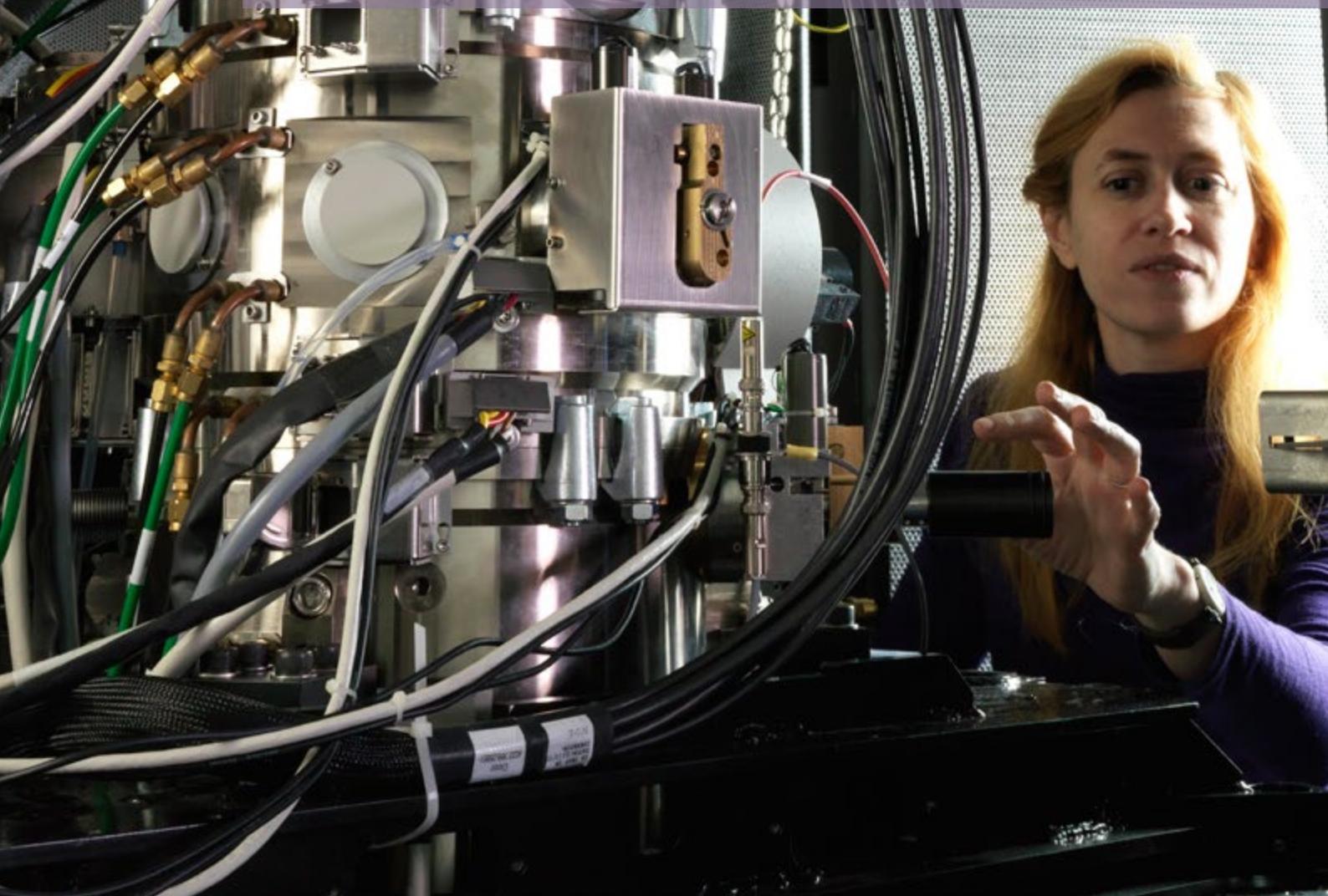




CentraleSupélec

RESEARCH CENTRE REPORT 2015

Research Areas - Research Departments
Research Centre



CENTRALESUPÉLEC: A MAJOR PLAYER IN THE DEVELOPMENT OF UNIVERSITÉ PARIS-SACLAY

The creation of CentraleSupélec, within Université Paris-Saclay, means that the new school has the means to achieve a challenging ambition: to become a reference institution on an international scale. CentraleSupélec and Université Paris-Saclay will enable them to undertake ambitious projects which they would not be able to carry out alone, and which will secure their future. In the long term, CentraleSupélec aims to be the “heart” of a worldwide network of interconnected organizations in the key developed and emerging countries, within which employees and students who wish to be members, as well as information, will circulate.



Three Major Projects

- **Launch of CentraleSupélec.** Through the significant increase in visibility and capacity for action and development, and the highly complementary nature of research carried out by the two Schools with a joint scientific positioning, “Systems and Complexity”, consistent with the educational and mainstream projects of partner companies.
- **Being a strong and committed actor within Université Paris-Saclay:** both schools have greatly contributed to the definition of the “Saclay Campus” project and its branding as an Initiative of Excellence (IdEx), contributing to the stature of Université Paris-Saclay. This provides a unique opportunity for CentraleSupélec to access a scientific environment of international standing, along with exceptional worldwide visibility and positioning. Our objective now is to affirm ourselves as one of the leaders of Université Paris-Saclay develop partnerships with all actors involved in the Cluster and especially with our neighbors in the Moulon area, as well as generating projects and new ideas to contribute to the thriving development of the University.
- **Completion of the Gif-sur-Yvette Campus extension and strengthening of the positions of the campuses in Metz and in Rennes** within their regions, with an intention to expand. The Lorraine region and Brittany are areas that are advantageous for forging relationships with SMEs, which themselves are encouraged to play a key role in the innovation and creation of jobs.

