involvement of stakeholders in socially acceptable techno-scientific choices.



Télécom Paris, through its research center LTCI, is an active member of the LMH (Labex Mathématique Hadamard), which covers the full spectrum of research in mathematics, from pure and fundamental studies to applied mathematics. A number of LTCI PhD students are registered in the “Hadamard Doctoral School of Mathematics shared” between Université Paris-Saclay and Institut Polytechnique de Paris.



### Seminar “Law, Society & AI”

Supported by the NoRDF Chair (see page 58) and organized with the help of HEC and École Polytechnique, the seminar “Law, Society & AI” is a series of invited talks by researchers on questions at the intersection of legal, societal, and artificial intelligence issues.

Nine talks from local and international speakers were held in 2022, covering topics such as anti-discrimination laws, AI, and gender bias in credit lending, legal contracts and smart contracts, as well as theory of artificial immutability.

▶ [lawsocietyandai.wp.imt.fr](https://lawsocietyandai.wp.imt.fr)

### Hi! PARIS first white book



Hi! PARIS visions of research were gathered in a white book entitled “Empowering society with Data and AI”, published in June 2022. The book focuses on the research carried out by the nine Hi! PARIS chair holders, and the five fellowship holders supported by the interdisciplinary Center.

Two chair holders are working at Télécom Paris: Damien Ernst (invited professor at Télécom Paris) explores reinforcement learning applied to energy, and Enzo Tartaglione (MM) holds the chair “Regularizing deep neural networks, debiasing, efficiency and beyond”.

▶ [www.hi-paris.fr/white-book-2022/](https://www.hi-paris.fr/white-book-2022/)

# IP Paris

## activities

### IP Paris 2022 Best thesis prize

The graduation ceremony for IP Paris doctoral students took place on July 1, 2022 at the École Polytechnique. The IP Paris thesis first prize was awarded to seven laureates, including three PhD students from Télécom Paris: **Kamélia Daudel (S2A)**, **Bozhang Dong (GTO)** and **Kimia Nadjahi (S2A)**.



Kamélia Daudel's thesis is part of the study of variational inference methods in statistical data analysis. The originality of the thesis is to propose new algorithms enriching the variational family beyond the traditionally used families, while guaranteeing at each step a decrease of the alpha-divergence, i.e. an improvement of a sometimes non-convex global criterion. The thesis provides results allowing to work with a variational family containing finite mixtures of parametric laws and establishing links between a systematic alpha-divergence decay approach and a more classical approach based on mirror descent and/or gradient descent, opening the way to an increased cross-fertilization between these different approaches. [1]



Bozhang Dong's dissertation focuses on developing high-performance sources for silicon photonics integrated circuits (PIC). In this thesis, he demonstrates that semiconductor quantum-dot (QD) lasers on silicon exhibit remarkable performance such as low threshold current, high thermal stability, and high degree of insensitivity for chip-scale back-reflection. To improve the transmission capacity, optical frequency comb (OFC) offering a wide range of optical channels is a promising solution. His dissertation highlights the potential of QD laser for ultra-quiet and high-bandwidth frequency comb generation. In particular, the rich optical nonlinearities offered by QD give insights for self-mode-locking and quantum state of light generation. These studies pave the way for ultra-compact, high-speed, uncooled, and isolator-free silicon PIC. [2]



The objective of Kimia Nadjahi's thesis is to deepen the study of the Sliced-Wasserstein distance (SW) to better understand the consequences of its use in modern machine learning problems, such as image generation by "deep learning". The thesis provides a set of theoretical results on SW that justify the performance of existing SW-based algorithms and encourage new applications. An important contribution is the proof of theoretical guarantees that demonstrate the effectiveness of SW in high dimension, thus confirming the observations of previous empirical work. In addition to a thorough theoretical study, the main contributions of the thesis include new practical tools inspired by SW that allow, for example, to speed up the execution time of neural networks for image generation, while improving the quality of results. This thesis has resulted in six scientific publications accepted in proceedings of highly recognized and competitive conferences in machine learning and signal processing, three of them being rewarded. [3]

► [1] **K. Daudel** and R. Douc, "Mixture weights optimisation for Alpha-Divergence Variational Inference," in *Advances in Neural Information Processing Systems*, 2021, vol. 34, pp. 4397–4408.

► [2] **F. Grillot, J. Duan, B. Dong,** and **H. Huang**, "Uncovering recent progress in nanostructured light-emitters for information and communication technologies," *Light: Science & Applications*, vol. 10, no. 1, p. 156, Jul. 2021.



► [3] **K. Nadjahi,** V. de Bortoli, A. Durmus, **R. Badeau, U. Şimşekli,** "Approximate Bayesian computation with the sliced-Wasserstein distance," *45<sup>th</sup> International Conference on Acoustics, Speech, and Signal Processing*, May 2020, Barcelona, Spain.

**Best student paper award**

**Kamélia Daudel** is now a postdoctoral researcher in the Department of Statistics at the University of Oxford.

**Bozhang Dong** is now a postdoctoral scholar within Prof. John Bowers' group at the University of California Santa Barbara.

**Kimia Nadjahi** is now a postdoctoral fellow at MIT's Computer Science & Artificial Intelligence Lab, in the Geometric Data Processing Group.

### ICE webinars

Two of our researchers gave a talk at the IP Paris ICE webinars in 2022.

**Bastien Sultan** (postdoctoral researcher, **LabSoC**) analyzed in his talk "Musical Languages and Formal Sciences: How Mathematics and Computer Science Can Help in Analyzing and Composing Music" the musical parameters that can be formally defined in the written musical language. He presented a dodecaphonic work composed with the help of TTool, the formal modeling toolkit developed by the LabSoC team. He also compared the evolution of modern music with that of modern mathematics.

**Maria Mushtaq** (associate professor, **SSH**), introduced in her talk "Microarchitectural Vulnerabilities—Assessment and Mitigation" a novel OS-level runtime detection-based mitigation mechanism, against Cache Side-Channel Attacks in general-purpose operating systems. This mechanism is also able to work on computational attacks like Spectre and Meltdown, which use the residual micro-architectural cache states that are left after speculative execution.



**Romain Alléaume**, Professor, is leading the QURIOSITY project-team between IP Paris and Inria, hosted at LTCI.

He joined Télécom Paris in 2005 and co-founded in 2008 the start-up company SeQureNet that developed and successfully commercialized the first continuous-variable quantum key distribution (CV-QKD) system in 2012. He currently coordinates Télécom Paris's participation in the European Quantum Technology Flagship (QSNP and OpenQKD projects), the PEPR QCommTestBed and the EuroQCI initiative.

Romain carries out a research activity on quantum and classical cryptography, quantum networks and photonic quantum information processing as well as on cross-disciplinary topics linking quantum information with cryptography, photonics and security.

## The vibrant quantum ecosystem of Saclay

QURIOSITY joint project team with Inria is an active member of the newly founded Quantum Saclay Center in which Institut Polytechnique de Paris and Université Paris-Saclay are joining their forces in order to build a leading international ecosystem on quantum technologies.

## New team: IQA becomes QURIOSITY, a joint Inria-IP Paris team

Starting January 1, 2023, QURIOSITY (or QTY) is replacing IQA as the Télécom Paris quantum team. It is now an Inria project-team, jointly with Télécom Paris - IP Paris. The team is part of LTCI and is affiliated with the Inria Saclay Île-de-France Research Center.

QURIOSITY will extend the application horizon of quantum information science by addressing novel questions positioned at the intersection between theoretical research in quantum information and the engineering of quantum devices, with a focus on approaches combining digital and quantum photonics technologies.

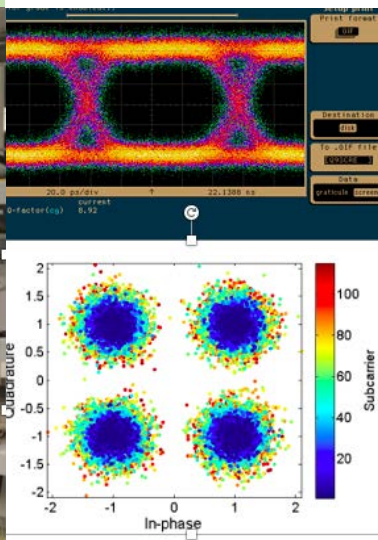
The team aims to develop strong synergies with the unique quantum ecosystem of Saclay and to pursue objectives that have the potential to bring radical advances to several application fields of quantum technologies, ranging from cryptography to computing: Design quantum-enhanced cryptographic hardware, leveraging concepts based on computational hardness and quantum information; Conceive and engineer photonic-based processors and systems capable of achieving quantum advantage in computation or communication tasks; Develop efficient quantum information processing schemes implementable on near-term hardware and advance the theoretical framework to understand the fundamental limits of noisy quantum information processing.

The firm belief that underpins the QURIOSITY project is that quantum photonics combined with digital technologies will play a leading role in unveiling the power of high-dimensional controllable quantum systems, and transition towards the demonstration of a useful quantum advantage, for communication and information processing tasks.

QURIOSITY capitalizes on strong past achievements. Founded in 2007, the IQA team developed as the largest quantum information group in France, with its research positioned at the highest international level in theoretical and experimental quantum cryptography and quantum networks, as well as in quantum information and quantum optics, and expanded towards quantum computing in 2012. IQA organized major conferences, participated to key international projects and collaborations, notably with AIT Vienna and University of Geneva in the context of the European projects SECOQC and OpenQKD, with the Institute of Quantum Computing (ANR International FREQUENCY) and with the Japanese-French Laboratory for Informatics in Tokyo. It played a central role in the foundation of the Paris Centre for Quantum Computing (PCQC), inaugurated in January 1st, 2014. The start-up SeQureNet, spin-off of IQA founded by Romain Alléaume in 2008, has actively contributed to push forward the industrialization of the continuous-variable QKD technology (CV-QKD) from 2008 to 2017.

QURIOSITY plans to develop 3 research themes:

- ▶ “Quantum cryptography complexity and hardware frontiers” will constitute the core research theme in the next 2-3 years, and a central theme for the contribution to the future SGA QT Flagship project (starting in 2023), in relation with the Quantum Technology Flagship QSN Partnership.
- ▶ “Multimode photonic systems for quantum information processing and communications” will develop collaborations with prominent experimental groups and start-up.
- ▶ “Mathematical foundations of quantum information” constitutes a backbone for the two other themes and will expand further at the intersection between theoretical computer science and quantum computing or cryptography.



### See also

- ▶ Quantum activities, page 40.





## ARTIST

ARTificial Intelligence and Scoring Trees

### Stephan Clemençon

Professor, S2A team

Today, we expect much more from Artificial Intelligence than its simple predictive capability. Explainability, transparency of the learning process, robustness properties and proper treatment of biases and equity issues are required. In addition, economic actors from various sectors (e.g. medicine/health, finance/insurance, security/safety, marketing) have a strong demand for the so-called “Machine Learning as a service” solutions.

In this context, ARTIST aims at developing a software to implement a powerful technology for scoring and selection bias detection, based on our recent research results, as well as the processing of real-life use cases. Written in Python, this software will implement the TreeRank/Ranking Forest methodology for learning scoring rules, which is the subject of a family of patents still in force (EP, US and CA). The desired properties are: optimization of the ROC curve/variety; flexibility (LeafRank bricks for binary classification, consensus rules for aggregating ranking trees); tools for interpreting scoring rules and related decisions, for assessing uncertainty (confidence regions); scaling up (parallelization, randomization); extension to multipartite ranking and functional data; nonparametric homogeneity tests in high dimensions and tools for interpreting the results.

## RAMSES

Refinement of AADL Models for the Synthesis of Embedded Systems

### Dominique Blouin

Research engineer, ACES team

RAMSES is a model transformation and code generation tool developed at Télécom Paris over several years that produces C code for POSIX, ARINC653 (aeronautic sector), or OSEK (automotive sector) compliant operating systems. However, until recently, it has not been easy to add specific extensions that could be commercialized, and the performances of RAMSES were insufficient for complex systems of realistic sizes, for instance a transportation system. To meet these requirements, a major redesign of RAMSES was performed in 2019-2020 bringing RAMSES to TRL 4 level.

At Lab-STICC, Eric Senn and Lucie Bourdon have developed a rich library of AADL (Architecture Analysis & Design Language) components that is very useful for modeling and analyzing robotics systems designs well before system implementation, therefore significantly reducing the time to market of these systems while improving their quality. We jointly published a paper on the AADL modeling approach and component library at the MPM4CPS (Multi-Paradigm Modeling for Cyber-Physical Systems) workshop of the MODELS 2022 conference [1]. The purpose of this innovative project is to extend RAMSES and the Lab-STICC approach with automatic code generation capabilities from AADL models, based on the ROS (Robotics Operating System) middleware adopted by a growing number of companies.

► [1] E. Senn, L. W. J. Bourdon, and D. Blouin, “Multi-Paradigm Modeling for Early Analysis of ROS-Based Robotic Applications Using a Library of AADL Models,” in *Proceedings of the 25<sup>th</sup> International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, New York, NY, USA, 2022, pp. 677–683.

### Élie Awwad

Associate professor, GTO team

In this project, we aim to detect vibrations through fiber optic cables of telecom networks via optical reflectometry and the digital processing of reflected signals, a subject that has recently attracted much attention. Two families of uses cases are envisioned: monitoring the state of the fiber network (integrity, anomaly), ensuring better availability and reconfiguration of this network in case of incident; monitoring of the urban environment: detection of vibrations due to construction or demolition work, anomalies in the water or gas distribution networks, monitoring of road traffic, etc. One approach providing accurate localization and high sensitivity, called Distributed Acoustic Sensing (DAS), is mastered quite well when performed on optical cables dedicated to vibration sensing. However, it requires several innovative adaptations and modifications when applying it over optical communication cables. For instance, in the access networks, the optical transceivers deployed in large numbers use simple modulation techniques and basic digital signal processing, hence low-complexity vibration detection solutions must be developed for these networks. In addition, the last kilometers being deployed in a point-to-multipoint topology, with splitters of 1-to-N fibers, the identification of individual fibers is problematic.

In partnership with Nokia Bell Labs, the DAS approach has been studied and improved during the last three years. We recently reported a detection, localization and identification of mechanical events on a deployed fiber cable up to 82km (core network) using a digital sensing signal co-propagating with adjacent 600Gb/s WDM data channels with zero impact on data transmission [1]. With SAFER, the goal is to adapt sensing techniques and develop novel schemes for vibration detection over access networks.

► [1] S. Guerrier, K. Benyahya, C. Dorize, E. Awwad, H. Mardoyan, and J. Renaudier, “Vibration Detection and Localization in Buried Fiber Cable after 80km of SSMF using Digital Coherent Sensing System with Co-Propagating 600Gb/s WDM Channels,” in *2022 Optical Fiber Communications Conference and Exhibition (OFC)*, 2022.

## Pietro Gori & Isabelle Bloch

Associate professor & Professor,  
IMAGES team

This project is set in the context of a multi-year collaboration with the Necker Enfants Malades Hospital on pelvic and abdominal organ segmentation, including blood vessels and nerves, and 3D modeling. These individual 3D models are digital twins of the patients. Our IMAG2 software proved to be interesting on some clinical cases, for the preparation of the surgical strategy and during intraoperative events, allowing personalized tailored surgery. One of the strong points is the segmentation and recognition of nerves, as well as their integration into the 3D model, allowing a good understanding of the relationships with anatomical structures and tumors.

The automatic segmentation tools (mainly by deep learning) developed today offer 3D modeling of bones, bladder, colon, vessels, kidneys, in a few clicks. The recognition of these structures allowed the development of algorithms guided by anatomical knowledge from diffusion tensor imaging sequences (diffusion magnetic resonance images, the reference for pediatric pelvis examination) in order to have a representation of the peripheral nervous network. This project will adapt the image segmentation tools developed for children to the automatic segmentation of pelvic organs in adult women, including the genital tract, which could not be automatically modeled in children because of the small size of these structures.

► C. O. Muller, E. Mille, **A. Virzi**, J.-B. Marret, Q. Peyrot, A. Delmonte, L. Berteloot, **P. Gori**, Th. Blanc, D. Grevent, N. Boddaert, **I. Bloch**, and S. Sarnacki, “Integrating tractography in pelvic surgery: a proof of concept,” *Journal of Pediatric Surgery Case Reports*, vol. 48, p. 101268, 2019.

## IP Paris 2022 call for innovative projects

The fourth call for projects to detect and support innovative projects from IP Paris laboratories ended in December 2022 with the selection of eleven projects, for a total budget of 875,240 euros. This helps the project holders to achieve a first proof of concept and to confront their ideas with market expectations and needs.

Five Télécom Paris projects are among the eleven selected, for a total budget of 436,500 euros.

## Midway++

Medical image harmonization by Midway

### Elsa Angelini

Associate professor, IMAGES team

Midway-BrainTumor is a software for processing MRI images of the brain to calculate difference maps and detect tumor growth by statistical thresholding between two examinations taken several months apart. During the development of its python version last year, new use cases and improvement requirements have appeared. The follow-up of this project will thus study two types of pathologies that involve adapting the method to other lesions and organs and to a new imaging modality, radiography.

In addition, raising concerns about the robustness of deep learning models on new image sets must be addressed. In a context of working with large cohorts, an effort of harmonization between image domains provided as input to our AI models targets: limiting biases between cohorts, limiting the risks of failure on future cohorts of pre-trained models on old cohorts, reducing the sizes of cohorts to be annotated, strengthening the confidence of physicians in our AI algorithms, and aiming for more frugal models in training cost.

#### See also

► Medical Imaging, page 49.

# Co

The following pages present the research conducted at Télécom Paris with our academic and industrial partners in 2022. Our research teams belong either to the Information Processing and Communications Laboratory (LTCI) or to the Interdisciplinary Institute on Innovation (i3). The LTCI and i3 labs frequently work together on topics that call on their respective disciplines.



The Information Processing and Communications Laboratory (LTCI) was created in 1982 and is characterized by its extensive coverage of topics in the field of information and communication sciences and technology. The laboratory is also active in issues related to systems engineering and applied mathematics. Organized into 15 research teams, it addresses three main fields: Digital Communications and Electronics—physical and hardware basis of processing and design/modeling/integration of objects in an information system; Computer Science and Networks—infrastructure, systems and digital networks, with a special focus on mathematical modeling, protocols and functions of next generation networks, computing architecture of systems and services, in their algorithmic and software aspects; Images, Data and Signal Processing—study and analysis of signals and images in all their forms, study and development of algorithms and statistical processing methods for learning, optimization and data analysis.