Successful participation in the “Investing in the Future” Program

For the Big Loan, the Ministry for Higher Education and Research has launched a cluster of calls aimed to provide future campuses with excellent shared structures, laboratories and equipment. CentraleSupélec laboratories, along with their partners, have successfully responded to these calls for tender in Saclay, Brittany and Lorraine region and are currently participating in:

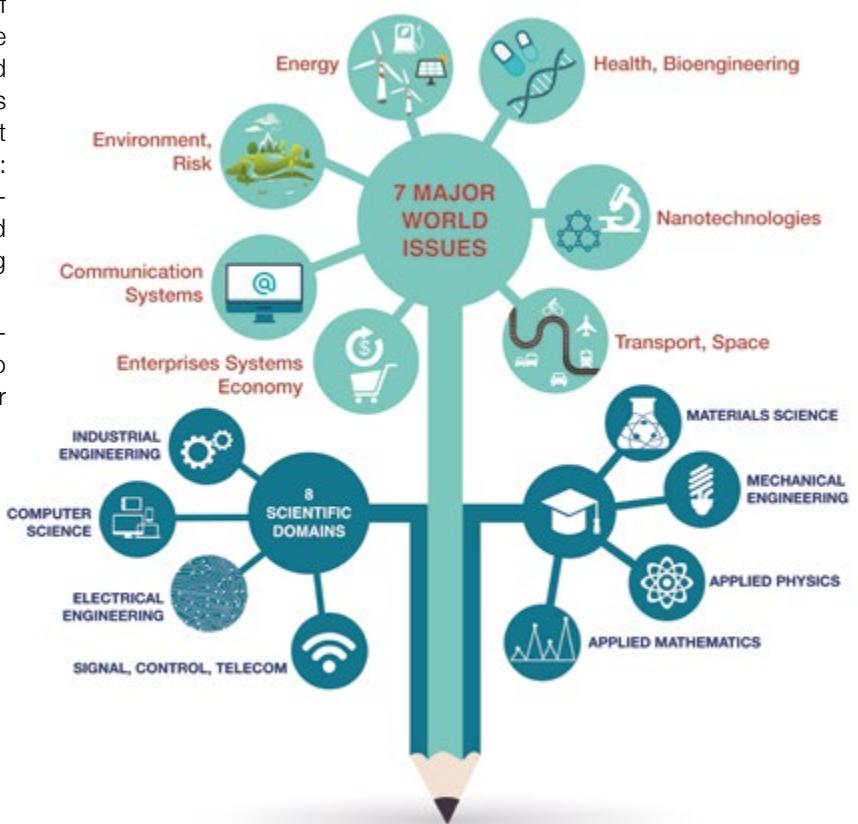
- **6 LABEX** (Laboratories of Excellence):
 - **CHARMMMAT** (Chemistry of Multifunctional Molecular Architectures and Materials)
 - **Comin-Labs** (*Digital Communications and Informatics for the Future*)
 - **DigiCosme** (Digital worlds: distributed data, programs and architectures)
 - **LaSIPS** (the Saclay Plateau Engineering Systems laboratory)
 - **Nano-Saclay** (interdisciplinary Nano-lab of Université Paris-Saclay)
 - **PALM** (Physics: Atom, Light, Matter)
- **2 EQUIPEX** (Equipment of Excellence):
 - **Digiscope** (development of techniques for interactive visualization of highly complex data)
 - **MatMéca** (development and in situ micromechanical characterization materials)
- **3 IRT** (Technology Research Institutes):
 - **B-Com** (digital networks and infrastructures)
 - **M2P** (materials, metallurgy, processes)
 - **SystemX** (digital sciences and ICTS)
- **3 ITE** (Institute for energy transition):
 - **PS2E** (Paris-Saclay Energy Efficiency)
 - **IPVF** (Île-de-France Photovoltaic Institute)
 - **VEDECOM** (carbon-free, communicating vehicle and its mobility)



The CentraleSupélec Center for Research, far from being limited to merely the “sum” of teams and skill sets, draws its strength from the complementarity of the reputed expertise of École Centrale Paris, and that of Supélec. CentraleSupélec offers a very large scientific spectrum, covering all Engineering and Systems Sciences.

CentraleSupélec Research aims to usefully contribute, through the progress of knowledge and developing innovative responses to major technological and social challenges. Their activities thus revolve around the key issues of the 21st century, and especially in 7 key fields: Communication Systems – Energy – Environment and Risks – Aeronautics and Transport – Health and Bio-Engineering – Nano-Sciences – Business Systems.

The research units cover eight scientific fields, in which they will continue to develop knowledge and increase their visibility and international reputation.



CentraleSupélec Research in numbers

| |
|---|
| 18 laboratories & research teams co-operated with major national research centers |
| 1 research federation in mathematics |
| 1 research institute with EDF |
| 4 international laboratories with China, Canada, United States & Singapore |
| 1 080 staff including: |
| <ul style="list-style-type: none"> • 300 faculty-researchers • 65 full-time researchers (CNRS, INRIA, ONERA) • 500 PhD candidates • 70 post-doctoral students • 145 administrative & technical staff |
| 591 publications in international reviews |
| 53 patents |
| 12 Chairs |



RESEARCH DEPARTMENTS & TEAMS

ÉNERGÉTIQUE MOLÉCULAIRE ET MACROSCOPIQUE, COMBUSTION - EM2C CNRS UPR 288

STRUCTURES PROPERTIES AND MODELING OF SOLIDS - SPMS CNRS UMR 8580

SOIL, STRUCTURE AND MATERIALS MECHANIC - MSSMAT CNRS UMR 8579

GÉNIE DES PROCÉDÉS ET MATÉRIAUX - LGPM EA 4038

MATHEMATICS IN INTERACTION WITH COMPUTER SCIENCE - MICS EA 4037

INDUSTRIAL ENGINEERING - LGI EA 2606

QUANTUM AND MOLECULAR PHOTONICS - LPQM UMR CNRS 8537 ENS CACHAN

CENTER FOR VISUAL COMPUTING - CVN

COMPUTER RESEARCH LABORATORY - LRI UMR CNRS 8623

SONDRA EA 4454

GROUP OF ELECTRICAL ENGINEERING – PARIS - GEEPS UMR CNRS 8507

LABORATORY OF SIGNALS AND SYSTEMS - L2S UMR CNRS 8506

LARGE NETWORKS AND SYSTEMS GROUP - LANEAS

SYSTÈMES ANALOGIQUES AVANCÉS

RESEARCH INSTITUTE FOR SMARTER ELECTRIC GRIDS - RISEGRID

UMI 2958 GEORGIA INSTITUTE OF TECHNOLOGY - CNRS

LABORATOIRE MATÉRIAUX OPTIQUES, PHOTONIQUE ET SYSTÈMES - LMOPS EA 4423

INSTITUT D'ÉLECTRONIQUE ET DE TÉLÉCOMMUNICATIONS DE RENNES - IETR UMR CNRS 6164

CONFIDENTIALITY, INTEGRITY, DISPOSIBILITY & REPARTITION - CIDRE, INRIA TEAM - IRISA UMR CNRS 6074

LABORATOIRE ÉNERGÉTIQUE MOLÉCULAIRE ET MACROSCOPIQUE, COMBUSTION - EM2C CNRS UPR 288

ENERGY RESEARCH AT THE HEART OF TWENTY-FIRST CENTURY INDUSTRIAL CHALLENGES

Energy and transportation have become major issues likely to severely disrupt the general organization of society. The scarcity of oil, the rational use of fossil fuels, reducing emissions, developing renewable energies and climate change risks pose many scientific questions. High level academic research on energy and combustion from molecular scales to more macroscopic scales and applied studies, in partnership with leading companies and research centers in the field of transport and energy, allows the EM2C laboratory from CNRS at CentraleSupélec, to contribute significantly to the advancement of knowledge of these difficult issues.

To meet these challenges, the research activities of the laboratory are organized around three axes: combustion, non-equilibrium plasmas, physics transfers and transverse action in Applied Mathematics.



COMBUSTION

Combustion activities focus on the understanding, control, simulation, improvement and optimization of combustion. The objectives are a better understanding of basic mechanisms and their interactions simultaneously developed through experimentation skills, modeling and high performance numerical simulation. This research is also based on innovations in the field of diagnostics, sensors, actuators, control methods and means of simulation.

NON-EQUILIBRIUM PLASMAS

Studies for non-equilibrium plasmas include firstly a fundamental part of the electric shocks and chemical kinetics and the diagnosis of non-equilibrium plasmas at atmospheric pressure, and, secondly, a component application in the fields of energy (ignition and stabilization of lean mixtures of fuel, hydrogen production), aerodynamics, atmospheric re-entry and the environment (waste gas treatment).

PHYSICAL TRANSFERS

Research conducted in the physical transfers team is around the transfer energy by radiation in gaseous media or transfers in porous media and nanothermic. By combining basic approaches and the development of effective models of heat transfer, this research addresses scientific and technological barriers related to applications as diverse as atmospheric re-entry spacecraft, transfer to a heart of a nuclear reactor or nanomaterials.

TRANSVERSAL ACTIVITY

Transversal action in applied mathematics relies on the implementation of projects at the interface of disciplines using scientific computing and high performance computing (HPC). It is conducted in close interaction with experimental researchers in the laboratory. These studies provide experimental results that are first considered for the validation of the codes developed in the laboratory. Simulations coupled with experimental results then form a new source of in-depth understanding of the physical phenomena studied.

KEY FIGURES

| | |
|---------------------------------------|--|
| FACULTY RESEARCHERS AND RESEARCHERS: | 30 |
| PhD STUDENTS: | 48 |
| POST-DOC: | 8 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 15 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): | 54 |
| RESEARCH CONTRACTS: | 2 000 000 € (IN ADDITION TO CHAIRS) |

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ACADEMIC PARTNERS

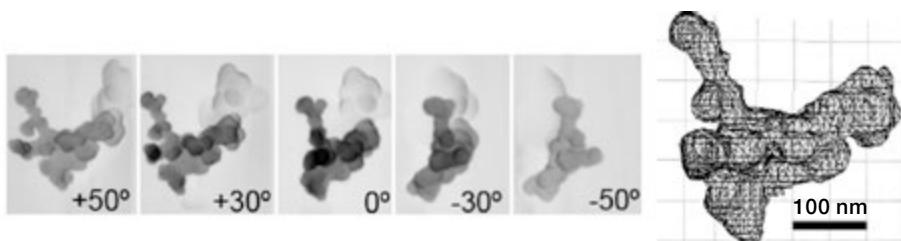
CERFACS, CORIA, CETHIL, ENS, ESPCI, LIMHP, PC2A, Colorado State University, Johns Hopkins University, Old Dominion University, Pennsylvania State University, Stanford University, Yale University, University of Rochester, MIT, Nasa Research Centers, Magdeburg, Université de Potsdam, Université Autonome de Madrid, Université d'Acunson Paraguay, JAXA, etc.

HIGHLIGHTS

- Sébastien Candel, Professor at the Ecole Centrale Paris, was elected vice-president of the French Academy of Sciences.
- Inauguration of the EM2C plasma torch facility.
- Hartnett-Irvine Award for “Numerical Study of Coupled Molecular Gas Radiation and Natural Convection in a Differentially Heated Cubical cavity” presented at ICHMT International Symposium on Advances in Computational Heat Transfer, Bath, England, by the authors, Laurent Soucasse, Philippe Rivière (EM2C), Shihe Xin, Patrick Le Quéré, and Anouar Soufiani (EM2C)
- A video presenting the ignition of the EM2C annular combustion rig using reactive large eddy simulation received the American Physical Society/Division of Fluid motion (http://www.em2c.ecp.fr/cms/lang/fr/le_laboratoire_em2c/video/movies)



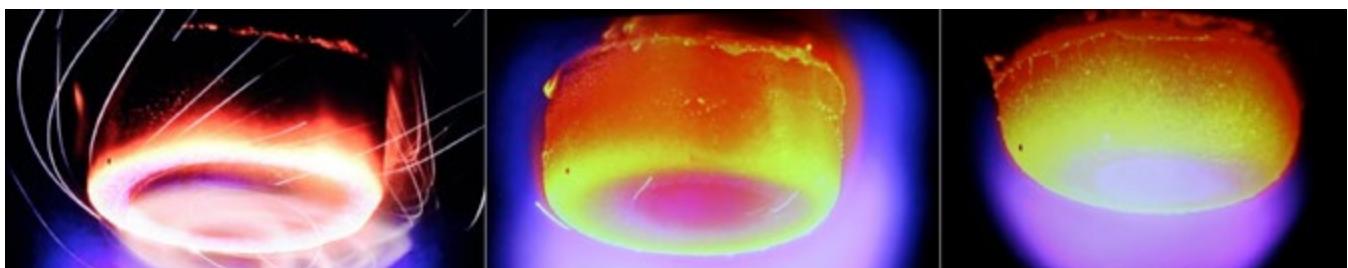
Annular combustion chamber MICCA (100 kW) equipped with 16 swirled injectors. This configuration is very close to a helicopter combustion chamber.



*Left: SEM micrographs of a propane/air soot aggregate with different observation orientations.
Right: 3D tomographic reconstruction of the soot.*



Snapshots of the number density of particles injected in a turbulent flow: computations with the Lagrangian model for the spray (left) and different kinds of Eulerian models.