The Interdisciplinary Institute on Innovation (i3) was created in 2012 by Mines ParisTech and Télécom Paris. École Polytechnique joined it in 2014. On January 1, 2015, i3 became a CNRS Mixed Research Unit (UMR 9217), which comprises five research teams who work on innovation and social sciences, into four cross-disciplinary themes. The Télécom Paris Economics and Social Sciences Department (ECO, INTERACT, NOS) constitutes one of those five teams, together with the École Polytechnique Management Research Center (CRG) and the CERNA, CGS and CSI teams at Mines ParisTech.

# Some Research Contributions



02

# Strategic focus areas

## - LTCI



**Data Science  
& Artificial  
Intelligence**



**Visual  
and Audio  
Computing,  
Interaction**



**Digital  
Trust**



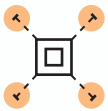
**Innovation  
Regulations**



**Transformation  
of Innovative  
Firms**



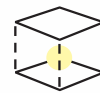
Nine strategic themes embody the potential of Télécom Paris research, on major issues related to the digital revolution across all industrial and economic sectors.



## Cyber-Physical Systems



## Communication Systems & Networks



Transversal focus

## Mathematics & Applications

# -i3



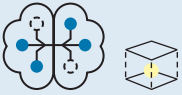
## Uses, Participation, Democratization of Innovation

# Télécom Paris

## research teams

### DIG

Data, Intelligence and Graphs



**Thomas Bonald**  
Group leader

#### Keywords

Data mining, Knowledge bases, Databases, Logic, Graphs, Data streams, Natural language processing, Artificial intelligence, Learning, Cognitive models

# 11

Permanent  
Researchers

### S2A

Signal, Statistics and Learning



**Stephan Cléménçon**  
Group leader

# 21

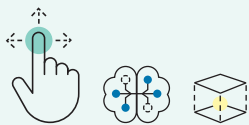
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Researchers

#### Keywords

Statistics, Probabilistic modeling, Machine learning, Data science, Audio and social signal processing

### IMAGES

Image, Modeling, Analysis, GEometry, Synthesis



**Yann Gousseau**  
Group leader

# 11

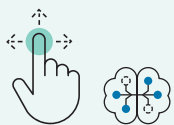
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Researchers

#### Keywords

Mathematics and artificial intelligence for images, Stochastic image modeling, Machine learning and deep learning, Image and video restoration, Image and video synthesis and editing, Discrete mathematics, Algebraic and structural models, Symbolic AI, Computer graphics, Geometrical and topological analysis, Rendering, Simulation, Remote sensing imaging, SAR imaging, Medical imaging, Computational photography, Creative industries

### MM

Multimedia



**Stéphane Lathuilière**  
Group leader

#### Keywords

Image and video compression, Transport and orchestration of multimedia content, Immersive media and interactivity, Deep learning for image and video generation, Deep learning with limited supervision

# 6

Permanent  
Researchers

### DIVA

Design, Interaction, Visualization & Applications



**James Eagan**  
Group leader

#### Keywords

Human-computer interaction (HCI), Touch- and gesture-based interfaces, Data visualization, Design, Behavior models, Virtual reality, Augmented reality, Mixed reality

# 4

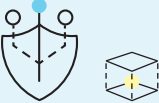
Permanent  
Researchers


# and activity

Most of the teams work on research that cuts across the strategic focus areas shown above, which are identified by their respective pictograms. The team's color matches its dominant research theme.

## IQA

Quantum Information and Applications





**Romain Alléaume**  
Group leader

# 2


Permanent Researchers


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**Keywords**  
Quantum communications, Quantum cryptography, Quantum computing, Quantum key distribution (QKD)

## ACES

Autonomous Critical Embedded Systems





**Ada Diaconescu**  
Group leader

# 13


Permanent Researchers


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**Keywords**  
Cyber-physical system, Security and safety, Embedded critical systems, Concurrent and distributed systems, Autonomic systems, Game theory, Blockchain

## SSH

Secure and Safe Hardware





**Jean-Luc Danger**  
Group leader

# 8

Permanent Researchers

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**Keywords**  
Architecture and design methods for embedded systems, Hardware security of embedded systems against physical and cyber attacks, Hardware reliability of embedded systems

## C<sup>2</sup>

Cybersecurity and Cryptography





**Duong Hieu Phan**  
Group leader

# 10

Permanent Researchers

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**Keywords**  
Cryptography, Privacy, Network security, Internet of Things, V2X communications security, Coding, Combinatorics, Graphs, Algebraic geometry

## RFM<sup>2</sup>

Radio Frequency, Microwaves  
& Millimeter waves



Jean-Christophe Cousin  
Group leader

### Keywords

Theory and modeling of RF systems, Antenna and RF circuit design, RF instrumentation, Metamaterials and metasurfaces

# 7

Permanent  
Researchers

## GTO

Optical  
Telecommunications



Yves Jauouën  
Group leader

### Keywords

Optical fiber communication, Optical networks, Nonlinear effects in optical fibers, Nonlinear Fourier transform, Advanced photonics components, Optoelectronics, Semiconductor laser dynamics, Optical fiber sensors

# 9

Permanent  
Researchers

## COMNUM

Digital Communications



Ghaya Rekaya  
Group leader

# 7

Permanent  
Researchers

### Keywords

Information theory, Network data processing, Coding, Distributed optimization, Security, Edge caching, Lattice theory, MIMO coding/decoding, Network coding, Machine learning

## RMS

Networks, Mobility  
and Services



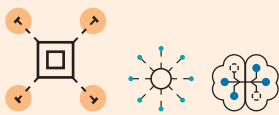
Laurent Decreusefond  
Group leader

### Keywords

Mobile networks, Cellular networks, 5G, 6G, Future Internet, Internet of things, Smart Grids, Data centers, Network storage, Cloud and edge computing, Virtualization (SDN/NFV), Network management and control, Metrology, SDR, Performance analysis, Optimization, Mathematical models (stochastic geometry game theory algebraic topology), Algorithm design, Artificial intelligence

## C2S

Circuits &  
Communications Systems



Patricia Desgreys  
Group leader

# 5

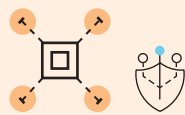
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Researchers

### Keywords

Smart AMS systems, Frugal signal processing, Smart radio, Cyber-physical system interfaces

## LABSOC

System on Chip



Ludovic Apvrille  
Group leader

### Keywords

Architecture exploration, Formal validation, Model engineering, Safety, Security and performance, Security of electronic circuits, Software/hardware architecture for signal processing applications

# 4

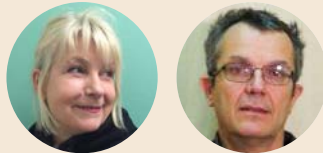
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Researchers

# 10

Permanent  
Researchers

## INTERACT

Interaction, Technology,  
Activity



Françoise Détienne /  
Christian Licoppe  
Group leaders

# 13

Permanent  
Researchers

### Keywords

Interaction, Activity, Mobility, Collaboration, Community, Interaction design, Creative design  
User experience, Technology-mediated interaction, Social robotics

## ECO

Economics



Marc Bourreau  
Group leader

### Keywords

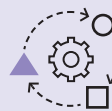
Digital platforms, Data,  
Innovation,  
Telecommunications,  
Infrastructure, Strategy,  
Digital transformation,  
Public policy, Regulation,  
Competition policy,  
Intellectual property,  
Privacy, Industrial  
organization, Econometrics,  
Qualitative methods

# 8

Permanent  
Researchers

## NOS

Digital Technologies,  
Organization and  
Society



Winston Maxwell /  
David Massé  
Group leaders

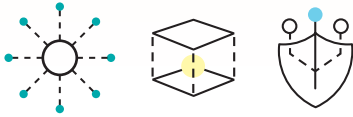
### Keywords

Science and technology  
studies, Participation,  
Democratization,  
Amateurs, Citizens, Digital  
labor, Design, Art-science

# 10

Permanent  
Researchers

# Highly efficient networks and energy sobriety



The use of applications that are becoming more and more critical and central to our daily lives makes it necessary for a communication network design to take into account constraints of speed, reliability and latency. When they are based on learning techniques and artificial intelligence, these applications need to be processed in a distributed way. In addition, environmental considerations require the design of energy efficient networks, while the number of connected objects is increasing drastically.

To provide highly efficient networks, we combine research on 6G networks and IoT, radio technologies, optical communications systems and networks, and cloud and virtualization.

RMS

## Modeling of wave propagation

Indoor coverage is a major challenge for millimeter waves, due to their propagation properties, namely their very short wavelength. We address this challenge through a novel theoretical framework that combines stochastic indoor environment modeling with advanced physical propagation simulation [1]. Its system implementation, so-called iGeoStat, generates parameterized typical environments that account for indoor spatial variations, then simulates radio propagation based on the physical interaction between electromagnetic waves and material properties.

Millimeter waves are extremely sensitive to even small obstacles. To study their impact on the quality of communications, a multiplicative cascade blockage model to emulate correlated blockage environments is proposed in article [2]. It is based on the geometry of obstacles and takes the joint blockage phenomenon into account.

► [1] G. Nassif, C. Gloaguen, and **P. Martins**, “A Combined Stochastic and Physical Framework for Modeling Indoor 5G Millimeter Wave Propagation,” *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 6, pp. 4712–4727, 2022.

► [2] F. Baccelli, B. Liu, **L. Decreusefond**, and R. Song, “A User Centric Blockage Model for Wireless Networks,” *IEEE Transactions on Wireless Communications*, vol. 21, no. 10, pp. 8431–8440, 2022.

RFM<sup>2</sup>

## Characterization and models for beyond-5G

A first step towards 6G requires a characterization of the reflection and absorption of building materials whose behavior is not really known in the 100-300 GHz band and which are seen as promising for 6G frequency ranges. The following study aims to extend the currently existing knowledge on wave-material interaction and make the link between below and above 100 GHz frequencies by providing reflection measurements from 2 to 170 GHz. The material reflection coefficients of seventeen different materials e.g. glass, wood, aerated concrete, and polystyrene are continuously reported along the measured band. Results showed a low frequency dependency of reflection coefficients over the measured band for the majority of measured materials.

► **M. A. Aliouane**, J.-M. Conrat, **J.-C. Cousin**, and **X. Begaud**, “Material Reflection Measurements in Centimeter and Millimeter Wave ranges for 6G Wireless Communications,” in *2022 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)*, 2022, pp. 43–48.

RFM<sup>2</sup>

## Multifunctional Metamaterial antenna

The arrival of 5G and the need to bring together many standards in a same location require multifunctional antennas. The objective is to combine metamaterials or metasurfaces with wideband or multi-band antennas to reduce their size but also to integrate new functionalities such as beam steering.

The bow-tie antenna is considered as a good candidate for many applications such as multiband WLAN/WiMAX/LTE, 5G, infrared polarimetry, ground-penetrating and short range radars. However, the radiation pattern of this kind of antenna is not stable and the gain in the broadside direction deteriorates with increasing frequencies. In the following paper, the operation of both the triangular and the rounded-edge versions of the bow-tie antenna is thoroughly investigated and a fair comparison of their broadside gain over frequency is made, leading to a technique to enhance the rounded-edge bow-tie performance.

► **R. Gonçalves Licursi de Mello**, **A. C. Lepage**, and **X. Begaud**, “The bow-tie antenna: Performance limitations and improvements,” *IET Microwaves, Antennas & Propagation*, vol. 16, no. 5, pp. 283–294, 2022.

On virtualization, see the four-year JCJC grant for **Leonardo Linguaglossa (RMS)**, entitled “Inference of networks characteristics via non-invasive data exploration”, that explores the “data uncertainty principle” in the context of data acquisition and analysis in Network Functions Virtualization (NFV) networks, page 15.



## Characterization, modeling and mastering of the EMF exposure

With the increasing use of wireless communication, research tackles the exposure to the electromagnetic waves to further assess impact on health. The main objectives are the characterization, modeling and mastering of the exposure. Many methods and tools are developed, including statistical tools, artificial intelligence and new measurement methods to assess the power density absorbed in the millimeter range. In the article below, we use the artificial neural network model for a spatial reconstruction of radio-frequency electromagnetic field exposure in an outdoor urban environment.

► **S. Wang, T. Mazloum, and J. Wiart**, “Prediction of RF-EMF Exposure by Outdoor Drive Test Measurements,” *Telecom*, vol. 3, no. 3, pp. 396–406, 2022.

## Resource allocation for cognitive satellite systems

This line of work, defended in **Arthur Louchart**'s thesis, addresses the problem of resource allocation for cognitive satellite communications, in a context where satellite communication systems are required to use frequencies already used by terrestrial systems. The management of the transmission power of the—secondary—satellite users becomes essential to limit the interference on the—primary—terrestrial network and, at the same time, to reach the maximum throughput of the system. The originality and novelty of this research is to have taken into account the nonlinearities from the satellite, especially the high-power amplifier.

In the context of multibeam satellite uplink communications [1], we derive a closed-form expression for the sum rate and propose a per-user power allocation for maximizing this sum rate. We resort to Signomial Programming. In the context of uplink multiband satellite communications [2], we propose practical and scalable algorithms for three power allocation problems: sum-power minimization, maximization of minimum per-user data rate, sum-rate maximization. The solutions mainly rely on Geometric Programming and/or Successive Convex Approximation approaches.

► [1] **A. Louchart, P. Ciblat**, and C. Poulliat, “Power Allocation for Multibeam Satellite Communications with Nonlinear Impairments,” in *WSA 2021; 25<sup>th</sup> International ITG Workshop on Smart Antennas*, 2021, pp. 1–6.

► [2] **A. Louchart, P. Ciblat**, and C. Poulliat, “Power Allocation for Uplink Multiband Satellite Communications With Nonlinear Impairments,” *IEEE Communications Letters*, vol. 25, no. 8, pp. 2713–2717, 2021.



## Digicosme activities



In April 2022, **Élie Awwad** (see page 17) co-organized and chaired the Digicosme Spring School on Emerging and Future Communication Networks with Marco Di Renzo, Michel Kieffer and Swanny Chaumeil-Debuchy.

The Labex DigiCosme organized on October 6, 2022 the 4<sup>th</sup> Junior Conference on Wireless and Optical Communications (JWOC). **Perrine Lognoné (ComNum)**, was awarded Best student presentation award for her work “Reciprocal modeling of AO pre-compensated ground to GEO optical link”.

## Chaos transmission for better privacy

Mid-infrared free-space optical communication is thought to play a key role in the 6G standard under development. The directivity of the beam, as well as the stealth conferred by the background emission, makes communication systems based on long-wave infrared quantum cascade lasers (QCL) highly desirable. However, some applications require a further level of privacy. Protecting the communication link against eavesdroppers is possible with chaos-based enciphering.

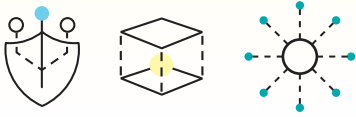
We show that two uni-directionally coupled quantum cascade lasers operating in the chaotic regime and the synchronization between them allow for the extraction of the information that has been camouflaged in the chaotic emission. This building block represents a key tool to implement a high degree of privacy directly on the physical layer. We realized a proof-of-concept communication at a wavelength of 5.7  $\mu\text{m}$  with a message encryption at a bit rate of 0.5 Mbit/s. Our demonstration of private free-space communication between a transmitter and receiver opens strategies for physical encryption and decryption of a digital message.

► **F. Grillot and O. Spitz**, “Chaos-based mid-infrared communications,” in *Physics and Simulation of Optoelectronic Devices XXX*, 2022, vol. 11995, p. 1199502.

► **O. Spitz, A. Herdt, J. Wu, G. Maisons, M. Carras, C.-W. Wong, W. Elsässer and F. Grillot**, “Private communication with quantum cascade laser photonic chaos,” *Nature Communications*, vol. 12, no. 1, p. 3327, Jun. 2021.

# Quantum information

## science



Research is focused on quantum computing, quantum information and quantum cryptography with an emphasis on optical systems. Our ambition is to extend the application scope of quantum information science by addressing novel questions positioned at the intersection between theoretical research in quantum information and quantum engineering.

IQA

The quantum team at Télécom Paris is an active member of Quantum Saclay Center in which Institut Polytechnique de Paris and Université Paris-Saclay have joined forces. It is also well positioned at National and European levels, as member of the Paris Region regional network on quantum technologies (DIM QuanTiP) and currently taking part in several projects from the European Quantum Technology Flagship and French National Quantum Strategy. Its research work, topics and publications reflect this continuous collaboration with other teams.

On the quantum cryptography—core research—topic, article [1] is the result of a collaboration between 14 researchers as part of the OpenQKD European project, that takes a stand against a recent claim of global quantum key distribution without trust assumption.

On the mathematical foundations research topic, article [2] is the result of a collaboration with the University of York, that quantifies the trade-off for a quantum system between the generation of randomness and the violation of Bell inequalities, which characterizes the non-local character of the associated probability distribution. This work provides an achievable upper bound on the amount of randomness that can be certified for any Clauser-Horne-Shimony-Holt value, and can be used to improve randomness generation rates in practice.

Concerning the multi-mode quantum photonics research topic, with the Centre for Nanosciences and Nanotechnology (C2N)—a joint research unit between the CNRS and Université Paris-Saclay—we investigate how to combine high-dimensional photonic gates, using the combined action of off-the-shelf telecom components such as Pulse Shapers and Electro-Optic Modulators, to efficiently synthesize high-dimensional unitary transformations. Article [3] analyzes the possibility to parallelize single-qubit unitaries with high success probability and gate fidelity, considering both time-bin and frequency-bin encodings.

► [1] B. Huttner, **R. Alléaume**, E. Diamanti, F. Fröwis, P. Grangier, H. Hübel, et al., “Long-range QKD without trusted nodes is not possible with current technology,” *npj Quantum Information*, vol. 8, no. 1, p. 108, Sep. 2022.

► [2] L. Wooltorton, **P. Brown**, and R. Colbeck, “Tight Analytic Bound on the Trade-Off between Device-Independent Randomness and Nonlocality,” *Phys. Rev. Lett.*, vol. 129, no. 15, p. 150403, Oct. 2022.

► [3] **A. Henry**, **R. Raghunathan**, **G. Ricard**, **B. Lefaucher**, **F. Miatto**, N. Belabas, **I. Zaquine** and **R. Alléaume**, “Parallelizable Synthesis of Arbitrary Single-Qubit Gates with Linear Optics and Time-Frequency Encoding.” *arXiv*, 2022.