Experimental investigation of the ablation of ASTERM® material by a high enthalpy air plasma flow representative of reentry conditions into Earth's atmosphere. The plasma is produced by the new 50 kW CentraleSupélec Plasma Torch facility. Left image: spallation in the swirled argon flow used during

INDUSTRIAL PARTNERS

Air Liquide, Areva, CEA, CNES, DGA, EDF, ESA, GDF-Suez, IFP Énergies Nouvelles, IRSN, MBDA, Onera, PSA, Renault, Safran, etc.

STRUCTURES, PROPERTIES AND MODELING OF SOLIDS

SPMS - UMR CNRS 8580

RESEARCH AXES

FUNCTIONAL MATERIALS FOR ENERGY

This research axis studies and proposes new materials for energy applications, more specifically for nuclear power and hydrogen technologies.

This axis includes the team CARMEN (joint Research Laboratory between Ecole CentraleSupélec, CNRS and CEA) which focuses on the properties of ceramic materials at thermodynamic equilibrium and out of equilibrium. This team also studies the influence of synthesis conditions on materials properties and the degradation of these properties under irradiation and extreme conditions of primer importance for nuclear applications.

This axis also includes an activity on materials for hydrogen technologies, whose objective is to propose high performance materials to make Solid Oxide Cells working at lower temperature or to produce hydrogen from solar light. An important activity concerns the measurement of electrical properties under controlled temperature and atmosphere.



ADVANCED FERROICS

This research axis focuses on functional oxides, whose properties are governed by electrical polarization, mechanical elasticity, magnetization and the coupling between all these ferroic properties. Our objective is (i) to design and develop new materials controlling different scales (crystals, ceramics, thin films, nanowires, nanocomposites, heterostructures...), (ii) study new functionalities for potential applications in electronics (ferroelectric memories, acoustic filters, spin electronics...), energy (energy harvesting, electrical energy storage, photovoltaics...), oil prospection (transducers) or even on bio-systems (biomechanical prostheses) and (iii) to understand the microscopic mechanisms (electromechanical, magnetoelectrical, photoelectrical coupling) involved in these functionalities to optimize and predict materials behavior. This research lays on advanced elaboration, nanostructuration, characterization and modelling tools.

ELECTRONIC STRUCTURES, MODELING AND SIMULATIONS

The scientific objective of the axis is the development of theoretical and experimental innovative methods for the understanding of crystalline solids. For theoretical aspects, we focus on the development of new functionals and approaches within the Density Functional Theory and on the treatment of quantum effects through molecular dynamics. From the experimental point of view, we could mention the non-photochemical laser induced nucleation and the specific methods for the joint analysis of solids from different experiences (diffraction, Compton...). This research is developed with the Parma University of Paris-sud. For this reason, all these methods have been widely applied to molecular drugs, but other systems include thermoelectric or dielectric oxides.

APPLICATION FIELDS

- Nuclear industry, ceramic materials for the 4th generation reactors,
- Functional ceramics, multilayer supercapacitors, piezoelectric transducers, electrostrictive actuators,
- Biomedical field, pharmaceutical industry, hydrogen technologies, nanostructured ceramics.

KEY FIGURES

| | |
|---------------------------------------|----|
| FACULTY RESEARCHERS AND RESEARCHERS: | 13 |
| ASSOCIATED RESEARCHERS: | 6 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 12 |
| PHD STUDENTS: | 18 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): | 36 |

SCIENTIFIC PARTNERS

National : CEA-Saclay, CEA-Bruyères, CEA-Cadarache, École Polytechnique, Faculty of Pharmacy (Châtenay-Malabry), University Paris XI, University Paris VI, ICMCB, ILL, ESRF, LLB, Soleil, LETI, Thiais, Vitry, etc.

International : University of Tokyo Waseda, Spring8, University of Arkansas, EPFL, University of Cracaw, University of Belgrade, University of Barcelona, Georgia Tech

CONTACT

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INDUSTRIAL PARTNERS

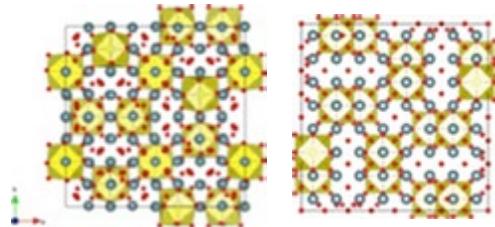
Schlumberger, NanoE, Coorstek, Thales et Thales Underwater Systems, Ferroperm, Imasonic, Ixsea (Sonar), ST micro, Leti, Horiba-Jobin Yvon, Saint-Gobain, NanoE, etc.

SAMPLE PROJECTS

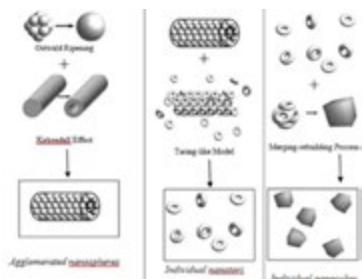
UNDERSTANDING NANOSCALE PHENOMENA IN ADVANCED NUCLEAR FUELS

Nuclear fuel safety, efficiency, and waste management are fundamental challenges that underpin technology development for advanced nuclear energy systems. The problem of understanding and developing a predictive capability for the evolution of fuels is challenging, even for phenomena that appear simple. Our research is aimed to understand microstructural evolutions and phase stability under relevant chemical and physical conditions, chemistry and structural evolution at interfaces, using neutron scattering, numerical models, and spectroscopies (Raman, tracer diffusion, impedance...) in uranium-based oxides and fission-product solutions, representing model nuclear fuels and waste forms. One of the results of our improved description of uranium oxidation on an atomic level is the assessment of a new model for the oxidation kinetics of nuclear fuels in accident scenarios.

Reference: D.A. Andersson, G. Baldinozzi, L. Desgranges, D.R. Conradson, S.D. Conradson, *Inorganic Chemistry* 03/2013; 52(5):2769-78



Experimental and simulated atomic scale changes of the O ion sublattice as the oxidation progresses in a uranium oxide fuels (left $\text{UO}_{2.24}$, right $\text{UO}_{2.33}$).



MORPHOGENESIS MECHANISMS OF FERROELECTRIC NANO-OBJECTS

Ferroelectric nano-objects are the next-generation bricks for advanced microelectronic. We have recently classified the different mechanisms at play during synthesis of these objects, some of them based on Turing original ideas about competing chemical reactions. We have also shown that depending of the shape of these objects, hyper-toroidal momentum of polarization could be used to build ultra-high density memories.

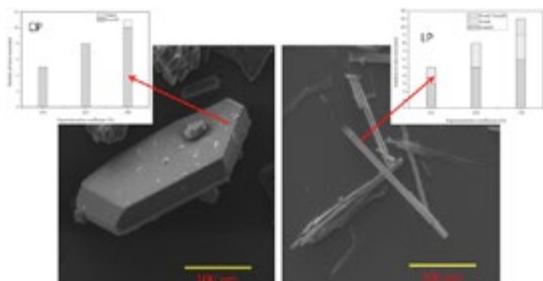
References: C. Bogicevic, G. Thorner, F. Karolak, P. Haghie-Ashtiani, J.M. Kiat, *Nanoscale*, 2015, 7, 3594–3603. G. Thorner, J.M. Kiat, C. Bogicevic, I. Kornev *Phys. Rev. B* 2014, B89, 220103(R),

Morphogenesis mechanisms of ferroelectric nano-objects

NON-PHOTOCHEMICAL LASER INDUCED NUCLEATION

NPLIN is a technique that allows the controlling of nucleation through laser light. The laser intensity and polarization (circular, linear) can be used to control the nucleation speed and polymorphic form. Briefly, a LASER light (532 nm, 7 ns, 10 Hz) is applied on a supersaturated i.e. metastable solution of an organic species. Once this solution is submitted to laser light during a short time (typically few seconds), some minutes to hours after, micrometric crystallites are detected via an optical microscope, indicating that nucleation has been induced by LASER. The term 'non-photochemical' is used to indicate that there is no chemical transformation of the molecules.

The potentialities of this method is (i) to be able to produce given structural forms of molecular crystals (ii) to produce high quality crystals with very little defect density [1, 2].



NPLIN of carbamazepine under linear (LP) or circular (CP) polarization. left) carbamazepine III right) carbamazepine I

References : [1] B. Clair, A. Ikni, W. Li, P. Scouflaire, V. Quemener, and A. Spasojevic-de Bire, *J. Appl. Cryst.* 47, 1252-1260 (2014); [2] A. Ikni, B. Clair, P. Scouflaire, S. Veesler, J.-M. Gillet, N. ElHassan, F. Dumas, and A. Spasojevic-de Biré, *Cryst. Growth Des.* 14, 3286-3299 (2014) [3] A. Spasojevic-De Biré, *International innovation*, 2013, sept, 44-46 [4] J. Belloni, A. Spasojevic-De Biré, S. Sorgues, M. Mostafavi, P. Scouflaire, N.-E. Ghermani, *Actualité chimique*, 2014, juil.-août-sept.-oct. 2014 - n° 387-388-389



Mechanical behavior of structures at very different scales - ranging from kilometers (seismic engineering) to nanometers (reinforced carbon nanotube composites) - based on strong multidisciplinarity competencies and a balanced approach between experimentation and supercomputing.

RESEARCH AXES

Materials Science & Engineering (SIM)

The research activity is focused on the microstructure / properties relationships and realized in various complementary fields. It is applied to metals, geomaterials, reinforced polymers, and biomaterials or biological tissues. The studies are carried out on different scales, analyzing nanoscale to bulk macroscopic samples. The methodology is based on a strong interactive coupling between experiments, modeling and numerical simulations.

Two main scientific themes are considered:

- **Materials processing and optimization:**
 - Nanotubes, living cells, micro- and nano-hybrid reinforced composites, metal alloys, biomaterials, soil behavior
 - Optimization of mechanical, physical, electrical, thermal properties
- **Prediction and simulation of materials behavior under severe in-use conditions:**
 - Behavior identification during monotonous and cyclic loading
 - Time and environment influence
 - Damage, fracture, fatigue

Using common approaches:

- **Experiments – numerical simulation coupling:**
 - Characterization and measurement at small local scale (3D imaging...)
 - Materials parameter identification under thermomechanical loadings, using field measurements
 - Complex mechanical test analyses based on mechanical modeling
- **Heterogeneous materials modeling at different scale levels:**
 - Quantification of the relationships between microstructure and properties
 - Identification of the optimal microstructures to reach optimal final properties

Numerical Science & Engineering (SIN)

The research in this field aims at developing numerical models and methods for the simulation of the mechanical behavior of materials and structures. The models developed range from the atomic scale, with ab initio finite elements to determine the mechanical properties of materials based on a simplified Schrödinger equation, to the kilometer scale for seismic computations to identify site effects in cities.

KEY FIGURES

| | |
|---------------------------------------|-------------|
| FACULTY RESEARCHERS AND RESEARCHERS: | 19 |
| PhD STUDENTS: | 39 |
| VISITING & POST-DOC: | 8 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 18 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): | 34 |
| RESEARCH CONTRACTS: | 1 045 875 € |
| (IN ADDITION TO CHAIRS) | |

ACADEMIC PARTNERS

Numerous universities and laboratories in France including CNRS (National Center for Scientific Research), CEA (Atomic Energy Commission).

Abroad: Technische Universität Wien, Université de Louvain and Université libre de Bruxelles, Universidade Federal do Rio de Janeiro, Ecole Polytechnique de Montréal and University of British Columbia, Institute of metal research Shenyang/Chinese Academy of Science, Institute of Physics/Chinese Academy of Science, Northwest University, Beijing University of Science & Technology and Beijing University of Aeronautics and Astronautics, Universidad de los Andes, Czech Technical University in Prague, Aristotle University of Thessaloniki, Università Mediterranea di Reggio Calabria, Saitama University, Instituto Superior Técnico de Lisboa and Universidade do Minho, Perm State Pedagogical University, BarcelonaTech, Tishreen University in Latakia, Faculty of Sciences of Bizerta, Institute for Engineering and Science (Texas University), Ames Lab (Iowa State University), University of Illinois, Jet Propulsion Laboratory (Nasa-Caltech, Pasadena, CA) and Columbia University (New York), Universidad Central de Venezuela.