July  
2022

01

### Kick-off of the QCommTestbed project

Part of the French Quantum Priority Research and Equipment Programme, a €150M program launched in March 2022, the QCommTestbed project gathers Sorbonne Univ., Univ. of Nice, Univ. Paris Cité, Télécom Paris, and CEA. It aims to provide France with a nationally coordinated quantum test platform, and to serve as an accelerator of technologies and a demonstrator of quantum communication applications developed from the stage of a laboratory system to the commercial products.

December  
2022

02

### Creation of the QURIOSITY project-team

The Télécom Paris quantum team formerly known as IQA has now become the joint Inria-IP Paris team QURIOSITY, see page 27.

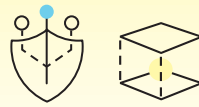
December  
2022

15

### QSNP European Project granted

QSNP (Quantum Secure Network Partnership) aims at creating a sustainable European ecosystem in quantum cryptography and communication. It federates 40 partners that include world-leading academic groups, research and technology organizations, spin-offs and major cybersecurity and telecom operators industry players. It will start in March 2023, for a duration of 3,5 years.





With the rise of cloud services and big data, new tools and techniques are necessary to enforce privacy on personal information, reduce trust requirements in authorities and tackle cryptographic questions against strong adversaries.

Two directions are specifically explored: decentralized cryptography to enhance privacy; algorithmic tools for advanced post-quantum cryptographic primitives.

C<sup>2</sup>

## Privacy guarantees

There has been overwhelming pressure in recent years from many governments to allow the government itself to access keys and messages of encryption systems (call it a “dictator’s demand”). We introduce in the following work a novel notion of “Anamorphic Encryption” which shows that even if the dictator gets the keys and the messages used in the system (before anything is sent) and no other system is allowed, there is a covert way within the context of well established public-key cryptosystems for an entity to immediately (with no latency) send piggybacked secure messages which are hidden from the dictator itself! This demonstrates the futility of the dictator’s demand. This work paves the way for new techniques for anamorphic cryptography making it a viable tool for bypassing dictators and a possible stronger answer to the futility of crypto wars.

► G. Persiano, **D. H. Phan**, and **M. Yung**, “Anamorphic Encryption: Private Communication Against a Dictator,” in *Advances in Cryptology – EUROCRYPT 2022*, Cham, 2022, pp. 34–63.

C<sup>2</sup>

## Attacks on post-quantum cryptography

There is a common belief that most post-quantum (PQ) cryptosystems are usually resistant against partial key exposure attacks, when one obtains some information—a certain fraction of the secret key bits (erasure model) or some erroneous version of the secret key (error model)—about the secret key, e.g. via side-channel leakage. We strongly question this belief by constructing partial key exposure attacks on code-based, multivariate, and lattice based schemes (BIKE, Rainbow and NTRU), and demonstrating that current post-quantum schemes allow for effective partial key exposure attacks, both in the erasure and the error setting. Our attacks exploit the redundancy that modern PQ cryptosystems inherently use for efficiency reasons.

► A. Esser, A. May, J. Verbel, and **W. Wen**, “Partial Key Exposure Attacks on BIKE, Rainbow and NTRU,” in *Advances in Cryptology – CRYPTO 2022*, Cham, 2022, pp. 346–375.

## Quantum key distribution

Modern implementations of continuous-variable Quantum Key Distribution (CV-QKD) are now converging with classical coherent communications system designs. Moving towards tighter QKD integration over existing networks, it is interesting to determine whether a pure reference signal is necessary or if a classical information-carrying channel can provide solid estimates for the quantum channel without inducing excess noise beyond the null key rate threshold. In article [1], we demonstrate for the first time a joint transmission over 15 km of a Quadrature Phase Shift Keying (QPSK) modulated classical channel and of a quantum channel carrying QPSK modulated QKD states for which carrier phase and frequency are directly recovered from the classical channel. The quantum and classical signals share hardware at emission while dedicated low-noise, low-bandwidth detectors are used at reception for the quantum channel.

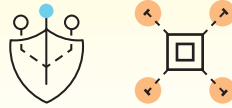
However, the QPSK modulation has some drawbacks in terms of key rate, and taking into account finite-size effects the secret key rate in the previous experiment vanishes. Using a 64-QAM modulation with a special random walk probability shaping distribution allows more power on the quantum channel and is more tolerant to excess noise. Implementing the joint transmission of quantum and classical data over a fiber length of 10 km, we obtained a secret key rate of 19.5 Mbps when taking into account finite-size effects, while no errors are accounted for on the classical channel [2]. This work contributes to reducing the overhead deployment costs of CV-QKD protocols, and represents a step towards the deployment of hybrid classical/quantum protocols.

► [1] **R. Aymeric**, **Y. Jaouën**, **C. Ware**, and **R. Alléaume**, “Symbiotic joint operation of quantum and classical coherent communications,” in *Optical Fiber Communications Conference and Exhibition (OFC)*, 2022, pp. 1–3.

► [2] **R. Aymeric**, **Y. Jaouën**, **C. Ware**, and **R. Alléaume**, “Quantum key distribution and classical communication coherent deployment with shared hardware and joint digital signal processing,” in *Quantum Technologies 2022*, vol. 12133, p. 1213307.



# Hardware security



SSH

COMNUM

Hardware security, a critical element of digital trust, involves three research themes: Vulnerability analysis, that focuses on Fault Injection Attacks (FIA)—carried out by using electromagnetic and laser sources on micro-controllers—and Side Channel Analysis (SCA); Secure protection, with the help of information theory and implementation in real circuits to prove security properties of code; Security primitives as Physically Unclonable Functions (PUF), that represent a self-generated physical fingerprint which greatly enhances the security of authentication mechanisms.

SSH

## Side channel analysis and fault injection attacks

Unintentional and uncontrollable variations in the manufacturing process of integrated circuits are used to generate silicon security primitives known as physical unclonable functions (PUFs). They represent a self-generated physical fingerprint which greatly enhances the security of authentication mechanisms. However, as Side Channel Analysis (SCA) and Fault Injection Attacks (FIA) can target them, they need to be thoroughly studied and thus enhanced with dedicated protections. In article [1], we introduce Cross-PUF attacks where a model is created using the power consumption of one PUF instance to attack another PUF created from the same GDSII file. Through simulations, we show that these attacks are highly effective in modeling PUF behaviors even in the presence of noise and mismatches in temperature and aging of the PUF used for modeling versus the targeted PUF. To mitigate the Cross-PUF attacks, we propose a lightweight countermeasure based on dual-rail and random initialization logic approaches.

Laser-based FIAs are mainly used when the adversary opts to target a specific location in a targeted circuit. However, thanks to the miniaturization of transistors, even small laser spots may illuminate more than one gate. In order to detect FIA, we propose in article [2] an array of time-to-digital convertors, aka digital sensors, to detect the laser shots. We show that by embedding these digital sensors in the target circuitry, the IR drop caused by the laser illumination can be sensed with a high accuracy.

► [1] T. Kroeger, **W. Cheng**, **S. Guilley**, **J.-L. Danger**, and N. Karimi, “Assessment and Mitigation of Power Side-Channel-Based Cross-PUF Attacks on Arbiter-PUFs and Their Derivatives,” *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, vol. 30, no. 2, pp. 187–200, 2022.

► [2] M. Ebrahimabadi, S. S. Mehjabin, R. Viera, **S. Guilley**, **J.-L. Danger**, J.-M. Dutertre, et al., “Detecting Laser Fault Injection Attacks via Time-to-Digital Converter Sensors,” in *2022 IEEE International Symposium on Hardware Oriented Security and Trust (HOST)*, 2022, pp. 97–100.

## What can information guess? Towards information leakage quantification in side channel analysis

The **SSH** and **ComNum** teams along with Secure-IC, the spinoff created in 2010 with Télécom Paris laboratories, with three of the school’s researchers as co-founders, **Jean-Luc Danger**, **Sylvain Guilley** and **Laurent Sauvage**, and now a global provider of end-to-end cybersecurity solutions for embedded systems and connected objects, have been conducting joint research on side-channel attacks for several years, especially recently with **Wei Cheng**’s thesis, defended in late 2021, under the supervision of **Olivier Rioul** (**ComNum**) and Sylvain Guillet (Secure-IC). Wei’s work was twofold: the leakage quantification of the most general form of masking equipped with the linear codes, so-called code-based masking, was first studied; then, the application of more generic information measures in a context of side-channel analysis was explored. This work pushed forward the evaluation and consolidation of side-channel security of cryptographic implementations. From a protection perspective, it provides a best-practice guideline for the application of code-based masking. From an evaluation perspective, the application of alpha-information enables practical evaluators and designers to have a more accurate (or even exact) estimation of concrete side-channel security level of their cryptographic chips.

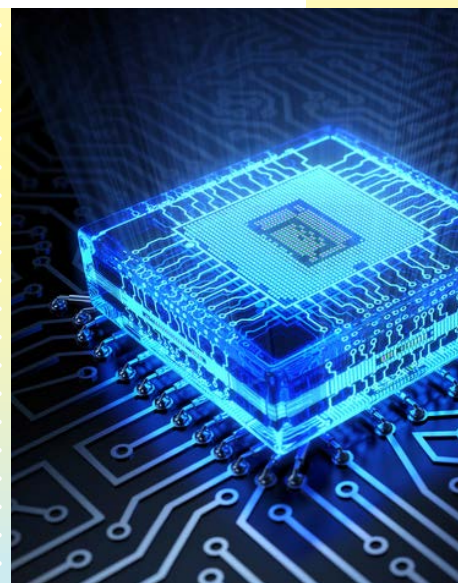


Wei Cheng, now in a post-doctoral position at Secure-IC and an invited associate researcher at Télécom Paris, was awarded the PhD thesis first prize of the ICE Department (IP Paris) in 2022.

► **W. Cheng**, **S. Guilley**, and **J.-L. Danger**, “Information Leakage in Code-Based Masking: A Systematic Evaluation by Higher-Order Attacks,” *IEEE Transactions on Information Forensics and Security*, vol. 17, pp. 1624–1638, 2022.

► **W. Cheng**, **J.-L. Danger**, **S. Guilley**, F. Huang, A. Bel Korchi, and **O. Rioul**, “Cache-Timing Attack on the SEAL Homomorphic Encryption Library,” Leuven, Belgium, Sep. 2022.

► **W. Cheng**, Y. Liu, **S. Guilley**, and **O. Rioul**, “Toward finding best linear codes for side-channel protections (extended version),” *Journal of Cryptographic Engineering*, Nov. 2022.





Intrusion Detection Systems (IDS) are essential tools to protect network security from malicious traffic. IDS have recently made significant advancements in their detection capabilities through deep learning algorithms compared to conventional approaches.

In the Vehicular communications domain, machine learning and natural language processing approaches to protect against cyber-attacks and to enhance safety by design are in extensive use.

## ACES

### Security via adversarial training

Intrusion Detection Systems (IDS) are susceptible to new types of adversarial evasion attacks. Deep learning-based IDS, in particular, are vulnerable to adversarial attacks based on Generative Adversarial Networks (GAN). In article [1], we identify the main threats to the robustness of IDS against adversarial sample attacks that aim at evading IDS detection by focusing on potential weaknesses in the structure and content of the dataset rather than on its representativeness. In addition, we propose an approach to improve the performance of adversarial training by driving it to focus on the best evasion candidates samples in the dataset. We find that GAN adversarial attack evasion capabilities are significantly reduced when our method is used to strengthen the IDS.

In the IoT application domain, past research on defending deep neural networks against adversarial examples required heavy computations in the model training or inference processes, making them impractical to be applied in IoT systems. In article [2], we propose a novel method, SUPER-IOT, to enhance the security and efficiency of AI applications in distributed IoT systems. The method utilizes a pixel drop operation to eliminate adversarial perturbations from the input and reduce network transmission throughput. It then adopts a sparse signal recovery method to reconstruct the dropped pixels and wavelet based denoising method to reduce the artificial noise. It is furthermore lightweight with negligible computation cost to IoT devices and little impact on the DNN model performance.

► [1] **H. Chaitou, T. Robert, J. Leneutre, and L. Pautet**, “Threats to Adversarial Training for IDSs and Mitigation,” in *Proceedings of the 19<sup>th</sup> International Conference on Security and Cryptography - SECURITY*, 2022, pp. 226–236.

► [2] **H. Qiu, Q. Zheng, T. Zhang, M. Qiu, G. Memmi, and J. Lu**, “Toward Secure and Efficient Deep Learning Inference in Dependable IoT Systems,” *IEEE Internet of Things Journal*, vol. 8, no. 5, pp. 3180–3188, 2021.

## SSH

### IDS based on language model

The high connectivity between the in-vehicle and the external networks paves the way for hackers who could use in-vehicle network protocols’ vulnerabilities. Among these protocols, the Controller Area Network (CAN), known as the most widely used in-vehicle networking technology, lacks encryption and authentication mechanisms

Inspired by the outstanding performance of bidirectional encoder representations from transformers (BERT) for improving many natural language processing tasks, we propose a deep learning based network intrusion detection system, to detect cyber-attacks on CAN bus protocol. We show that the BERT model can learn the sequence of arbitration identifiers in the CAN bus for anomaly detection using the “masked language model” unsupervised training objective. We tested our approach with success on the “Car Hacking: Attack & Defense Challenge 2020” dataset.

► **N. Alkhatib, M. Mushtaq, H. Ghauch, and J.-L. Danger**, “CAN-BERT do it? Controller Area Network Intrusion Detection System based on BERT Language Model.” arXiv, 2022.

## LABSOC

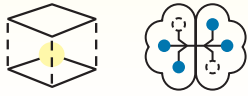
### Formalization and validation of textual requirements for the automotive industry

Technical specifications and intended functionalities often feature in documents that include requirements written in a constrained natural language, that is, natural-like language with restricted syntax. In the automotive industry one challenge is the ability to produce safe vehicles, emphasizing the importance of safety by design. Using a case studies based on functions of autonomous vehicles, we introduce a systematic process for building formal models from automotive requirements written in natural language, and for verifying them. By allowing formal verification at the earliest stages of the development cycle our aim is to avoid the costly discovery of errors at later stages.

► **A. Yasmine, R. Ameer-Boulifa, P. Guitton-Ouhamou, and R. Pacalet**, “Automatic Support for Requirements Validation,” 11<sup>th</sup> Embedded Real-Time Systems Congress (ERTS’2022), Jun 2022, Toulouse, France.



# Data science and graphs



*Graphs and game theory offer tools and methods used across both disciplines and application fields*

ACES RMS

## Using game theory to understand multi-agent interactions

In another line of research conducted in the **ACES** team, agents in a multi-agent system (MAS), typically operating under imperfect information about the other agents and the environment, are investigated. The model checking problem for MAS against specifications in the alternating-time temporal logic ATL, under perfect recall and imperfect information, is known to be undecidable. Recent approaches have attempted to overcome these difficulties, however restricting the class of MAS considered. To tackle this problem, article [1] introduces a notion of bounded recall under incomplete information. It paves the way to exploring the combinations of bounded recall with other notions of interest in specifications for multi-agent systems, including strategy logic and epistemic logic, and the combination between recall bounds and bounded resources.

The research interests of the **RMS** team lie in the design and study of future and emerging networking technologies, architectures and services. Theoretical aspects are tackled using advanced approaches and tools, such as stochastic geometry, simplicial homology, game theory, optimal control and scheduling. In article [2], the coinvestment framework between several stakeholders of different types, namely a physical network owner, operating network nodes and a set of service providers is formalized using coalitional game theory. Showing the convexity of the game, it is proved that it is always possible to form the “grand coalition”, made of all players.

- ▶ [1] F. Belardinelli, A. Lomuscio, **V. Malvone**, and E. Yu, “Approximating Perfect Recall When Model Checking Strategic Abilities: Theory and Applications,” *J. Artif. Int. Res.*, vol. 73, May 2022.
- ▶ [2] R. Patanè, A. Araldo, T. Chahed, D. Kiedanski, and **D. Kofman**, “Coalitional Game-Theoretical Approach to Coinvestment with Application to Edge Computing,” *IEEE Consumer Communications & Networking Conference (CCNC)*, 2023, Las Vegas, United States.

See also: **Yann Issartel**, who joined **S2A** in September 2022, and whose research on inference on random graphs falls within the scope of data science and graphs (page 12).

## Graphs at the cutting edge

Pursuing previous projects on applications of Optimal Transport (OT) in machine learning, **Luc Brogat-Motte** (**S2A**) introduced a novel and generic framework to solve the task of supervised labeled graph prediction by leveraging OT tools [1]. Numerical experiments showed the strength of the method on simulated data and on a difficult metabolic identification problem where it reached very good performance with very little engineering. Supported by the DSAIDIS Chair, this is also conducted with Energy4Climate (E4C) at IP Paris and École des Ponts Paris-Tech.

**Damien Ernst** (invited professor at Télécom Paris) developed Graph-Based Optimization Modeling Language (GBOML) [2], a modeling language well-suited for representing problems involving the optimization of discrete-time dynamical systems over a finite time horizon and possessing a block structure that can be encoded by a hierarchical hypergraph, such as those found in applications ranging from energy system planning to supply chain management. Before joining **S2A** in September, **Charlotte Laclau** published the first survey dedicated to fairness for relational data and the specific challenges related to the intrinsic nature of graphs [3], and explored the static and dynamic nature of graph when learning node representations and the extent to which the latter influences the success of such learning process, assessing the importance of temporal information [4].

**Simon Delarue** began a thesis entitled “Enriched graph models and algorithms for transparent machine learning” under the supervision of **Thomas Bonald** (**DIG**) that aims to develop formal methods and algorithms able to quantify and describe the transparency of a machine learning system, tackling both societal and algorithmic stakes. Simon received a Best poster award for his work on sparse graph neural networks, both at the Hi! PARIS Summer School in July and at the IP Paris PhD Welcome Day, in the Computing, Data and Artificial Intelligence category, in December.

**Olivier Hudry** (**C<sup>2</sup>**) continued his work on complexity and graph theory [5,6]. Within the XAI-4-AML Chair, **Tiphaine Viard** (**NOS**) studies the use of graph networks to better characterize abnormal and suspicious behaviors in bank transactions (see page 58).

In June, **Thomas Bonald** (**DIG**) organized a workshop on spectral methods for graph embedding as part of the TALia joint laboratory (see page 61), and the TrustShare Chair (see page 56) welcomed Sathya Peri (IIT Hyderabad) for a talk on dynamic non-blocking graph algorithms.

**Mauri Sozio** (**DIG**) pursued his work on graphs and on outliers. In article [7], he considered the robust version of the classic k-center clustering problem, where the idea is to remove outliers, under the fully dynamic adversarial model, where points can be inserted or deleted arbitrarily. He provided the first constant bi-criteria approximation algorithm for such a problem.

- ▶ [1] **L. Brogat-Motte**, R. Flamary, C. Brouard, J. Rousu, and **F. D’Alché-Buc**, “Learning to Predict Graphs with Fused Gromov-Wasserstein Barycenters,” in *Proceedings of the 39<sup>th</sup> International Conference on Machine Learning*, Jul. 2022, vol. 162, pp. 2321–2335.
- ▶ [2] B. Miftari, M. Berger, H. Djelassi, and **D. Ernst**, “GBOML: Graph-Based Optimization Modeling Language,” *Journal of Open Source Software*, vol. 7, no. 72, p. 4158, 2022.
- ▶ [3] M. Choudhary, **C. Laclau**, and C. Largeron, “A Survey on Fairness for Machine Learning on Graphs,” arXiv, 2022.
- ▶ [4] J. Tissier, **C. Laclau**, “Understanding the Benefits of Forgetting when Learning on Dynamic Graphs,” *ECML-PKDD*, 2022.
- ▶ [5] **O. Hudry** and A. Lobstein, “On the Complexity of Determining Whether there is a Unique Hamiltonian Cycle or Path,” *WSEAS Transactions on Mathematics*, 2022.
- ▶ [6] **O. Hudry** and A. Lobstein, “Complexity of the unicity of an optimal vertex cover in graphs,” *Stockholm, Sweden*, Jun. 2022.
- ▶ [7] T.-H. H. Chan, S. Lattanzi, **M. Sozio**, and B. Wang, “Fully Dynamic k-Center Clustering with Outliers,” in *Computing and Combinatorics*, Cham, 2022, pp. 150–161.



**Gaël Richard (S2A)** has been awarded an advanced European Research Council (ERC) grant from the European Union for a project on machine listening. This initiative aims to develop hybrid approaches that combine signal processing with deep machine learning for the purpose of understanding and analyzing sound.

**Gaël Richard**, Professor (S2A) and Scientific Co-Director of Hi! PARIS (see page 25), was awarded the 2020 Grand Prix IMT-Académie des Sciences. His research, anchored in the field of digital transformation sciences and technologies, focuses on the analysis, transformation, recognition, understanding and automatic indexing of sound signals (including speech, music, environmental sounds), and brings into play advanced principles of statistical signal processing, optimization and machine learning. In particular, he developed several source separation methods for audio and musical signals based on machine learning approaches.

He is currently the Vice-chair of the IEEE Audio and Acoustic Signal Processing Technical Committee, member of the EURASIP and AES and fellow member of the IEEE.

*Using signal models, or physical sound propagation models, in a deep learning algorithm would reduce the amount of data needed for learning while still allowing for the high controllability of the algorithm*

### Hi-Audio: an ERC grant for Gaël Richard

AI for Sound is defined as the general field of Artificial Intelligence applied to audio analysis, understanding and synthesis by a machine. It can also be viewed as the intertwined domain of Machine learning and audio signal processing and is applicable in a wide range of fields. As in other AI fields, this one has rapidly moved toward so-called end-to-end neural approaches, which aim to directly solve the machine learning problem for raw acoustic signals but often only loosely taking into account the nature and structure of the processed data. Actual audio models are recognized as being overly complex, require massive amounts of data to be trained and extreme computing power to be efficient (in terms of task performance), and they remain largely unexplainable and non-interpretable.

Gaël Richard believes that our prior knowledge about the nature of the processed data, their generation process and their perception by humans should be explicitly exploited in neural-based machine learning frameworks to be able to build more frugal and interpretable AI systems. Moreover, the integration of physical sound propagation models can improve the characterization and configuration of the types of sound analyzed and help to develop an automatic sound recognition system. It is therefore promising to build hybrid deep approaches combining parameter-efficient and interpretable signal models, musicological and physics-based models, with dedicated neural generative networks.

This research is at the heart of Gaël Richard's ERC advanced project "Hi-Audio" (Hybrid and Interpretable Deep neural audio machines). Targeted industry applications are varied, including speech and audio scene analysis, identification of a recording's sound environment, sound event detection and classification, quality control based on the sound resonance of the object to control, music information retrieval, new musical transformation and creation capabilities (style transfer, rhythmic transformation, word changes) and sound synthesis.

Hi-Audio started on October 1st, 2022 and is funded by the ERC Advanced Grant for five years for a total amount of €2.48 million (n°101052978 ERC-2021-ADG).

► **K. Schulze-Forster**, C. S. J. Doire, **G. Richard**, and **R. Badeau**, "Phoneme Level Lyrics Alignment and Text-Informed Singing Voice Separation," IEEE/ACM Transactions on Audio, Speech, and Language Processing, vol. 29, pp. 2382–2395, 2021.

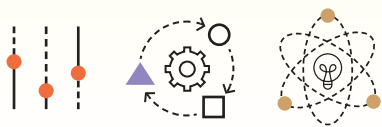
► **G. Peeters** and **G. Richard**, "Deep Learning for Audio and Music," in *Multi-faceted Deep Learning: Models and Data*, J. Benois-Pineau and A. Zemmari, Eds. Cham: Springer International Publishing, 2021.

► **D. Perera**, **S. Essid**, and **G. Richard**, "Latent and Adversarial Data Augmentation for Sound Event Detection and Classification," Nancy, France, Nov. 2022.

► See also the Keynote talk at Dafx'2022: "Hybrid deep learning for audio", Sept. 2022, Vienna, Austria.



# Operating in an uncertain world



*Academic research in the sciences and humanities can bring order to an uncertain world, transforming the uncertain into the probable, and the unknown into the known*

**Valérie Fernandez and Thomas Houy (NOS)** have a track record of supporting large groups and start-ups in their innovative projects. Based on these experiences, they made a twofold observation. Societal, environmental and digital upheavals have generated a step change. We have moved from a world of risk, which we may be able to cover, to a world of uncertainty that renders obsolete the traditional management tools—business plans, market studies, competition studies—used by companies. For the past ten years, the difficulty of predicting the future has made them inoperative. And yet, scientific research has made major advances in disciplines related to decision making in an uncertain world. Unfortunately, companies are not aware of this work.

With the simultaneous open access publication of “Déplier l’incertain”, a book, a MOOC on Coursera and a practical tool—a Decision Model Canvas, our researchers adopt an approach that is still rare in the social sciences: to build bridges between the academic and professional worlds in order to provide business leaders with tools for managing operational projects in an uncertain, unpredictable and unstable environment.

May  
2022

25

INTERACT

## The way we think of belief and the way it operates have recently shifted

Each new advance in communications technology opens up new possibilities for how people present—and misrepresent—themselves and the things they believe.

In a seminar organized by **Michael Baker (INTERACT)**, **Eli Gottlieb**, guest professor at Télécom Paris, argued that the increasing difficulty in distinguishing fabricated stories and pictures from genuine ones is affecting not only what we believe but also how we believe. He showed that the idea of belief as a continuous variable measured in degrees of certainty is being replaced by the idea of belief as a binary function of “all in” versus “all out.”

September  
2022

09

COMNUM

## Does specific knowledge always reduce uncertainty?

**Olivier Rioul (ComNum)** explained his point of view as a mathematician, as did **Divna Petković**, Doctor of linguistics, on the topic of “Uncertainty and Knowledge: Mathematical and Linguistic Polysemy”, during the “Nuit de l’ENS”.

ECO

## Scapegoating and discrimination in times of crisis: Evidence from Airbnb

In the following paper, **Michelangelo Rossi (ECO)** presented evidence that discrimination against Asian-American Airbnb users increased sharply at the start of the Covid-19 pandemic. Results point to the role of platform design choices in enabling discrimination.

► **M. Luca**, **E. Pronkina**, and **M. Rossi**, “Scapegoating and Discrimination in Times of Crisis: Evidence from Airbnb,” National Bureau of Economic Research.

All books authored or edited by Télécom Paris researchers in 2022 are listed pp. 66–67.

# Living in a digitized world

ECO

## Digitization

Digitization can make our societies and economies more resilient to shocks. For instance, we found evidence that consumers adjusted rapidly during the first Covid-19 lockdown period, mitigating the effects of mobility restrictions via an increasing shift toward online purchasing [1].

Removing cross-border barriers to online commerce may thus seem beneficial, but we find only modest gains from this policy, stemming mainly from increased product choice. Besides, the gains are unevenly distributed between high-income and low-income countries [2].

Digitization and the move towards a knowledge economy may require rethinking public policy. For instance, we found evidence that companies tend to relocate their patents when they face a tax increase, encouraging inefficient tax competition between countries [3].

Finally, digitization may affect content creators themselves. In particular, we have shown that the development of streaming platforms has led to a significant increase in music's acoustic diversity [4].



*Exploring our understanding of digital transformations and their impact on the economy, companies and public policy*

► [1] **D. Bounie, Y. Camara** and J. Galbraith (2022). Consumer Mobility and Expenditure during the COVID-19 Containments: Evidence from French Transaction Data, European Economic Review, Forthcoming.

► [2] N. Duch-Brown, **L. Grzybowski**, A. Romahn and F. Verboven (2022). International price differences in online markets - Evidence from portable computers, American Economic Journal: Micro, Forthcoming.

► [3] **L. Ciaramella** (2022). Taxation and the Transfer of Patents: Evidence from Europe, European Economic Review, Forthcoming.

► [4] **M. Bourreau**, F. Moreau and P. Wilström (2022). Does digitization lead to the homogenization of cultural content? Economic Inquiry, 60, 427-453.

NOS

## Innovating in times of crisis

Crises challenge us in our ability to find solutions to unprecedented difficulties, to re-examine problems that we thought had been solved, or to accelerate developments that had only been sketched out. In a word, they encourage us to innovate.

Written by researchers in management, economics, sociology, and information and communication sciences, under the coordination of Hervé Dumez, CNRS, École polytechnique, **Benjamin Loveluck**, Télécom Paris (NOS) and Alexandre Mallard, Mines Paris PSL, this book testifies to the strength of individual and collective approaches that emerged during the pandemic, and to the variety of forms in which innovation phenomena are presented.

ECO

## Digital platforms

The development of digital platforms has brought significant benefits to our economies and societies. For instance, microtasking platforms like Amazon Mechanical Turk represent an opportunity for less educated workers to earn income in unemployment phases [1].

Online marketplaces facilitate the entry of new service providers, e.g., hosts on Airbnb. Consumers care about the number of hosts available but also their reputation. However, more competition between hosts may erode their incentives to offer high-quality services, highlighting a trade-off between the quantity and quality of service providers [2].

The market power of platforms raises concerns about their ability to bias recommendations or search results to the detriment of users. In particular, a vertically integrated platform may have the incentive to make its products more prominent than rivals' products [3].

► [1] **U. Laitenberger**, S. Viète, O. Slivkó, M. Kummer, K. Borchert and M. Hirth (2022). Unemployment and Online Labor - Evidence from Microtasking. Management Information Systems Quarterly, Forthcoming.

► [2] **M. Rossi** (2022). Competition and Reputation in a Congested Marketplace: Theory and Evidence from Airbnb. Management Science, Forthcoming.

► [3] M. Cure, M. Hunold, R. Kesler, **U. Laitenberger** and T. Larrieu (2022). Vertical integration of platforms and product prominence, Quantitative Marketing and Economics, Forthcoming.



Web

<https://clavel.wp.imt.fr/>



**Chloé Clavel**  
Professor, Social Computing

Chloé Clavel’s research contributes to the development of methods from artificial intelligence (computational models of socio-emotional behaviors by combining symbolic and machine learning approaches) and affective computing (analysis and synthesis of socio-emotional signals) and is part of a larger topic of Social Computing that she coordinates within the LTCl. She has been working on the automatic analysis of social signals in various types of audio and multimodal conversational data (e.g., call-centers and job video interviews). She is currently working on interactions between humans and virtual agents, including the analysis and the generation of the socio-affective behavior (verbal and non-verbal) and the definition of socio-emotional interaction strategies.

Her main research contributions and interest are in: explainable and tractable AI for socio-emotional behavior (trust, engagement, opinions, social stances, emotions, etc.) analysis and generation in interactions; creation (collection and annotation) and distribution of spontaneous human-human or human-agent interactions including the recent promising UE-HRI for the study of the user’s engagement in human-robot interactions.

She has contributed to several European and national collaborative projects relating to Social Computing (e.g. H2020 ITN ANIMATAS (ended in 2022), aria-valuspa UE-TIC, Labex smart). She is Co-head of the NoRDF Chair (see page 58), and co-responsible for the fourth research theme—Learning through interactions with environment—of the DSAIDIS Chair (see page 59). She is also part of the academic team of the French National Agency of Research (ANR) REVITALISE (viRtual bEhaVioral skills TrAining for pubLic SpEaking) that aims to improve the practice of public speaking skills with technologically-mediated tools. She is also a reviewer of several journals and conferences on affective computing, natural language processing, machine learning and robotics. She is Associate Editor for the IEEE Transactions of Affective Computing and was Area Chair for Interspeech in 2021 and 2022.

#### PUBLICATIONS

- ▶ **L. Hemamou**, A. Guillon, J.-C. Martin, and **C. Clavel**, “Multimodal Hierarchical Attention Neural Network: Looking for Candidates Behaviour which Impact Recruiter’s Decision,” IEEE Transactions on Affective Computing, 2021.
- ▶ **C. Chhun**, P. Colombo, **F. Suchanek**, and **C. Clavel**, “Of Human Criteria and Automatic Metrics: A Benchmark of the Evaluation of Story Generation,” 29<sup>th</sup> International Conference on Computational Linguistics (COLING 2022), Oct 2022, Gyeongju, South Korea.
- ▶ **G. Guibon**, **M. Labeau**, H. Flamein, L. Lefevre, and **C. Clavel**, “Few-Shot Emotion Recognition in Conversation with Sequential Prototypical Networks,” The 2021 Conference on Empirical Methods in Natural Language Processing (EMNLP 2021), Nov 2021, Punta Cana, Dominican Republic.

# Social

# computing



Studying social computing and human-robot interaction provides opportunities to address various challenges in multilingual and business contexts, using specific or synthetic conversational datasets.

A crucial step is the identification of underlying information in the user’s behavior—communicative intent, dialog, emotions—that takes place during multimodal interactions.

## INTERACT

### Social robotics

**Damien Rudaz**’s thesis aims to gain a better understanding of the way in which opening sequences are organized between a robot and a human, in a public or commercial space, in order to draw industrial applications for social robots. In article [1], the multi-modality—proxemics for social navigation, gaze mechanisms, kinesics, and social dialogue—of an interaction with a robot is investigated. The multi-modal social behaviors are evaluated and the effects on perceived social intelligence through both objective and subjective measurements are analyzed.

Constructs intended to capture social attitudes and behavior towards social robots are incredibly varied, with little overlap or consistency in how they may be related. In an other study [2], exploratory analyses between participants’ self-reported attitudes and behavior towards a social robot are conducted. The social attitudes towards the robot that were examined span social trust, liking, rapport, competency trust, technology acceptance, mind perception, social presence, and social information processing.

Damien’s thesis is being carried out at Aldebaran, under the direction of **Christian Liccoppe** (INTERACT).

▶ [1] K. Tatarian, R. Stower, **D. Rudaz**, M. Chamoux, A. Kappas, and M. Chetouani, “How does Modality Matter? Investigating the Synthesis and Effects of Multi-modal Robot Behavior on Social Intelligence,” International Journal of Social Robotics, vol. 14, no. 4, pp. 893–911, Jun. 2022.

▶ [2] R. Stower, K. Tatarian, **D. Rudaz**, M. Chamoux, M. Chetouani, and A. Kappas, “Does What Users Say Match What They Do? Comparing Self-Reported Attitudes and Behaviours towards a Social Robot,” Naples, Italy, Aug. 2022.

▶ See also: **D. Rudaz**, K. Tatarian, R. Stower, and **C. Liccoppe**, “From Inanimate Object to Agent: Impact of Pre-Beginnings on the Emergence of Greetings with a Robot,” Accepted at ACM Transactions on Human-Robot Interaction.

# Co-designing in the urban space



March 2022 **30**

**INTERACT**

## i3 interdisciplinary study day: Why, with whom and how to design?

Co-organized by **Aliénor Morvan** (INTERACT), this one-day seminar brought together researchers from various disciplines (design, sociology, ergonomics, management sciences, etc.) and professionals from different levels of design (public authorities, innovation management, designers, architects, urban planners, etc.) to explore the figure of the citizen-user, the methodological adaptations which include the clarification of processes and the reinvention of the project's tools, and the decision-making processes.

November 2022 **17**

**INTERACT**

## Empowerment of users in the design of housing architecture

During a round-table at a one-day seminar at the Académie d'Architecture, **Benjamin Loiseau** (INTERACT) presented his work on the renovation of the Grand'Goule district in Poitiers, a 274-unit experimental social housing project built in the 1970s and currently being rehabilitated with a codesign approach.

Benjamin's thesis aims to create a rigorous evaluation method to identify projects resulting from collaborative approaches in the design of housing architecture. This methodology will bring out the recurrent problems faced by professionals and inhabitants involved in collaborative processes and check invariants allowing the elaboration of an innovative co-design project, resulting in a model for assessing the adequacy of project intentions and outcomes.

**INTERACT**

## Disability

**Marc Relieu** (INTERACT) produced several contributions on different aspects of mobility skills used by visually impaired people finding their way in the city. For instance, based on video recordings of locomotion and orientation lessons for visually-disabled students, he examined how occasioned maps drawn in the student's palm are traced interactionally, felt and noticed, emphasizing among other observations how coparticipants establish a mutual bodily position which facilitates the drawing process.

► **M. Relieu**, "Geometrical Touch: Drawing an occasioned map on the hand", under review.

It has become more and more common to involve citizens in the life of the city through co-design processes. Issues as varied as transport and mobility, environment and ecology, architecture, new inhabitants, employment, or accessibility are indeed conducive to a work of co-creation.

However, the mobilization of the public from the genesis of a project raises a number of questions: Between requiring information and embodying the uses, what is the exact place of citizen/user? What are the objectives of co-design and what is expected of the citizen? Who should be involved? What are the tools and methods for co-design that can support citizens' capacities to generate innovative concepts? Which conceptual tools and approaches should be mobilized and implemented collectively? Moreover, there is little systematic post-evaluation of the projects carried out, and of the methods and tools implemented.

These issues are central to two ongoing theses by **Benjamin Loiseau** (architect) and **Aliénor Morvan** (designer) in the INTERACT team, under the supervision of **Stéphane Safin** and **Françoise Détienne**. In 2022, they co-organized two seminars illustrative of the multidisciplinary approach of these topics, where they also presented their work in progress.