EQUIPMENTS

- **Microscopy:** SEM with EDS and EBSD , FIB -SEM , TEM JEOL120 and TEM TITAN, AFM
- **Mechanical tests:** Traction-torsion and traction-compression machines (monotonous and fatigue, -200/1200°C, Helium quenching, quasi-static up to 1m/s), nano-indentor, micro-machines for in situ tests in SEM and RX, tests on mono micro-fibers
- **Physical measures:** X-ray diffraction (textures and internal stresses), thermal measures, (di)electrical measures, DMA, porosimetry.
- **Elaboration:** Nanotubes produced by CVD, in situ diagnostics, production of composites, cell culture
- **High Performance Calculation:** Access to CentraleSupélec cluster (parallel cluster with over 1000 cores)

The scientific competencies center around two main points:

- **Develop advanced models for specific media:**
 - Geomaterials considering their multi-physics characteristics
 - Random media and wave propagation for seismic engineering
 - Entangled media for the behavior of cables and textiles
- **Elaborate efficient and tuned numerical methods:**
 - *ab initio* finite elements
 - Field parameter identification through inverse approach
 - Space-time adaptive finite elements
 - Model coupling and multi-scale methods

The synergies between the SIN and SIM teams build on:

- Elaboration of models from experimental identification
- Validation and calibration of simulations from experiments
- Interpretation and control of experimental exploration using simulations

The effort to provide efficient applications results in a strong involvement of the laboratory in the CentraleSupélec High Performance Calculation cluster to promote the use of high performance computing and parallelism.

THEMATIC AXES OF RESEARCH

Characterization and Multi-scale Modeling of Materials (CM3)

This research topic aims at characterizing and accounting for phenomena at very different scales as well as their complex interactions, with applications as polycrystalline materials and braided cables. It is a transverse theme within the laboratory, which creates synergy of varied expertise and allows the joint use of rich experimental means and original numerical tools.

As a response to many current scientific locks, the C3M axis aims at breeding original projects in the field of multi-scale sciences, with a view at the Horizon 2020 stakes and in synergy with the other two axes of the laboratory.

Dynamics, Waves and Hazard (DynOdAs)

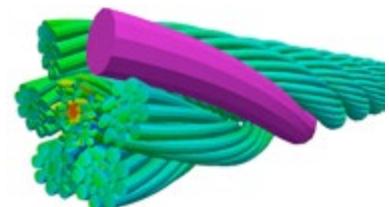
The main objective of this theme is the numerical modeling of the dynamic behavior of soils, structures and materials, particularly related to the phenomena of wave propagation. It is built in particular on multi-scale dynamical numerical models and probabilistic models and simulations. It relies heavily on HPC simulations for wave propagation.

Multiphysics and Interfaces (MPI)

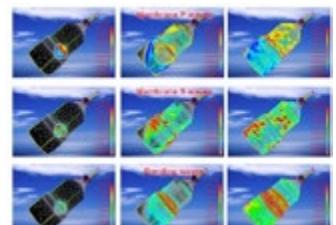
This theme aims at improving the macroscopic mechanical and physical properties of materials, including porous and/or living materials, based on experimental and numerical analyses at the nano-scale.

Several domains are studied :

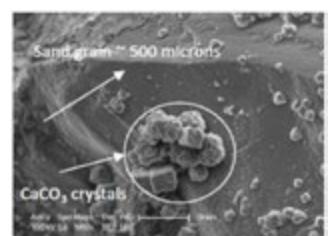
- Porous media: poro-mechanical, anti- pollution barrier, clogging, capillarity, infiltration...
- Cell culture within a dual porosity bioreactor
- Vapor-phase chemical deposition for the elaboration of nano-/micro-reinforcements
- Elaboration and characterization of high performance composites
- Quantitative electronic microscopy coupling observations and chemical analyses
- Development of multi-physics numerical tools for high performance computing.



Determination of stresses within a multi-threaded cable



Adaptive capture of shock wave propagation in the space launcher Ariane5



Observation of calcification in the simulation of bio-reinforcement of sands

INDUSTRIAL PARTNERS

ARCELOR-MITTAL, AREVA, AUBERT & DUVAL, BOUYER-LE-ROUX, CEA, CNES, EADS, EDF, GECKO BIOMEDICAL, IFTH, INERIS, ITER, LHOIST, MICHELIN, NECS, NEXANS, ORONA, SCHLUMBERGER, SNCF, SNECMA, THALES.

CONTACT

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LABORATOIRE DE GÉNIE DES PROCÉDÉS ET MATÉRIAUX

LGPM EA 4038

SUSTAINABLE INDUSTRIAL PRODUCTION AS A KEY CHALLENGE FOR THE TWENTY-FIRST CENTURY

LGPM has two principal interrelated axes of interest, namely, Process Engineering and the study of Materials. Key words for the activities of this Department include: Modelling, simulation and experimentation. These activities are encountered as a common thread in all the activities of the Department (LGPM).

The complementary nature of the Department's activities permit the application of the knowledge of microscopic phenomena to the construction of models, their simulation and the optimization and intensification of the processes under study. Our particular know-how and competence is the application of the "sustainability" aspects (e.g. use of renewable materials, economy of materials and energy) of processes in general to bioprocesses in particular. These Departmental competences have been strengthened by the participation of the Department in the creation of a Centre of Excellence for Industrial Biotechnology (CEBB) at the end of 2010, permitting full-time employment of two Professors, two Lecturers and two Engineers. This allows us to be deeply involved in the promising field of bio-economy

The Department is organized in three Teams:

MATERIALS AND BIOMATERIALS

- Metals, wood and natural fibers
- Development and transformation processes
- Tribocorrosion

CHEMISTRY AND SEPARATIVE PROCESSES

- Liquid-liquid extraction and extraction using emulsions
- Particle transport and deposition
- Analytical and preparative chromatography

BIOPROCESSES

- Multiscale bio-modelling, control-command strategies for bioreactors
- Use of microorganisms to capture CO₂ and/or to treat sewage
- Anaerobic digestion and methane generation
- Production and purification of high value molecules using plant cell cultures

REMARKABLE EQUIPMENT

Spectrophotometers (elemental analysis, ICP-AES, UV, IR, atomic absorption, fluorescence X), liquid and gas chromatographs, environmental ESEM + EDS, confocal microscope, Raman microscope, interferometric microscopy, thermo-balance coupled GS-MS, DMA, mass diffusion, permeability, sorption isotherms, BET, laser granulometer, tensiometer, Particle Image Velocity.

KEY FIGURES

| | |
|---------------------------------------|---|
| FACULTY RESEARCHERS AND RESEARCHERS: | 13 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 19 |
| PHD STUDENTS: | 20 |
| VISITING & POST-DOC: | 6 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): | 15 |
| RESEARCH CONTRACTS: | 862 000 € <small>(IN ADDITION TO CHAIRS)</small> |

CONTACTS

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INTERNATIONAL ACADEMIC PARTNERS

School of Mathematical Sciences QUT (Australia), Universidade de São Paulo and Universidade, Université du Québec in Abitibi-Témiscamingue (Canada), Cornell University (USA), Poznan University of Life Sciences (Poland), Univeritatea Dunarea de Jos de Galati (Romania), State Teaching University of Perm (Russia), École Nationale d'Ingénieur de Monastir (Tunisia).