**INTERACT**

## Mobility

**Béatrice Cahour** (INTERACT) is involved in two new projects for 2022-2025: Taxirail, a light autonomous shuttle train project supported by ADEME, the French Agency for Ecological Transition, will feature in postdoctoral research on codesign approaches and future services, focusing on benefits and fears from the users' point of view; With Renault, a thesis entitled "Risk and stress management in an automotive context: Cognitive model and prescription of a support system" will aim at developing aids for drivers who are still apprehensive about driving in certain situations and who feel strongly embarrassed, or even handicapped, by the feeling of stress or risk that they experience and which may lead them to give up driving. In addition and still with Renault, research on ownership processes and trust evolution in level 2 autonomous driving systems is ongoing.

See also: **Panos Mavros**, who joined INTERACT in December 2022, and whose research interests will reinforce the team competences on urban issues (page 13).



# Facing real world conditions



*When it comes to deploying real-world applications, issues such as local constraints, malicious use and abuse and regulatory requirements constantly evolving, must be considered and taken into consideration very early on*

MM

## Lightly-supervised learning and domain adaptation

In article [1], we study a target domain—Person Re-Identification, i.e. recognizing a query of person-of-interest within a gallery of images—that consists of a stream of data in a practical real-world application, where data is continuously arising from the network’s cameras. In addition, regulations stating that the collected data can be stored for only a limited period add a constraint. We present a new yet practical online setting for Unsupervised Domain Adaptation (UDA) for person Re-ID with these two main constraints of online adaptation and privacy protection, and adapt and evaluate the state-of-the-art UDA algorithms on this new setting.

Multi-target domain adaptation (MTDA), which consists in adapting a single model from an annotated source dataset to multiple unannotated target datasets that differ in their underlying data distributions, is addressed in [2] for the semantic segmentation task where it was previously understudied. We present a novel MTDA framework for semantic segmentation that employs a self-training strategy based on pseudo-labeling to induce better synergy between different domains. In addition, to prevent the network from over-fitting to noisy pseudo-labels when the domain-shift is large, we devise a cross-domain cooperative rectification strategy that captures the disagreement in predictions from different classifiers.

► [1] **H. Rami**, M. Ospici, and **S. Lathuilière**, “Online Unsupervised Domain Adaptation for Person Re-Identification,” in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops*, Jun. 2022, pp. 3830–3839.

► [2] **Y. Zhang**, S. Roy, H. Lu, E. Ricci, and **S. Lathuilière**, “Cooperative Self-Training for Multi-Target Adaptive Semantic Segmentation.” arXiv, 2022.

NOS

## Legal and ethical requirements for facial recognition systems

European and international texts are rapidly increasing and stakeholders are calling for a certain number of recommendations to be respected, such as the robustness and safety of systems, transparency and explainability, non-discrimination and fairness (HLEG, 2020). European law is also evolving with the European Commission’s proposal for a regulation on AI—the AI Act. As part of the LIMPID project (see page 63), **Mélanie Gornet**’s thesis (NOS), “Ethics and regulation of machine learning systems: building operational requirements for image recognition algorithms”, aims to understand the ecosystem around so-called “trustworthy AI” and the shortcomings of the ethical principles defended by international texts, in particular concerning their operability.



Mélanie presented her work at the Interdisciplinary Institute on Innovation (i3) PhD students day in May during a workshop on cities and territories, and at the IP Paris PhD Welcome Day in December, where she received the Best Poster Award in the Economy, Management and Social Sciences category.

INTERACT DIVA

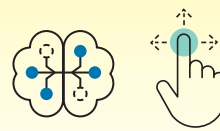
## Virtual-physical perceptual manipulations

Making a user (really) fall down a staircase: This is one of the virtual reality manipulation scenarios studied in a collaborative project involving **INTERACT** and **DIVA** teams and the University of Glasgow. “Virtual-Physical Perceptual Manipulations” (VPPMs) leverage knowledge of the limits of human perception to effect changes in the user’s physical movements, as they become able to nudge their physical actions to enhance interactivity in VR. However, malicious uses of VPPMs can pose high threats and risks to the user. We propose in the following paper several mitigations and preventative recommendations against such malicious uses, and implement two sample applications demonstrating how existing VPPMs could be trivially subverted to create the potential for physical harm.

► **W.-J. Tseng**, **E. Bonnail**, M. McGill, M. Khamis, **E. Lecolinet**, **S. Huron**, et al., “The Dark Side of Perceptual Manipulations in Virtual Reality,” in *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, New York, NY, USA, 2022.







Supported by the spectacular development of AI, the field of visual computing is facing new challenges. Research is being conducted in image analysis and understanding, computer vision and 3D computer graphics—covering the entire spectrum of the modeling, analysis, transformation, representation, interpretation and synthesis of images, 3D and digital objects—and for the entire life cycle of multimedia documents and signals— acquisition, coding, transmission, transport, interactivity and recognition.

A wide range of application fields is covered by this topic: medical imaging, remote sensing, image and video editing with tasks ranging from denoising and classification to scene understanding.

### SAR imaging

Speckle fluctuations seriously limit the interpretability of synthetic aperture radar (SAR) images. In line with previous works on speckle reduction through deep neural networks techniques, and as speckle-free images are generally not available, we introduced in article [1] a self-supervised strategy based on the separation of the real and imaginary parts of single-look complex SAR images, completely suppressing the need of building training sets with reference images. This paves the way to very large scale training using entire archives of SAR images that could lead to unprecedented despeckling performances.

Article [2] was awarded Best Student Paper (2<sup>nd</sup> place) at EUSAR 2022. Article [3] received the 2021 IEEE GRSS Symposium Prize Paper Award during IGARSS 2022.

- ▶ [1] **E. Dalsasso**, L. Denis, and **F. Tupin**, “As if by magic: self-supervised training of deep despeckling networks with MERLIN,” *IEEE Transactions on Geoscience and Remote Sensing*, vol. 60, 2022.
- ▶ [2] **E. Dalsasso**, L. Denis, M. Muzeau, and **F. Tupin**, “Self-supervised training strategies for SAR image despeckling with deep neural networks,” Leipzig, Germany, Jul. 2022.
- ▶ [3] **E. Dalsasso**, **I. Meraoumia**, L. Denis, and **F. Tupin**, “Exploiting Multi-Temporal Information for Improved Speckle Reduction of Sentinel-1 SAR Images by Deep Learning,” Jul. 2021.

See also Medical Imaging: Projects IMAG2 (Pietro Gori & Isabelle Bloch) and Midway+ (Elsa Angelini), IP Paris 2022 call, page 27.

### Interactive computer graphics

The article below introduces a simple framework for coloring raster sketches with gaps in the contours, based on a novel Delaunay-triangulation-based coloring method, that uses an intuitive flow mechanism. Implemented as an interactive tool, the method allows the artist/user to modify or adjust the result with minimum effort. An automatic companion method is also provided. This handy tool for automatic pre-segmentation and fast interactive segmentation correction has been tested in a medical use case. Indeed, when identifying tumors in a medical image, especially from MRI scans, 3D segmentation input is needed, and manual labeling in 2D is still used for training data. Our method could enrich or simplify this time-consuming process.

- ▶ **A. D. Parakkat**, P. Memari, and M.-P. Cani, “Delaunay Painting: Perceptual Image Colouring from Raster Contours with Gaps,” *Computer Graphics Forum*, vol. 41, no. 6, pp. 166–181, 2022.

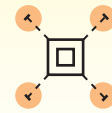
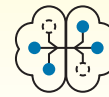
### Generative networks

In line with previous projects, article [1] presents “Playable Environments” (PE), a new representation for interactive video generation and manipulation in space and time. A method to construct PEs of complex scenes is proposed that supports a large set of interactive manipulations, allowing the user to interactively generate videos by providing discrete actions and controlling the camera pose. Based on a new compositional NeRF that handles deformable objects with different visual styles and an action module that operates in the latent space of the NeRF model, the method can represent environments with multiple objects and their varying poses and appearances and is robust to imprecise inputs.

In article [2], a novel architecture for GAN inversion, called Feature-Style encoder, is proposed. The novelty is to learn an encoder in the feature-style space, which maps an image to a feature code and a latent code. The feature code encodes spatial details, and the latent code is used for editing. The model achieves accurate inversion of real images from the latent space of a pre-trained style-based GAN model, obtaining better perceptual quality and achieving a balanced trade-off between reconstruction quality and editing capacity.

- ▶ [1] W. Menapace, **S. Lathuilière**, A. Siarohin, C. Theobalt, S. Tulyakov, V. Golyanik, et al., “Playable Environments: Video Manipulation in Space and Time,” in *2022 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 2022, pp. 3574–3583.
- ▶ [2] **X. Yao**, **A. Newson**, **Y. Gousseau**, and P. Hellier, “A Style-Based GAN Encoder for High Fidelity Reconstruction of Images and Videos,” in *Computer Vision – ECCV 2022*, Cham, 2022, pp. 581–597.

# AI frugality and sustainability



S2A

A more frugal and resilient digital era cuts across all the research themes and teams at Télécom Paris. This spans energy efficient networks and devices, smart materials, resource allocation, use of machine learning to better design, and study of frugal innovations and their socio-economic impact. On the pure data science side, one main question is “How to reduce complexity of statistical learning in time or/and in memory?” These issues are dealt with using several approaches such as approximations by random projections, compression by design (learning a quantized network), parameter reduction by a posteriori compression, and frugality by meta-learning strategies (few-shot learning and transfer learning), to name just a few. Mathematical expertise in fields such as learning theory or numerical optimization, and the quest to always design algorithms with theoretical guarantees, strengthen all our contributions towards a more sustainable digital.

## Optimization towards frugal AI

Many machine learning applications, from generative adversarial networks to robust reinforcement learning, result in nonconvex-nonconcave constrained minimax problems, which pose notorious difficulties to the scalable first order methods. In article below, we introduced an extragradient-type algorithm for a class of such problems satisfying the weak Minty variational inequality (MVI). This problem class captures non-trivial structures for which a large family of existing algorithms provably converge to limit cycles. Our proposed algorithm requires a less restrictive parameter range in the weak MVI compared to what is previously known, and guarantees global convergence for an even larger class of problems.

► T. Pethick, P. Latafat, P. Patrinos, **O. Fercoq**, and V. Cevher, “Escaping limit cycles: Global convergence for constrained nonconvex-nonconcave minimax problems,” International Conference on Learning Representations, 2022.

► See also the research works presented during a workshop on optimization and neural networks, organized by the DSAIDIS Chair in November: <https://datascienceandai.wp.imt.fr/en/agenda/optimization-workshop/>

C2S

MM

SSH

## Rethinking artificial neurons, a step towards saving computational resources

Today’s deep neural networks are still processed on GPUs with von Neumann architecture where memory and computing units are separated, causing a bottleneck in time and energy when moving data between these units. Hence, non-von Neumann architecture inspired by the brain is a promising architecture. Introduced in 2017 as a more biologically plausible back-propagation algorithm, the Equilibrium Propagation algorithm has been used for analog neural networks in 2020. However, the impacts of the learning rate and the scaling factor of the feedback current have not been discussed. They are studied in article [1] together with the ratio of those two parameters on the algorithm convergence.

Recent advances in deep learning optimization showed that, with some a-posteriori information on fully-trained models, it is possible to match the same performance by simply training a subset of their parameters. In a research work produced as part of Energy4Climate Interdisciplinary Center (E4C) of IP Paris and École des Ponts ParisTech, we introduce and study the knowledge of neuronal equilibrium, looking for entire structures of the deep model at equilibrium, not requiring further optimization and gradient computation, which self-adapts to very specific experimental setups on very different learning scenarios [2].

Large-scale deployment of Convolutional Neural Networks in embedded devices is still limited by huge computational and memory bandwidth requirements. In article [3], we show that it is possible to replace multipliers by minimum operations in the forward propagation under certain constraints, i.e. given similar mean and variances of the feature and the weight vectors. A modified training method which guarantees the above constraints is proposed. In addition, we used transfer learning to achieve accuracy similar to standard networks during inference.

► [1] **F. Z. Kiraz, D.-K. G. Pham**, and **P. Desgreys**, “Impacts of Feedback Current Value and Learning Rate on Equilibrium Propagation Performance,” in *2022 20<sup>th</sup> IEEE Interregional NEWCAS Conference (NEWCAS)*, Quebec City, Canada, Jun. 2022, pp. 519–523.

► [2] A. Bragagnolo, **E. Tartaglione**, and M. Grangetto, “To update or not to update? Neurons at equilibrium in deep models.” arXiv, 2022. NEURIPS 2022.

► [3] **X. Yang, S. Chaudhuri, L. Likforman**, and **L. Naviner**, “Minconvnets: a New Class of Multiplication-Less Neural Networks,” in *2022 IEEE International Conference on Image Processing (ICIP)*, 2022, pp. 881–885.

# Safety by design for cyber-physical systems and industry 4.0

Cyber-Physical systems are at the heart of the digital transformation with Industry 4.0. Coupled with digital twins, they pave the way to smart manufacturing, in which real-time transmission and analysis of data in embedded systems and distributed systems are fundamental issues. For these systems that commonly act on their environment with actuators, and on which cyber-attacks can induce severe safety consequences on their environment, nonfunctional properties such as criticality, autonomy or security must be guaranteed. Innovative methodological tools to specify, model, simulate, design, deploy mechanisms and finally verify the effectiveness of these mechanisms are of prime importance towards a safe and trustworthy industry.

## LABSOC

### Security countermeasures on Cyber-Physical Systems

Deploying security countermeasures on CPS can induce side-effects that potentially exceed their benefits. When CPS are safety-critical systems, performing efficiency and impact assessments of security countermeasures early in the design flow is essential. We introduce a new method based on SysML-Sec—called “W-efficiency and impact assessment method”, W-Sec method for short—that consists in two interwoven formal modeling and verification cycles. It brings two main improvements: reducing models complexity while enhancing the model precision for hardware and security aspects, and widening its assessment basis through more fine-grained security analyses. The method was evaluated with an autonomous rover swarm case-study.

► **B. Sultan, L. Apvrille,** and P. Jaillon, “Safety, Security and Performance Assessment of Security Countermeasures with SysML-Sec,” Vienna, Austria, 2022.



## C2S

### Using machine learning to better design analog integrated circuits

Analog integrated circuit design is widely considered a time-consuming task. An important research effort has been conducted along the years to reduce the front-end design cycles of analog circuits by means of various automation approaches. Today, machine learning is a good candidate to secure this process in an acceptable way, but to what extent?

The following paper provides a comprehensive overview of the existing state-of-the-art machine learning techniques used in analog circuit sizing and analyzes their effectiveness in achieving the desired goals. The contribution is twofold: (1) to provide answers on which circuits and to which extent ML techniques were effectively used to help analog designers achieve good results; (2) to elaborate on the existing limitations that require further investigations in the field, and to point out the remaining open challenges, as well as the most relevant research directions to be explored.

► **R. Mina, C. Jabbour,** and G. E. Sakr, “A Review of Machine Learning Techniques in Analog Integrated Circuit Design Automation,” *Electronics*, vol. 11, no. 3, 2022.

## ACES

### Trustworthy design

Aiming at proving conformance to memory standards and bound memory access latency, recently proposed real-time DRAM controllers rely on paper and pencil proofs, which can be difficult to read and review. Lacking a formal link between implementation and proofs, they can easily diverge.

We proposed a new framework written in Coq, in which we model a DRAM system as a formal specification. The timing requirements are written as proof obligations, which all arbiter instances must comply with. Trustworthiness is twofold: 1) proofs are now certified by Coq’s kernel, and 2) the reviewer’s job develops into making sure that the formal specification matches the standards—instead of performing a thorough check of the underlying mathematical formalism. We also refined the specification with two implementations, extracted code from our model and used it as a “trusted core” on a cycle-accurate simulator.

This paper received the Best Paper Award at the 30<sup>th</sup> International Conference on Real-Time Networks and Systems (RTNS).

► **F. Lisboa Malaquias,** M. Asavaoae, and **F. Brandner,** “A Coq Framework for More Trustworthy DRAM Controllers,” in *Proceedings of the 30<sup>th</sup> International Conference on Real-Time Networks and Systems*, New York, NY, USA, 2022.





## A new step for Télécom Paris Novation Center

A precursor in incubation since 1999, Télécom Paris has to date assisted more than 500 companies—including some of the best FrenchTech startups—in the acceleration and development of their products and services, in digital technologies such as data and AI, blockchain, cybersecurity, robotics, etc. Thanks to close ties with the Institut Polytechnique de Paris and its network of founders, the School's incubator, Télécom Paris Novation Center, is gaining a strong reputation in the digital field in Paris.

Starting from July 1, 2022, and inaugurated on September 20, the incubator is now based at Station F—the world's largest startup campus in the heart of Paris. The objective of this new program at Station F, placed under the governance of Télécom Paris and managed operationally by the school's incubator team, is to provide support over a period of 18 months to startups from pre-seed to Series A, most of which have been founded or co-founded by alumni of Institut Polytechnique de Paris. It will also host projects linked to the IP Paris schools' key research themes, such as digital trust, frugal AI, networks and data science, as well as to advanced student entrepreneurship projects, with a particular focus on those at Télécom Paris.



# Innovate & Transfer

03



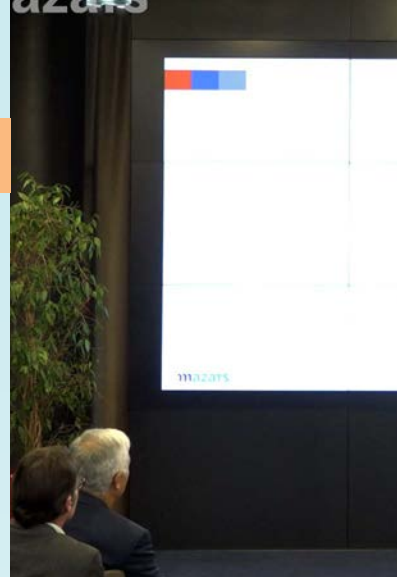


# Industrial chairs

Télécom Paris runs an active training and research program in partnership with companies to proactively support and enhance innovation with the help of Fondation Mines Télécom. Within its Chairs, a multidisciplinary research approach contributes to guide companies, citizens and public authorities.

This multidisciplinary dimension falls under three headings: most of our Chairs bring together members of different research teams; for specific subjects, work carried out with a single industrial partner, as part of a multi-year project or in a joint laboratory (see pp. 58-59), may establish links with some of the Chair research themes; finally, “initiatives” such as the Operational AI Ethics program (see pp. 60-61), that bring together complementary expertise of researchers from several teams, are also linked to the objectives of several Chairs.