INDUSTRIAL PARTNERS

ARCELORMITTAL, ARD, CEA, CNES, CRISTAL UNION, EMUL-SAR, ENNESYS, ERAMET (Le Nickel, CRT), EURODIA, FUTUR-OL, IPF Energies Nouvelles, OENOCONCEPT, OLYGOSE, RIO TINTO ALCAN, SAINT-GOBAIN, SOLIANCE, VALE (Brazil).

PROCESSES AND PILOT DEVICES:

- Liquid-liquid extraction,
- Preparative gas and liquid chromatography,
- Ultra- and nano-filtration,
- Reverse osmosis,
- Bioreactors,
- Photo-bioreactors,
- Drying,
- Thermal treatment,
- Surface treatments.

SAMPLE PROJECTS

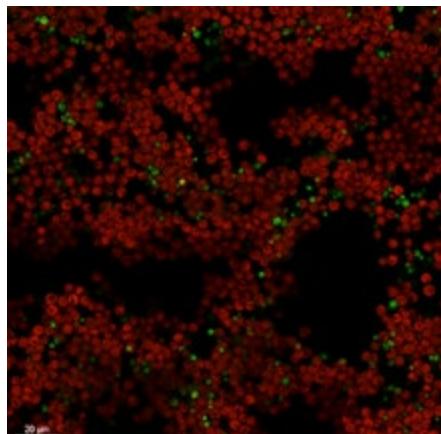


Fig. 1 – Two examples of confocal image: left) growth of fungi and right) mixed culture of Chlorella (red) and yeast (green).

Images can be grabbed automatically over time, which builds up perfect databases for our bio-modeling approaches (images Cyril Breton, LGPM).

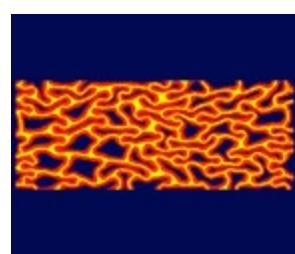
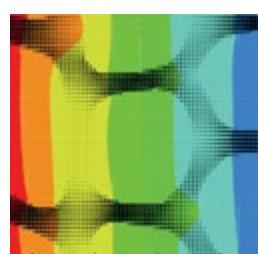
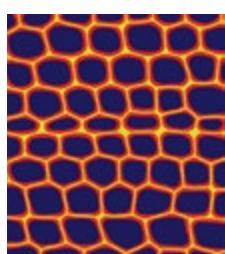
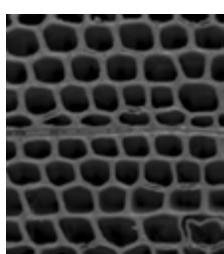


Fig. 2 – Image-based modeling of biomass tissues, from left to right: initial ESEM image of spruce, digital representation of this cellular morphology, temperature field and heat flux computed on this structure using Lattice Boltzmann method (zoom over one tracheid), Compression at high deformation rate computed using the Material Point Method (Perré et al., Annals Forest Sci., in press).

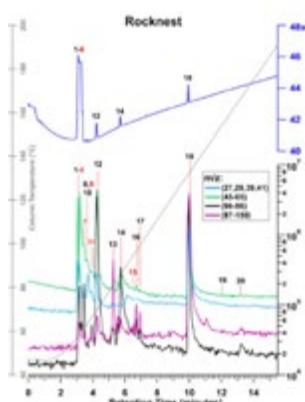


Fig. 3. Could Mars ever have supported small life forms?

Our lab is involved in the Curiosity mission. This figure presents the separation and identification by the module SAM-GC-TCD-QMS of volatiles issue from the Martian soil at Rocknest.

Among identified components: 2, carbon dioxide; 3, sulfure dioxide; 6, chloromethan; 7, dichloromethan; 9, trichloromethan (L. Leshin et al., Science, 2013, Ming et al., Science, 2013).

MATHEMATICS IN INTERACTION WITH COMPUTER SCIENCE

MICS - EA 403

RESEARCH THEMES

Founded in the early 2000's, MICS (former MAS) is the research laboratory in Mathematics and Computer Science at École Centrale Paris. Research at MICS is concerned with analyzing, modelling, simulating and optimizing complex systems, whether they come from an industrial environment, biosciences, financial markets, information technology or networks.

DIGIPLANTE - PLANT GROWTH MODELLING

Modelling and estimating the plant dynamical system in its environment; formal grammar and symbolic methods; optimal control of culture and genetic improvement; multi-physic and multi-scale landscape simulation.

PARTIAL DIFFERENTIAL EQUATIONS AND SCIENTIFIC COMPUTING

Non-smooth fluid-structure interactions; dynamics of ecosystems; interface dynamics; massively parallel computing; GPU; asymptotic-preserving numerical schemes; nonlinear wave equations.

FORMAL METHODS IN COMPUTER SCIENCE AND KNOWLEDGE MODELLING

Formal design of complex systems; ontologies, decisional and fuzzy logic for image interpretation; unified semantics for structured and unstructured data.

BUSINESS INTELLIGENCE (SAP RESEARCH CHAIR)

Business intelligence & visual analytics.

QUANTITATIVE FINANCE (BNP-PARIBAS RESEARCH CHAIR)

Financial market modelling; market microstructure; high frequency data; econophysics; derivatives.

PROBABILISTIC MODELLING AND UNCERTAINTIES (INCLUDING INRIA PROJECT REGULARITY)

Local regularity of stochastic processes; processes with prescribed regularity; set-indexed processes; ergodic theory; statistical properties of graphs; structured data.

BIO-MATHEMATICS

Mathematical modelling of in vivo cellular behaviour; DNA chips; epidemiology.

APPLICATIONS

Industrial systems (aerospace, construction, energy, transportation); environment (plants, hydrology, landscapes, acoustics); life sciences (molecular biology, genetics, epidemiology); markets and companies (finance, capital markets, business intelligence); information technology and networks (internet, multimedia, knowledge management); art and architecture (colorimetrics, virtual reality).

KEY FIGURES

| | |
|---------------------------------------|-----------|
| FACULTY RESEARCHERS AND RESEARCHERS: | 21 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 9 |
| PHD STUDENTS: | 37 |
| Post-Doc: | 10 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): | 26 |
| RESEARCH CONTRACTS: | 827 000 € |
| (IN ADDITION TO CHAIRS) | |

CONTACT

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MAIN ACADEMIC PARTNERS

INRIA, CEA, ENS Cachan, École Polytechnique, INRA, CIRAD, Université Paris XI, Université Versailles Saint-Quentin, LIAMA, Université de Montréal, ENSI Tunis, Saha Institute of Nuclear Physics, Institut Louis Bachelier, Supélec.