Here is a selection of notable activities in 2022.



## Modeling, Characterization and Control of Exposures

The C2M Chair is part of the European consortium for two (among the four) Horizon Europe projects selected for funding from the call HORIZON- HLTH-2021-ENVHLTH-02-01 Exposure to electromagnetic fields (EMF) and health: SEAWave and GOLIAT (see page 22). These projects, started in June 2022, will last 3 and 4 years respectively.

The Chair is also partner of the Kapteos' TopTen project, developed in partnership with CEA-Leti, and supported as part of the French government recovery plan, which aims to accelerate the development of 5G by reducing the time and cost of designing antennas and radars, particularly in the test phase.

Two webinars for the scientific community and the Chair's partners were held in 2022.

April **26** 2022

“Electromagnetic field exposure assessment, standardization of compliance verification methods and impact of 5G”, with Emmanuelle Conil (ANFR) and Christophe Grangeat (Nokia).

May **19** 2022

“Coordinating EMF mitigation activities and supporting energy efficiency programs”, with Monica Guxens, GOLIAT project leader, and Theodoros Samaras, SEAWave project leader, who presented the objectives and expected results of these two initiatives.

The C2M Chair explores five research areas: Numerical and experimental dosimetry; Statistical modeling of exposure; Stochastic dosimetry; Influence of network technologies and architectures on exposure, standardization of exposure assessment methods; Parameters governing the social perception of risk.

Partners: Huawei, ANFR, MGX, Orange, TDF, Atos

► [www.chairec2m.wp.imt.fr](http://www.chairec2m.wp.imt.fr)

## TrustShare



April **14** 2022

Inauguration of the TrustShare Chair with Mazars, Caisse des Dépôts and the Fondation Mines-Télécom.

The aim of the Chair, initiated in 2021, is to design decentralized algorithms that are more efficient, respect confidentiality and are adapted to the variety of uses of the blockchain.

Two workshops for partners, focusing on the work of doctoral students, held in October 2021 and September 2022. The latter was introduced by **Petr Kuznetsov**, holder of the Chair [1-3].

► [1] **J. P. Bezerra** and **P. Kuznetsov**, “Brief Announcement: How to Tame Multiple Spending in Decentralized Cryptocurrencies,” in *Proceedings of the 2022 ACM Symposium on Principles of Distributed Computing*, New York, NY, USA, 2022, pp. 427–429.

► [2] **J. P. Bezerra**, **P. Kuznetsov**, and A. Koroleva, “Relaxed Reliable Broadcast for Decentralized Trust,” in *Networked Systems*, Cham, 2022, pp. 104–118.

► [3] **P. Kuznetsov** and A. Tonkikh, “Asynchronous reconfiguration with Byzantine failures,” *Distributed Computing*, vol. 35, no. 6, pp. 477–502, Dec. 2022.

June **13** 2022

The Chair welcomed Sathya Peri (IIT Hyderabad), for a talk on dynamic graph algorithms.

The scientific project of the TrustShare Chair is to explore the use of storage and state-machine-replication algorithms for sharing data in a consistent, secure and available way in decentralized systems where every component can be inconsistent, insecure, or unavailable.

Partners: Mazars, Caisse des Dépôts

► [www.trustshare.telecom-paris.fr](http://www.trustshare.telecom-paris.fr)



November **03** 2022



### A new rendez-vous: Bringing together several Chairs around the table

“Anomaly detection in Finance, Connected Vehicles and Industry 4.0” was the subject of a first *joint chairs webinar*, hosted by **Rida Khatoun** (Connected Cars & Cyber Security chair), **Tiphaine Viard** (Explainable AI for Anti-Money Laundering chair) and **Pavlo Mozharovskyi** (Data Science & Artificial Intelligence chair). The audience appreciated this cross-conference format, which paved the way to multi-domain discussions. This kind of event is expected to be repeated in 2023.

Videos of the talks and slides are listed below under the references [X1,X2,X3].

### Connected Cars and Cyber Security

Three workshops dealing with the future scientific program of the Chair have been held for the Chair’s partners in 2022. Two PhD theses have been defended [1,2]. A full-day workshop on “Cybersecurity for Connected and Autonomous Cars” has been organized in December, with the aim to promote the dialogue on automated and connected vehicles and infrastructure between scientists, researchers, professionals, industry practitioners, policy makers, and users.

- ▶ [1] **E. Tehrani**, “Cryptographic primitives adapted to connected car requirements,” PhD thesis, Institut Polytechnique de Paris, 2022.
- ▶ [2] **M. Ayrault**, “Défenses dynamique pour l’amélioration de la résilience des voitures connectées”, PhD thesis, Institut Polytechnique de Paris, 2022.
- ▶ [X1] Webinar Anomaly Detection: **R. Khatoun**, “How Machine Learning can Protect Connected Cars from Cyberattacks?”, Nov. 2022. [www.youtube.be/36Z3lG\\_c9YE](https://www.youtube.be/36Z3lG_c9YE)

December **12** 2022

A full-day seminar on “Cybersecurity for Connected and Autonomous Cars”, with topics such as misbehavior detection, securing V2X communication in the context of 5G, and machine learning for intrusion or denial of service detection. An introduction on connected vehicles cybersecurity and an overview of automotive perception security were also presented to the participants.

The C3S Chair addresses issues surrounding connected and autonomous vehicles that crystallize some of the most advanced and complex technical challenges of the digital transformation.

Partners: Nokia, Renault, Thales, Valeo, Wavestone

- ▶ [www.telecom-paris.fr/c3s](https://www.telecom-paris.fr/c3s)

### Values and Policies of Personal Information

In January, the VP-IP Chair welcomed new associate researchers Josep Domingo-Ferrer, Professor of Computer Science, ICREA-Acadèmia researcher at Universitat Rovira i Virgili, Tarragona, Catalonia, and the founding Director of CYBERCAT-Center for Cybersecurity Research of Catalonia, Sophie Chabridon, Professor at Télécom SudParis, and Nathanaël Denis, PhD student on IoT and privacy [1]. At the annual conference of the European Association for Industrial Economics held on August 25-26, 2022 in Vienna, Austria, **Patrick Waelbroeck** presented a paper, “Privacy and Competition”, co-authored with his economist colleagues **David Bounie** and **Antoine Dubus**. Souha Masmoudi’s thesis on privacy-preserving technologies has been defended in December [2,3].

- ▶ [1] N. Denis, S. Chabridon, and M. Laurent, “Bringing Privacy, Security and Performance to the Internet of Things Through Usage Control and Blockchains,” in *Privacy and Identity Management. Between Data Protection and Security*, Cham, 2022, pp. 57–72.
- ▶ [2] S. Masmoudi, “Technologies malléables préservant la vie privée pour des systèmes de gestion des identités respectueux de la vie privée”, PhD thesis, 2022.
- ▶ [3] S. Masmoudi, M. Laurent, and N. Kaaniche, “PIMA: A privacy-preserving identity management system based on an unlinkable MAlleable signature,” *Journal of Network and Computer Applications (JNCA)*, p. 103517, Sep. 2022.

The VP-IP Chair gathers a cross-disciplinary team of researchers who work on the legal aspects of regulation and compliance, technical aspects of systems and data security, and economic aspects of the sharing of personal information. Partners: IN Groupe, BNP Paribas, Orange, Dassault Systèmes, CNIL

- ▶ [www.cvpip.wp.imt.fr](http://www.cvpip.wp.imt.fr)

### Innovation and Regulation

Hosted and sponsored by the Innovation and Regulation Chair at École Polytechnique and Télécom Paris, and held in the School premises, this 2-day international Conference gathered academic researchers involved in the field of Digital Economics.

Digital platforms, competition and pricing, data and privacy, information, cooperation, labor markets, innovation and startups were some of the topics discussed during the sessions, from an empirical and theoretical point of view. The keynote lecture, “Firms’ innovation portfolios: implications for mergers and start-up acquisitions”, was held by José Luis Moraga-González, Professor of Microeconomics at the Department of Economics of the Vrije Universiteit Amsterdam, and also a visiting professor at Télécom Paris. **Marc Bourreau**, **Lukasz Grzybowski**, **Ulrich Laitenberger**, and **Michelangelo Rossi** from the **ECO team** were in the organizing committee.

# Industrial chairs

## Modeling and Extracting Complex Information from Natural Language Text

Two new partners joined the NoRDF Chair in 2022: Sereneo, a French software and digital services provider, and leader in AI-enhanced omnichannel customer experience, that combines the best of humans and robots through Djiin, its automated customer relationship execution platform; the Gendarmerie Nationale, one of two national law enforcement forces of France and a branch of the French Armed Force.

The YAGO software was awarded by the Committee for Open Science in August (see page 66).

Three workshops were held for the Chair's partners: "Sentiment Analysis", with **Chloé Clavel**; "Fact Extraction / Knowledge Representation", with **Fabian Suchanek**; "Argumentation Mining: Challenges and Opportunities in Detecting Fallacious Reasoning", with Oana Balalau, researcher at CEDAR group at Inria Saclay. In addition, nine seminars "Law, Society & AI" were co-organized with the help of HEC and École Polytechnique.

Among the different scientific contributions of the Chair this year, the article below tackles the known poor performances of transformer-based language models before textual entailment tasks when datasets contain negations. Experimental results across negated textual entailment benchmarks showed that our method can significantly increase the performance of different transformer-based models without sacrificing performance on datasets without negation.

► **C. Helwe, S. Coumes, C. Clavel, F. Suchanek**, "TINA: Textual Inference with Negation Augmentation", Findings of the Association for Computational Linguistics: EMNLP, 2022.

## December 09 2022

The Chair organized its first scientific day on December 9, where the academic team presented the results of its numerous projects. This spanned regulatory challenges in using NLP, knowledge extraction, vagueness and non-named entities extraction, evaluation of story generation, embeddings in language models (see article below), neuro-symbolic reasoning and reasoning on hypothesis.

► L. Chen, G. Varoquaux, and **F. Suchanek**, "Imputing Out-of-Vocabulary Embeddings with LOVE Makes Language Models Robust with Little Cost," in *Proceedings of the 60<sup>th</sup> Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, Dublin, Ireland, May 2022, pp. 3488–3504.

The scientific project of the NoRDF Chair aims to model and extract complex information from natural language text. Partners: EDF, Schlumberger, Converteo, Groupe BPCE, Sereneo, Gendarmerie Nationale, the French National Research Agency, the French Defense Innovation Agency

[www.nordf.telecom-paris.fr](http://www.nordf.telecom-paris.fr)

## Explainable Artificial Intelligence for Anti-Money Laundering

The XAI-4-AML Chair led to research on human cognitive biases that decrease the effectiveness of algorithmic explanations, including a paper presented at the 2022 AAAI / ACM Conference on AI, Ethics, and Society [1]. In addition, several articles were published on the use of algorithmic tools in the fight against money laundering and their compliance with human rights [2,3].

Within this Chair, **Tiphaine Viard (NOS)** studies the use of graph networks to better characterize abnormal and suspicious behaviors in bank transactions. Not only are such graphs able to identify new typologies of organized crime, they also visualize them and explain the algorithmic results better to compliance experts in banks. It is therefore an approach that both improves knowledge by revealing new aspects of crime not yet known, and an explainability tool to better justify actions that would be taken following a report [X2].

► [1] **A. Bertrand, R. Belloum, J. R. Eagan, and W. Maxwell**, "How Cognitive Biases Affect XAI-Assisted Decision-Making: A Systematic Review," in *Proceedings of the 2022 AAAI/ACM Conference on AI, Ethics, and Society*, New York, NY, USA, 2022, pp. 78–91.

► [2] **W. Maxwell**, "The GDPR and private sector measures to detect criminal activity," *Revue des Affaires européennes/Law European & Affairs*, Aug. 2021.

► [3] **A. Bertrand, W. Maxwell, and X. Vamparys**, "Do AI-based anti-money laundering (AML) systems violate European fundamental rights?," *International Data Privacy Law*, vol. 11, no. 3, pp. 276–293, Apr. 2021.

► [X2] Webinar Anomaly Detection: **T. Viard**, "Identifying Fraud in Bank Transactions", Nov. 2022. [www.youtube.be/eK-PRMShvH4](https://www.youtube.be/eK-PRMShvH4)

The XAI-4-AML research Chair addresses artificial intelligence explainability in the context of anti-money laundering and countering the financing of terrorism. Its work contributes to the activities of the Télécom Paris "Operational AI Ethics" program.

Partners: PwC, ACPR Banque de France, Dataiku, the French National Research Agency (ANR)

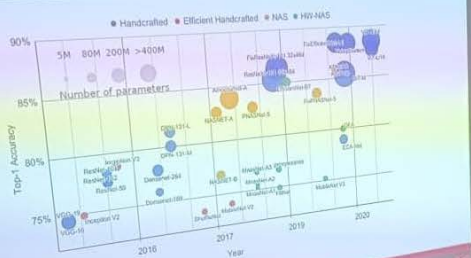
► [www.xai4aml.org](http://www.xai4aml.org)

## See also

► The Operational AI Ethics research initiative pp. 60-61.



## Recent trends in ANNs



### Data Science & Artificial Intelligence for Digitalized Industry & Services

The DSAIDIS Chair prioritizes two cross-cutting issues: How to develop Machine Learning tools so that they are applicable in realistic conditions of use? (see page 50); How to impose during or after learning (by-design/post-hoc) reliability, robustness, fairness, and explainability? To explore these issues, the Chair aims to develop theoretical tools and algorithms in Data Science and AI that work in realistic usage condition, meet trustworthiness criteria, tend to be data-efficient/frugal in memory/computation, and are supported by theoretical guarantees.

The various projects conducted within the Chair are presented in major conferences. In 2022, two papers were accepted at AISTATS 2022, three papers at ICML 2022 and seven papers at NeurIPS 2022. One paper was awarded outstanding student paper at AAAI 2022 [1]. Some of our researchers were also senior area chair at NeurIPS 2021 and ICML 2022.

► [1] P. J. A. Colombo, **C. Clavel**, and P. Piantanida, “InfoLM: A New Metric to Evaluate Summarization & Data2Text Generation,” in *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 36, no. 10, pp. 10554–10562, Jun. 2022.

► See references on learning from graphs page 42, audio data page 43, social computing page 46, visual computing and biomedical imaging page 49, frugal digital systems page 50, knowledge extraction to enable reasoning page 56 and trustworthy machine learning page 61.

### January 27 2022

The sixth workshop for the DSAIDIS Chair partners covered subjects such as representation learning, instance-conditioned GAN or learning generic dialog embeddings.

### June 15 2022

The annual full-day rendez-vous offered an overview of the research conducted within the Chair, along its four axes. Slides and videos are available on the website. Some of these presentations are directly related to the aforementioned papers in major conferences.

### Digital Finance

The expertise of the Chair was solicited by the French mainstream media and 8 articles have been published. A PhD thesis on economics in the era of high-frequency data has been defended [1]. Works on the long run have also been updated [2].

► [1] **Y. Camara**, “Quatre Essais sur l’Économie Empirique à l’Ère des Données à Haute Fréquence,” PhD thesis, 2022.

► [2] **D. Bounie**, A. Dubus, **P. Waelbroeck**, “Collecting and Selling Consumer Information: Selling Mechanisms Matter,” (November 4, 2022). Available at SSRN: <http://dx.doi.org/10.2139/ssrn.3454193>

The Digital Finance Chair carries out research in all the innovations, services, products and organizations in digital computing that may impact the work of financial intermediaries. Partners: Université Paris II Panthéon-Assas, Institut Louis Bachelier, Groupement des Cartes Bancaires (CB), La Banque Postale

► [www.digit-finance.com](http://www.digit-finance.com)

The DSAIDIS Chair explores four research themes: Building predictive analytics on time series and data streams; Exploiting large scale, heterogeneous, partially labeled data; Machine learning for trusted and robust decision; Learning through interactions with the environment.

Partners: Airbus Defence & Space, Engie, Idemia, Safran, Valeo

► [www.telecom-paris.fr/dsaidis](http://www.telecom-paris.fr/dsaidis)

# Joint laboratories

“Alternative” joint laboratories, typically set up for a five-year period, are groupings that bring together the research potential of Télécom Paris, with that of one or several companies, higher education institutions and research centers on a given topic.

## SEIDO, Internet of Things and trusted telecommunications for industry, energy services and customers

2022 marked the launch of a new five-year period for SEIDO Lab, a joint lab created in 2012 by EDF R&D and Télécom Paris to conduct research on the Internet of Things and Cybersecurity applied to EDF’s industrial challenges, and extended since to the CNRS LAAS research laboratory, Télécom SudParis, and École des Mines de Saint-Étienne.

Two theses were defended in 2022, that led to the filing of three patents: Étienne Houzé proposed a novel approach in the framework of explainable AI in an autonomous system to estimate events memorability and use them as relevant hypotheses to a surprising phenomenon. This high-level approach to explainability aims to be generic and paves the way towards systems integrating more advanced modules, guaranteeing smart home explainability. The overall method can also be used for other Cyber-Physical Systems.

Sameh Khalfaoui studied in his thesis the secure bootstrapping process of resource-constrained devices and introduced two security schemes: A hybrid ad-hoc pairing protocol that efficiently combines a state-of-the-art fast context-based scheme with the use of an auxiliary channel; an enrollment solution that exploits a physical unclonable functions model in the authentication process.

These activities formed part of the program of the 9<sup>th</sup> annual workshop, along with two keynote presentations about the French regulator for electronic communications work on measuring the environmental impact of digital technology, and on the topic of digital sovereignty ecosystems.

During the visit of Jean-Bernard Levy (CEO EDF), a demonstration of a 5G link between EDF Lab Paris-Saclay and Télécom Paris was presented by the partner teams. This was an opportunity to present the progress in 5G as part of the 5G-mMTC project (see Annual report 2021, page 60).

Since November 2021, SEIDO Lab has dedicated premises hosted by EDF Lab Paris-Saclay.

► **É. Houzé, J.-L. Dessalles, A. Diaconescu**, and D. Menga, “What Should I Notice? Using Algorithmic Information Theory to Evaluate the Memorability of Events in Smart Homes,” *Entropy*, vol. 24, no. 3, p. 346, Mar. 2022.

► **É. Houzé, A. Diaconescu, J.-L. Dessalles**, and D. Menga, “A generic and modular reference architecture for self-explainable smart homes,” in *2022 IEEE International Conference on Autonomic Computing and Self-Organizing Systems (ACSOS)*, 2022, pp. 101–110. doi: 10.1109/ACSOS55765.2022.00028.

► **S. Khalfaoui**, A. Villard, J. Ma & **J. Leneutre** (2021, June). Procédé et système d’authentification d’un dispositif équipé d’un circuit PUF. FR 2107112.

► **S. Khalfaoui**, A. Villard, J. Ma & **J. Leneutre** (2020, May). Procédé d’appairage. EP 3913951A1.

► <https://seido-lab.com>

## ISA, Identity & Security Alliance

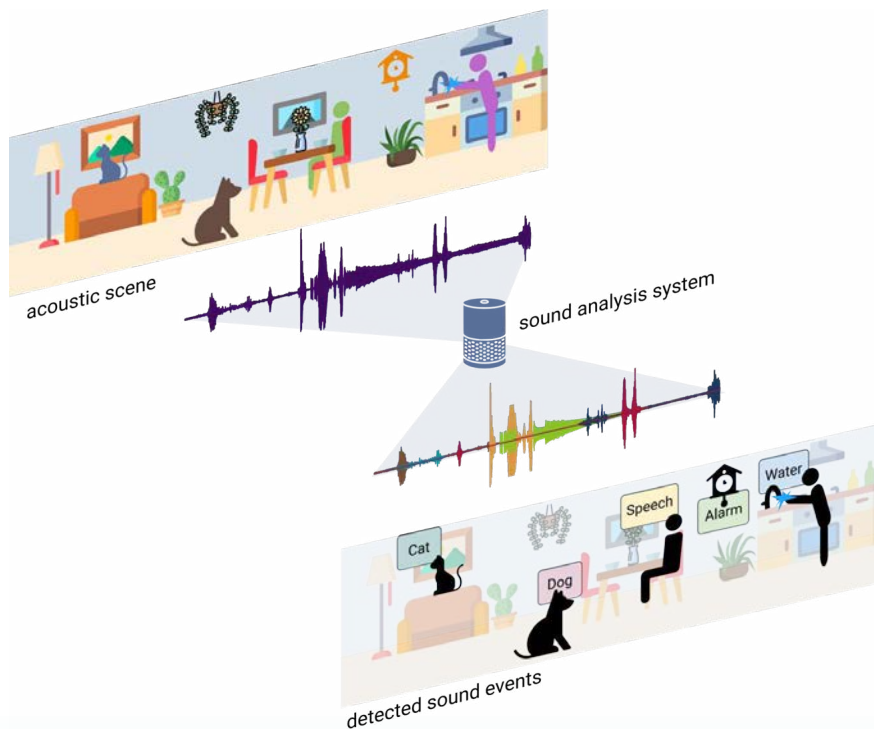
ISA is a joint laboratory that started in 2011 with Morpho (now Idemia) and Télécom Paris to address the technological challenges of identity protection and data security, with a focus on developing and enabling next-generation identity-based applications while guaranteeing security and privacy.

Research in the lab is now twofold: securing deep learning algorithms against physical attacks such as SCA (Side Channel Analysis) or faults [1]; respecting privacy by using cryptographic techniques for biometric recognition or, more generally, for establishing identities. We thus presented at the IEEE Global Communications Conference held in December 2022 a new wallet recovery process that associates visual passwords—a photograph of a secretly picked object—with ImageNet classifiers transforming images into binary vectors and obfuscated fuzzy matching for the storage of visual passwords/retrieval of wallet seeds [2].

► [1] In the framework of Linda Guiga’s thesis. See the focus on protecting convolutional neural networks architectures against cache attacks, Annual report 2021, page 43.

► [2] **H. Chabanne**, V. Despiegel, and **L. Guiga**, “One Picture is Worth a Thousand Words: A New Wallet Recovery Process.” arXiv, 2022.





## LISTEN: machine listening

LISTEN is a joint laboratory launched in March 2022 by Télécom Paris with Valeo, Bruitparif and Music World Media, over a three-year cycle, and headed by **Slim Essid (S2A)**. It aims at developing adapted artificial intelligence systems in order to extract from sound signals (music, speech, common environmental sounds, etc.) the fundamental characteristics that are useful for understanding them. The Télécom Paris team at the heart of the project includes the six members of the ADASP (Audio Data Analysis and Signal Processing) research group, which is part of the **S2A team**.

LISTEN conducts work on five fundamental issues: frugal learning based on scarce data; multi-view, multi-task & distributed learning; model-based deep learning; self-supervised learning; learning of (deep) generative models. It is expected to develop major breakthroughs in five machine listening application fields: environmental sound analysis, robust speech processing, source separation, enhancement and localization, ecological applications, and music content analysis.

In 2022, the lab organized seminars on a regular basis, with invited speakers on topics such as sound event detection, audio data—between music and sound scene—analysis, an open-source speech toolkit, green machine listening models, robust speech separation algorithms, and a live captioning solution.

During its half-day workshop held in July, the ADASP PhD students presented their ongoing research, while an invited speaker discussed on the similarities and differences between machine learning algorithms and the human auditory system. All seven PhD students' research was further presented at the first partner meeting in November, with a special focus by Salah Zaiem about the 2022 edition of Interspeech [1].

► [1] **S. Zaiem**, T. Parcollet, and **S. Essid**, “Automatic Data Augmentation Selection and Parametrization in Contrastive Self-Supervised Speech Representation Learning,” in *Interspeech 2022*, Incheon, South Korea, Sep. 2022, pp. 669–673.

► [www.listen.telecom-paris.fr](http://www.listen.telecom-paris.fr)

## TALia, natural language processing

Télécom Paris and onepoint joined forces in 2021 to create TALia, a joint research laboratory dedicated to natural language processing. It has programmed its work over a five-year cycle and is held mostly by **Thomas Bonald (DIG)**.

TALia focuses its work on three issues: to humanize our relationships with machines; to maintain linguistic sovereignty, via the control over the data sets used to train automatic language processing models, and the defense of the French language; to contribute to the transmission of contemporary knowledge, the empowerment of society and the empowerment and training of its individuals.

The lab organized more than 20 seminars in 2022, with contributions and animations from the PhD students and members of both academic and industrial partner teams. Videos and slides are published in open access on the website.

Two PhD theses are ongoing—Generation of Python business code from a natural language description; Algorithms for adaptive learning: automatic recommendation of learning paths, resource design and representation—that led to two papers in 2022 [1,2].

► [1] N. Beau and B. Crabbé, “The impact of lexical and grammatical processing on generating code from natural language,” in *Findings of the Association for Computational Linguistics: ACL 2022*, Dublin, Ireland, May 2022, pp. 2204–2214.

► [2] J. Vassoyan, “Vers un modèle général de recommandation de trajectoires d'apprentissage,” in *Neuvièmes Rencontres Jeunes Chercheur/ses en EIAH*, RJC-EIAH, Lille, France, May 2022, pp. 110–117.

► [www.laboratoire-talia.telecom-paris.fr](http://www.laboratoire-talia.telecom-paris.fr)

# Research initiatives

With its industrial chairs and joint laboratories, “initiatives” represent the third way that research can be undertaken at Télécom Paris on cross-cutting topics which are of interest to a number of large corporate and public sector partners. By combining a transdisciplinary academic team, the School brings together complementary expertise and use cases that allow researchers to explore novel approaches well beyond their respective disciplines.

Here are some notable activities of the Operational AI Ethics initiative, which was the first of its kind. More are planned for the coming years.

## Transatlantic reflections on AI regulation

On May 12 and 13 several members of the OpAIE team participated in a conference on AI ethics and regulation which took place at HEC Paris. The Transatlantic Dialogue on Humanity and AI Regulation, whose organizers included David Restrepo Amariles, Janine Hiller, Angie Raymond, and **Winston Maxwell (NOS)**, brought together scholars and experts from across the Americas and Europe for interdisciplinary discussions on how we can best conceive the implementation of AI for today and the future.

In June, the Paris office of international law firm Baker McKenzie signed a partnership with Télécom Paris as part of the OpAIE research program. Comparing the different approaches with the five major OpAIE interdisciplinary research topics in the European Union and the United States, their joint work, which will be the subject of several workshops and academic contributions, attempts to identify a few common principles that can be used as input for transatlantic reflection.

## Operational AI Ethics

Launched in February 2021, “Operational AI Ethics” (OpAIE) is a program around the ethical issues raised by artificial intelligence and conducted by an interdisciplinary team grouping six academic fields—applied math, statistics, computer science, economics, law and sociology—spanning the **DIG, DIVA, ECO, NOS** and **S2A teams**. It includes five interdisciplinary research topics: algorithmic bias; explainability; AI liability; governance/regulation; and AI for the public interest.

Directly connected to the DSAIDIS, NoRDF, XAI-4-AML and Digital Finance chairs activities and seminars (see pp. 56-57), OpAIE is also associated to the following interdisciplinary research partnerships:

- ▶ Regulatory and machine learning approaches to trustworthy image recognition systems (LIMPID), with IDEMIA and the French National Research Agency;
- ▶ Bias and neutrality in public interest search and recommendation engines with the Caisse des Dépôts et des Consignations;
- ▶ Human-centric AI with the international law firm Baker McKenzie;
- ▶ Data sharing and governance in finance industry with Groupe BPCE.

The research works and results also benefit to seven AI ethics courses for 1<sup>st</sup> and 2<sup>d</sup> year engineering students, Master 2 students, PhD track students (including in biomedical engineering) and executive education, spanning law and ethics of AI, law and ethics of human enhancement, economic, social and ethical challenges of AI, and AI and the fight against discrimination.

▶ [www.telecom-paris.fr/ai-ethics](http://www.telecom-paris.fr/ai-ethics)

## Clarifying the moral foundation of explainable AI

The ‘unpacking’ characteristic of XAI (Explainable Artificial Intelligence) is one of the reasons it has subsequently been argued to increase the trustworthiness of AI by helping with regulatory audits, identifying errors, and informing users about its outputs. XAI, however, also has moral worth as an instrumental means to preserve meaningful human control in AI. It helps preserve meaningful human control by permitting humans to justify a course of action in morally important situations. By allowing justification, XAI helps enable responsibility, which in turn conveys meaningful human control.

In the following paper, **Joshua Brand (NOS)**, proposes an introductory clarification of the ethics behind XAI implementation. This will help give further depth and justification for other discussions on the requirement of XAI, particularly from a legal perspective. Indeed, philosophical analysis clarifies the normative pull that connects concepts like explainability, justification, accountability, and trust with XAI.

▶ **J. Brand**, “Clarifying the Moral Foundation of Explainable AI” (The Digital Constitutionalist, 10 November 2022).



## Protection under anti-discrimination laws

On November 9, Prof. Sandra Wachter (University of Oxford) presented her forthcoming paper, “The Theory of Artificial Immutability: Protecting Algorithmic Groups Under Anti-Discrimination Law”, as part of the Law, Society & AI interdisciplinary research seminar organized by HEC Paris, Télécom Paris, and École Polytechnique, where she examined the tension between AI used in decision-making processes and the rationale of Western anti-discrimination law. Defining algorithmic groups as AI-profiling based on groups that do not map to or correlate with legally protected groups, she argues that these groups should be protected by non-discrimination law and shows how this could be achieved. **Joshua Brand** and **Mélanie Gornet**, PhD researchers at OpAIE, connected their own works to Wachter’s approach.

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► [www.telecom-paris.fr/ai-anti-discrimination-law-remarks-sandra-wachter](http://www.telecom-paris.fr/ai-anti-discrimination-law-remarks-sandra-wachter)

## AI explainability

During a research internship at Google, **Astrid Bertrand**, PhD student in the Operational AI Ethics team and a member of the XAI-4-AML Chair (see other results page 56), produced an interactive web article, where she explores how saliency methods can help to detect the unintended biases models have learned. Astrid was also awarded the “Association française des investisseurs institutionnels” Young Researcher 2022 grant for the research project she is conducting with the Autorité de contrôle prudentiel et de résolution (ACPR).

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► **A. Bertrand**, A. Pearce, and N. Thain, “Searching for Unintended Biases with Saliency,” PAIR Explorables, 2022.

## Post-hoc interpretability

Attributes that aid understandability of deep learning models may largely be dependent on the data modality. In the following work within the audio domain, the aim is to interpret decisions of a network in terms of high-level audio objects that are also listenable for the end-user. A carefully regularized interpreter module is trained to take hidden layer representations of the targeted network as input and produce time activations of pre-learned non-negative matrix factorization components as intermediate outputs. The methodology generates intuitive audio-based interpretations that explicitly enhance parts of the input signal most relevant for a network’s decision.

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► **J. Parekh**, **S. Parekh**, **P. Mozharovskiy**, **F. d’Alché-Buc** and **G. Richard**, “Post-hoc interpretability for audio networks with NMF,” in *Advances in Neural Information Processing Systems*, 2022, vol. 35.

## Trustworthiness on image recognition

LIMPID (Leveraging Interpretable Machines for Performance Improvement and Decision), a three-year interdisciplinary research program started in December 2020, addresses the four main topics of trustworthiness—reliability, robustness, fairness, explainability—through two generic use cases: automatic detection of people exhibiting certain types of behavior considered as incorrect, in an image recognition context; fairness in a face recognition context. It is conducted by Télécom Paris and IDEMIA, and funded in part by the French National Research Agency (ANR).

Several projects carried out in 2022 focused on the issue of biases. Article [1] shows how to build a “nearly debiased” training statistical population from biased samples and the related biasing functions. In article [2], the gender bias of deep Face Recognition networks is investigated. Two new fairness metrics that better reflect the inherent deployment needs of Face Recognition systems are proposed. Gender bias is then mitigated through a new post-processing methodology which transforms the deep embeddings of a pre-trained model to give more representation power to discriminated subgroups. Extensive numerical experiments on a variety of datasets showed that a careful selection significantly reduces gender bias.

In September 2022, IDEMIA’s biometric technology stood out in the latest international NIST Facial Recognition Vendor Test 1:1 by combining fairness and accuracy. Its facial recognition technology ranked first on the false match rate fairness test among the 100 most accurate algorithms in the test, with more than twice the fairness of the twenty most accurate.

LIMPID renewed its dissemination website in 2022, with scientific publications and research notes made available for all: <https://limpid.telecom-paris.fr/>.

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► [1] **S. Cléménçon** and **P. Laforgue**, “Statistical learning from biased training samples,” *Electronic Journal of Statistics*, vol. 16, no. 2, pp. 6086–6134, 2022.

► [2] **J.-R. Conti**, **N. Noiry**, **S. Cléménçon**, V. Despiegel, and S. Gentic, “Mitigating Gender Bias in Face Recognition using the von Mises-Fisher Mixture Model,” in *Proceedings of the 39<sup>th</sup> International Conference on Machine Learning*, Jul. 2022, vol. 162, pp. 4344–4369.

## AI, ethics and insurance

A special webinar on AI, ethics and insurance, featuring three world-class scholars, **Xavier Vamparys** (XAI-4-AML Chair), Arthur Charpentier (Université du Québec à Montréal), Sylvestre Frezal (Covéa) was organized on November, 29.

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► <https://youtu.be/MidJgubL960>

► <https://youtu.be/jVosnprnbfo>



# Deep Tech Factory

The **Annual Innovation Day**, a day to discover innovation projects developed by students at Télécom Paris as well as start-ups from the School's incubator, Télécom Paris Novation Center, took place on December 8, 2022. BIB Batteries (dedicated to optimize batteries' performances, expand their lifecycle and reduce their environmental footprint, based on data analysis) and Cybershen (sovereign cyber threats protection solution for companies and public entities) received the incubator start-up awards, and Eyenime (re-enchanting manga reading by offering fans a video format) received the student start-up award.

March  
2022 **25**

The “Deep Tech for business” training course offered as part of the Observatoire Technologies et Souveraineté Numérique (Technology and Digital Sovereignty Observatory) created by Netexplo and Télécom Paris in 2021, received one of the three “Coup de Cœur” awards in the Digital Learning 2022 Trophies (<https://t-dl.fr/>). The course raises the awareness of senior and high-potential executives to the applications, potentials and challenges of critical technologies such as the Internet of Things, the Cloud, Artificial Intelligence, Cybersecurity and Quantum.

**July 2022**

Initiated in 1999 by the French Ministry of Research within the framework of the law on innovation and research, i-Lab is the French national competition for the creation of innovative technology companies. The national jury selected 78 winners from 396 applications. Two of them come from Télécom Paris's incubator: Télécom Paris Novation Center. Entreview is a deep-tech start-up that develops lithium battery diagnostic software for gigafactories, electric vehicles and energy storage to reduce production losses and drastically increase battery life. Fractal Energy is developing the first energy box to adjust household consumption to the production of renewable electricity in order to limit the impact of constant electricity price increases on households while providing them with a first lever to improve their carbon footprint by favoring the consumption of local renewable energy.

November  
2022

**17**

Orosound, Greenwaves, NaoX Technologies, Télécom Paris and Sorbonne University pooled their complementary expertise to develop TWS (True Wireless Stereo), a large-scale Deeptech project that aims to produce headphones “enhanced” with Artificial Intelligence, designed and manufactured in France. The reference design will incorporate advanced audio algorithms combined with a low-power processor and a miniaturized EEG sensor. The combination of high-performance components and artificial intelligence-based algorithms will pave the way for more powerful and easily developed True Wireless headphones.

**Slim Essid (S2A)**, Professor and coordinator of the signal processing and audio data analysis research theme, is the Télécom Paris referent for the project, which is financed by the French government as part of France 2030.







The Annual days for Télécom Paris' corporate partners took place on March 10-11, 2022, on the Palaiseau campus, located on the Saclay plateau. This is an opportunity for research teams involved in industrial chairs and joint laboratories, particularly doctoral and post-doctoral students, to showcase their work and future prospects.

# & Innovation with our industrial partners

June 02  
2022

In June, the Observatoire Technologies et Souveraineté Numérique invited a panel on digital sovereignty for the second time. **David Bounie (ECO)** presented a study on eight ecosystems implemented by France's largest companies, for which digital sovereignty in critical technologies is crucial. The study reveals the levers for working on competitiveness, developing innovation, attracting and retaining the best talent around common values, becoming part of the territories and making the most of public strategies, linking research and industry and making interdependence an asset.

► <https://youtu.be/i6aO1sJ5VuA>

## Paris AIoT, a new initiative on tracks

Paris AIoT is a collaborative initiative launched in the fall of 2022 between Télécom Paris and industrial companies. Its purpose is to educate and train world-class researchers and PhD students to enable truly ubiquitous sensing, computing and communication with fully distributed AI and embedded intelligence.

Application-oriented and system-oriented research areas of interest include: AI for training data efficiency - adequate development of training data; AI defined network (centralized, hybrid and distributed) and distributed intelligence; distributed edge intelligence with bandwidth-, energy- and memory-efficiency AI; energy efficient, secure and reliable hardware accelerator, smart sensors and low-power cognitive connectivity; AI, algorithms and encryption for privacy and security. This includes software and hardware at all levels of the system stack offering innovative and pioneering solutions on the convergence of AI and IoT.

# Open science

July  
2022

08

Télécom Paris COSI (Center for Open Software Innovation) groups all the projects staff have initiated or contributed to. Some thirty software packages have been made available to everyone, covering four major fields: Multimedia, Data Science and Artificial Intelligence, Programming, and Smart Networks and Objects.

► <https://telecom-paris.fr/cosi>

## Insights on diversity, from the Software Heritage project

In an exploratory, large-scale, longitudinal study of 50 years of commits to publicly available version control system repositories published in June at the International Conference on Software Engineering (ICSE 2022) **Stefano Zacchioli (ACES)** and Davide Rossi (University of Bologna) revealed that over the past 12 years, the proportion of women in open source software production has steadily increased worldwide to about 10% of active female contributors worldwide, confirming previous results about the gender gap in public code [1]. However, a decrease in the ratio of female participation was observed during the Covid-19 pandemic, suggesting that women's ability to contribute to public code has been more hampered than that of men.

In an other article published in May at the associated MSR 2022 (Mining Software Repositories) conference, the authors studied the geographic origin of contributions from the same dataset, showing that geographic diversity has increased over time, re-balancing contributions to Europe (and to a lesser extent Asia) after decades of American dominance [2]. Gender diversity is progressing in much smaller proportions than geographic diversity. The vast majority (86.5%) of contributors are still men (10.4M for only 1.6M women) and the imbalance is even larger when looking at commits, where 91.9% of commits have been authored by men v. 8.1% by women. The long-term growth of female participation is still a worldwide phenomenon, as this can be shown by breaking down the results by world regions.

This exploratory study of 50 years of commits represented 160 million software projects, for a total of 2.2 billion commits contributed by 43 million distinct authors. Data was collected from Software Heritage, the largest source code archive in the world and an initiative launched in 2015 by Roberto Di Cosmo and Stefano Zacchioli, that aims at providing an open knowledge base to help with the traceability of open source software.

Stefano Zacchioli (ACES) and Davide Rossi (University of Bologna) were selected to receive the 2022 Google Award for Inclusion Research Program for their proposal "What Causes the Lack of Diversity in Open Source?" based on this work.

► [1] D. Rossi and **S. Zacchioli**, "Worldwide Gender Differences in Public Code Contributions: And How They Have Been Affected by the COVID-19 Pandemic," in *Proceedings of the 2022 ACM/IEEE 44<sup>th</sup> International Conference on Software Engineering: Software Engineering in Society*, New York, NY, USA, 2022, pp. 172–183.

► [2] D. Rossi and **S. Zacchioli**, "Geographic Diversity in Public Code Contributions: An Exploratory Large-Scale Study over 50 Years," in *Proceedings of the 19<sup>th</sup> International Conference on Mining Software Repositories*, New York, NY, USA, 2022, pp. 80–85.

**Stefano Zacchioli** has been elected chairman of the International Federation for Information Processing (IFIP) Working Group 2.13 on Open Source Software, for a 3-year term. This working group, which he joined in 2021, enables a mixed community of researchers and practitioners to rigorously study the technology, work practices, development processes, and community dynamics of free and open source software ecosystems.

## YAGO software awarded by the French Committee for Open Science

For the first year, the French Ministry of Higher Education and Research awarded a Prize for Open Science in Research Data to projects, teams and young researchers engaged in exemplary practices in the management, dissemination and reuse of research data. The "YAGO knowledge base" project is one of the three winners in the "jury's special prize" category, which rewards ideas and projects that are exemplary in terms of accessing and sharing data.

Resulting from 15 years of collaboration between two institutions, the Max Planck Institute for Informatics (Saarbrücken, Germany) and Télécom Paris, and led by **Fabian Suchanek (DIG)**, YAGO is now a reference on the Semantic Web. Since its beginnings in 2007, the YAGO knowledge base has been made available for free.

November  
2022

08

## Motion Spell deploys GPAC open source software with Netflix

The GPAC Project on Advanced Content (GPAC), is an open source software that provides a modular multimedia framework for packaging, streaming, inspecting and playing content. It provides a wide range of tools for processing media content and has a strong focus on standards. The project is hosted at Télécom Paris, under the supervision of **Jean Le Feuvre (MM)**. Motion Spell, based in Paris, which exclusively handles commercial licensing for GPAC, announces the conclusion of an 18-month transition phase, working with the world's leading streaming entertainment service, Netflix, for the integration of GPAC Open Source Software into Netflix's worldwide content operations.

► <https://gpac.wp.imt.fr>

## Scikit-network updates

The **DIG team** develops and maintains scikit-network, a Python package inspired by scikit-learn for the analysis of very large graphs such as social media, web graphs and relational data. The package provides state-of-the-art algorithms for ranking, clustering, classifying, embedding and visualizing graphs. High performance is achieved through a mix of fast matrix-vector products (using SciPy), compiled code (using Cython) and parallel processing. Source code, documentation and installation instructions are available online. The package benefited from several additions and updates in 2022.

**Simon Delarue** added a graph neural networks (GNN) section along with tutorials. GNN are extending neural networks to operate on graph structures, in order to learn embeddings. The new code allows node classification, inference, and the use of GraphSAGE, a framework for inductive representation learning on large graphs, generating low-dimensional vector representations for nodes, and is especially useful for graphs that have rich node attribute information.

In the Graph embedding algorithms section of the package, **Thomas Bonald** updated the spectral embedding, a technique used for non-linear dimensionality reduction, based on the spectral decomposition of the Laplacian matrix or the transition matrix of the random walk.

► <https://scikit-network.readthedocs.io/>

► **T. Bonald, N. de Lara, Q. Lutz,** and B. Charpentier, “Scikit-network: Graph Analysis in Python,” *Journal of Machine Learning Research*, vol. 21, no. 185, pp. 1–6, 2020.

## Télécom Paris becomes an associate member of the Open Infrastructure Foundation



Télécom Paris uses and teaches open source technologies and relies on them for its digital

infrastructure. The School has therefore joined the Open Infrastructure Foundation as an associate member on February 16, 2022, along with five other new members.

The Open Infrastructure Foundation, created in 2012 to manage the governance of the Openstack project, supports the development of open source projects and communities in the fields of free software infrastructure, mainly on cloud technologies.

► <https://openinfra.dev/>

# & Open source software

## Web

<https://a3nm.net/>



## Antoine Amarilli DIG



Antoine Amarilli works in theoretical computer science, proving mathematical results about abstract topics inspired by computers. This spans such questions as: How to efficiently evaluate queries on data? How to tractably perform probabilistic computations on uncertain data? How to concisely represent, explain, or enumerate large collections of query answers? How to efficiently update query results when data is modified? How to reason with expressive logical languages? More broadly, Antoine Amarilli is interested in enumeration algorithms, formal languages, circuits, counting problems, dynamic data, computational logic, and graph theory, among other topics.

He co-authored works which received the best paper award at the International Conference on Database Theory (ICDT) in 2020 and at the International Colloquium on Automata, Languages and Programming (ICALP, track B) in 2021. He served as program committee member in several conferences, including ICALP 2022, STACS 2021, KR 2021, AAAI 2021 (outstanding PC member), IJCAI 2021, ICDT 2019. He is a Managing Editor for TheoretiCS, a peer-reviewed Diamond Open Access electronic journal covering all areas of Theoretical Computer Science. He is a member of two projects funded by the French National Research Agency: CQFD (Complex ontological Queries over Federated and heterogeneous Data) and EQUUS (Efficient Query answering Under UpdateS).

Antoine Amarilli is interested in improving academic practices, specifically with regard to open science. He is a board member of the CAPSH nonprofit which develops the Dissemin website and is part of the initiative “No free view? No review!”. He also cares about the climate crisis, in particular in academia: He is a member of the TCS4F movement (Theoretical Computer Scientists for Future), and facilitates discussions on the climate crisis in computer science conferences (ICDT, Highlights, ACM DEBS).

## PUBLICATIONS

► **A. Amarilli** and İ. İ. Ceylan, “The Dichotomy of Evaluating Homomorphism-Closed Queries on Probabilistic Graphs,” *Logical Methods in Computer Science*, vol. 18, Issue 1, Jan. 2022.

► **A. Amarilli, L. Jachiet,** M. Muñoz, and C. Riveros, “Efficient Enumeration for Annotated Grammars,” in *Proceedings of the 41<sup>st</sup> ACM SIGMOD-SIGACT-SIGAI Symposium on Principles of Database Systems*, New York, NY, USA, 2022, pp. 291–300.

► **A. Amarilli, L. Jachiet,** and C. Paperman, “Dynamic Membership for Regular Languages,” in *Proceedings of the 48<sup>th</sup> International Colloquium on Automata, Languages, and Programming (ICALP 2021)*, Dagstuhl, Germany, 2021, vol. 198, p. 116:1–116:17. Best paper award of ICALP’21 track B

## CV

► Computer science research master (MPRI), École normale supérieure, 2012

► PhD, Télécom Paris, 2016

► Associate professor at Télécom Paris (**DIG team**) since 2016



## Waiting for Robots



**Antonio Casilli's** latest book "Waiting for Robots. An Inquiry Into Digital Labor", is now translated in Arabic, following previous Italian and Spanish translations. The US

edition by University of Chicago will be out in 2023.

See also "Invisibles - Les travailleurs du clic", a documentary series born of a partnership between France TV and Télécom Paris on the basis of Antonio's work (NOS) in 2019. The documentary won the Étoiles award from SCAM (Société civile des auteurs multimédia) in 2021 and the award for best documentary of the year at the Bangkok International Documentary Awards (Thailand) in 2020.



Antonio Casilli is also co-editor of a special issue of the renowned Italian journal "Sociologia del lavoro" dedicated to digital labor and the crisis of the wage-labor system.

► [casilli.fr](http://casilli.fr)

► [france.tv/slash/invisibles](http://france.tv/slash/invisibles)

► F. Cicchi, M. Marrone, and **A. A. Casilli**, "Introduction. Digital labor and crisis of the wage labor system," *Sociologia del lavoro - Sezione Open Access*, Sep. 2022.

## Innovating in times of crisis



Coordinated by **Hervé Dumez**, CNRS, École polytechnique, **Benjamin Loveluck** (NOS), Télécom-Paris and Alexandre

Mallard, Mines Paris PSL, and written by researchers in management, economics, sociology, information and communication sciences gathered in the Interdisciplinary Institute of Innovation (i3), "Innovater en temps de crise" examines how the Covid epidemic provided an opportunity for innovation in a whole range of situations.

► ISBN: 978-2-35671-833-4

## Will the 21<sup>st</sup> century be heroic?



In the face of the crises and dangers that lie ahead, is a new heroism required? What will these new heroes look like? Are they the problem or the solution?

In his book, "Le nouvel héroïsme", **Olivier Fournout** (INTERACT), sociologist and semiologist, analyzes the conditions that allowed the installation of a model of success riddled with paradoxes. He offers an unprecedented look at contemporary individualism, self-entrepreneurship on the networks, the challenges of ecology and the influx of controversies in the public space.

► ISBN: 978-2-35671-691-0

## Corporate social responsibility & digital ethics

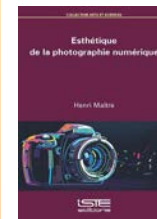


In their afterword to the book "RSE et Numérique", **Laura Draetta** (INTERACT), sociologist of the environment and sustainable development, and **Valérie**

**Fernandez** (NOS), Professor of digital economics, question the societal impact of some digital technologies and the associated controversies in order to propose an approach to digital innovation based on an ethic of responsibility and of the future.

► ISBN: 978-2-37687-527-7

## Why (and how) do we say that a photo is beautiful?



Nowadays, automatically evaluating the aesthetic qualities of a picture feels like a challenge to the techniques of artificial intelligence, but also a gateway towards new economic and social promises. In his book entitled "Esthétique de la photographie numérique" **Henri Maître** (IMAGES) presents the theories developed over the last 25 centuries by philosophers and art critics, pulled between the objectivity of perception and the subjectivity of human judgment. He shows the advances and limits in neuro-aesthetics, compares and contrasts aesthetic conjectures with experimental verifications, and critically examines attempts to "scientifically" measure this beauty.

► ISBN: 978-1-78405-815-9



# Recently published

These books, chapters or special issues of journals were published or co-authored by our researchers in 2022.

## Management of Citizens and Volunteers



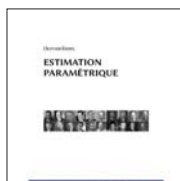
The main results of the “MACIV” project: “Management of Citizens and Volunteers: the social media contribution to crisis management” funded by the French

National Research Agency (2018-2021) has been published in a book by **Caroline Rizza** (NOS, Télécom Paris) and Sandrine Bubendorff (University of Strasbourg). The project studied information flows and citizen initiatives on social media during a major event in order to help crisis management actors to integrate them into their practices. In close collaboration with the main French institutional actors in charge of crisis management, MACIV allowed the observation of real crisis situations, including health crises, and the setting up of civil security exercises. It also aimed at developing a module dedicated to the management of volunteers and citizen initiatives within a dedicated platform. The book highlights and discusses the challenges involved in these new practices.

► ISBN: 978-2-35671-871-6

► **C. Rizza**, “MACIV - Management of citizens and volunteers: the social media contribution in crisis situation,” ANR (Agence Nationale de la Recherche - France), Research Report, Apr. 2022.

## Parametric Estimation



**Olivier Rioul** (ComNum) is the author of “Estimation paramétrique”, a 148-page book, accessible to

Bachelor’s and Master’s students, that aims to present a mathematical framework as simply as possible to understand the essential ideas of estimation, both with the frequentist and Bayesian approaches.

► ISBN: 978-2-36693-120-4

## Unfold the uncertain



Through the simultaneous publication of a book entitled “Déplier l’incertain”, a MOOC on Coursera and an actionable tool—a Decision Model Canvas— in open access, **Valérie Fernandez** and **Thomas Houy** (NOS) provide business leaders with tools for managing operational projects in an uncertain, unpredictable and unstable environment.

► [incertain.fr](http://incertain.fr)

Télécom Paris is a member of Carnot Télécom & Société Numérique (TSN), the first Carnot dedicated to information and communication science and technology, which is part of a network of 39 Carnot Institutes. The Carnot Label was created in 2006 to promote research projects undertaken by public laboratories in partnership with socio-economic players, primarily industry (from SMEs to large corporations), to serve their needs.

The Carnot TSN brings together laboratories and research teams from 11 leading French scientific institutions, including the LTCI at Télécom Paris, totaling more than 1,700 researchers and 974 PhD students. It provides cutting-edge research and integrated solutions to complex technological issues raised by transformations in the French production sector.

► [www.carnot-tsn.fr](http://www.carnot-tsn.fr)

## Researchers at Télécom Paris engaged in international and multidisciplinary academic collaborations wish to thank their colleagues from:

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- Infinera Corporation (Germany)
- Institute for Quantum Computing (Canada)
- Instituto Tecnológico de Aeronáutica (Brazil)
- ITMO University (Russia)
- Kobe University (Japan)
- KTH (Sweden)
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- ▶ Axa
- ▶ Axione
- ▶ Axys
- ▶ be ys
- ▶ BloomFlow
- ▶ BnF
- ▶ BNP Paribas
- ▶ Bouygues Telecom
- ▶ Caisse des Dépôts
- ▶ Canon
- ▶ Capgemini
- ▶ Cardiologs
- ▶ Carrefour
- ▶ CGI
- ▶ Cisco
- ▶ CNIL
- ▶ Convertio
- ▶ Crédit Agricole
- ▶ CRITEO
- ▶ Danone
- ▶ Dassault Aviation
- ▶ Dassault Systèmes
- ▶ Datadog
- ▶ Dataiku
- ▶ DCNS
- ▶ DEEZER
- ▶ Delta Dore
- ▶ Devoteam
- ▶ DGA
- ▶ DxOMark
- ▶ EASYRECRUE
- ▶ ECA Group
- ▶ EDF
- ▶ Ekinops
- ▶ EMAKINA
- ▶ Engie
- ▶ Ericsson
- ▶ Eutelsat
- ▶ EXFO OPTICS
- ▶ Fabernovel
- ▶ Fondation d'entreprise Carrefour
- ▶ Fondation MAIF
- ▶ Gemalto
- ▶ General Electrics Healthcare
- ▶ Google
- ▶ Greenwaves
- ▶ Groupe BPCE
- ▶ Groupement des Cartes Bancaires
- ▶ Guerbet
- ▶ Headmind Partners
- ▶ HN Services
- ▶ Huawei
- ▶ IBM
- ▶ IDAaas
- ▶ Idemia
- ▶ Ikos
- ▶ IN Group
- ▶ Incepto
- ▶ Innovation Defense Lab
- ▶ InProcess
- ▶ Intelcia
- ▶ Interdigital
- ▶ Ionos DX
- ▶ Kardham Digital
- ▶ KEEN EYE
- ▶ Kering
- ▶ La Banque Postale
- ▶ La Poste
- ▶ Lateam AI
- ▶ LinkByNet
- ▶ L'Oréal
- ▶ MAIF
- ▶ Mazars
- ▶ MBDA
- ▶ MC2I
- ▶ Facebook / Meta
- ▶ Milvue
- ▶ Ministère des Armées
- ▶ Mitsubishi
- ▶ MVG
- ▶ Naval Group
- ▶ Navigacom
- ▶ Nokia
- ▶ Nokia Bell Labs
- ▶ NXP
- ▶ Onepoint
- ▶ Orange
- ▶ OTIS
- ▶ PHILIPS FRANCE
- ▶ PMP
- ▶ PWC
- ▶ REGIENOV
- ▶ Renault
- ▶ Rexel
- ▶ Safran
- ▶ SLB
- ▶ SECURE IC
- ▶ Sierra
- ▶ SNCF
- ▶ Société Générale
- ▶ Softbank Robotics
- ▶ Sonos
- ▶ Sony CSL
- ▶ Sopra Steria
- ▶ STMicroelectronics
- ▶ STREAMROOT
- ▶ Symocore
- ▶ Talan
- ▶ TDF
- ▶ TECHNICOLOR et INTERDIGITAL
- ▶ Thales
- ▶ Tiime
- ▶ TotalEnergies
- ▶ Ubisoft
- ▶ UTAC
- ▶ Valeo
- ▶ Véolia
- ▶ Vinci
- ▶ Wavestone
- ▶ Wordline
- ▶ Zaion

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