MAIN INDUSTRIAL PARTNERS

BNP Paribas, SAP, Alcatel, Bionatics, Bull, GDF-Suez, Institut Pasteur, CS-SI, Dassault Aviation, EDF, ESI, France Télécom, KXEN, Myosix, Renault, Thales.
System@tic, Finance Innovation, Cap Digital.
TERATEC

EXEMPLES DE TRAVAUX

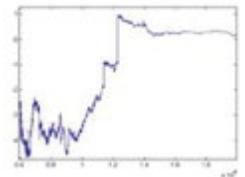
INGÉNIERIE SCIENTIFIQUE ET VISUALISATION

Les techniques de modélisation, de simulation et d'optimisation sont devenues des outils essentiels pour l'analyse et la conception de produits et systèmes.

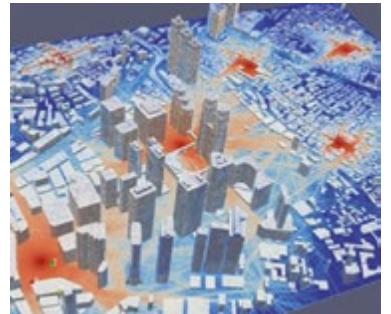
Cet axe de recherche s'intéresse aux systèmes complexes modélisés par des systèmes dynamiques, aux techniques d'optimisation et de contrôle, et aux environnements de pré- et post-traitement associés. Deux projets-phare se sont développés : Digiplante en lien avec l'INRIA, le CIRAD, AgroParis-Tech et le LIAMA à Pékin, autour de la modélisation de la croissance des plantes, depuis le génome jusqu'au paysage ; le grand projet pluridisciplinaire CSDL (Complex System Design Lab) du Pôle System @tic, où le laboratoire coordonne des approches de modélisation, simulation déterministe ou probabiliste et de visualisation décisionnelle avancée.



Restitution de la couleur par modèle numérique



source Regularity : régularité empirique sur des reliefs montagneux et simulation de processus à régularité prescrite



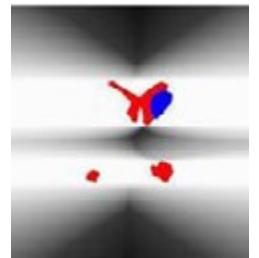
source Équipe HPC : calcul parallèle de grands modèles acoustiques du bruit à Tokyo

MODÉLISATION PROBABILISTE ET STATISTIQUE

La modélisation probabiliste et la modélisation à partir des données sont deux axes de recherche importants. On peut citer d'une part la finance quantitative et la modélisation des marchés financiers à partir des données haute fréquence, dans le cadre d'une chaire industrielle avec BNP Paribas ; d'autre part, la modélisation fine de la régularité des processus stochastiques et la prise en compte des incertitudes dans les modèles, en collaboration avec l'INRIA.

ARCHITECTURES DES SYSTÈMES D'INFORMATION

Les systèmes d'information connaissent une évolution rapide en termes d'architectures, mais aussi de modes de fonctionnement. Ce thème s'intéresse aux nouvelles architectures de type cluster-Grille ou *cloud computing*, aux architectures et au traitement de grandes masses d'informations, notamment multimédia, au domaine de la Business Intelligence dans le cadre d'une chaire avec SAP-Business Objects et aux approches d'ingénierie formelle pour les systèmes complexes. Le laboratoire est impliqué dans plusieurs initiatives européennes, en particulier EGEE, BEINGRID et PEGASE, et se développe sur les architectures HPC parallèle (par exemple projet Open GPU).



source MASDOM : représentation du raisonnement spatial flou sur motifs d'images médicales

LABORATOIRE GÉNIE INDUSTRIEL LGI - EA 2606

INDUSTRIAL ENGINEERING DEPARTMENT

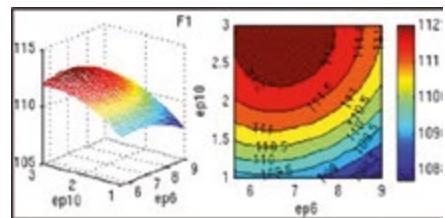
The goal of the Industrial Engineering (IE) Department (Laboratoire Génie Industriel, LGI) is to develop models, methods and tools for diagnosing, specifying, designing, developing, manufacturing, launching, exploiting, recycling at best socio-technical systems. These systems are industrial systems (production systems, value chains, eco-parks), complex products (airplanes, cars...), complex factories, transportation systems, health systems, energy networks, service systems and construction systems. Key principles of our research are: multidisciplinarity, life-cycle thinking, societal issues, model-based engineering approaches.

Studied systems are often characterized by the following:

- The presence of sophisticated technical components but also of human agents (organizations, policy makers, operators)
- A large number of individual components that interact,
- Heterogeneity of these components, each with specific individual behavior,
- Systems that must often be analyzed at different physical, spatial and temporal scales and from different points of view (technical performance, cost, environmental impacts, material flows, skills...)
- A system feedback on its components and the emergence of macroscopic properties.

The control of such systems presents many challenges and issues from both a technical and scientific point of view as well as practical and application perspectives like financial profitability, efficiency, continuity and reliability of service, security. The integration of technical systems is already challenging regarding, for example, aerospace, automotive or energy systems, but it is even more complex when it comes to inter-network systems («System of Systems» paradigm) such as health systems, human mobility infrastructure, distribution of products and services, transport and regulation of energy, gas, water, and other socio-technical systems including human or various agents such as organizations with different and even contradictory strategies, goals and preferences.

Our scientific approach consists in adequately modeling for analyzing and simulating in order to better understand the system behavior through virtual experiments on models and, ultimately, finding optimal solutions for the design, deployment and monitoring. Often many life cycle phases of these systems must be modeled and analyzed: collection of needs and requirements specification, development (architectural design, design, validation, manufacture and market launch or startup), system management (its regulation, its maintenance, its failure modes, its upgrade), its dismantling and end of life.



Simulation paramétrique des performances et optimisation du prédimensionnement d'un produit complexe

KEY FIGURES

| | |
|---------------------------------------|-----------|
| FACULTY RESEARCHERS AND RESEARCHERS: | 20 |
| VISITEURS ET PostDocs: | 4 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 6 |
| PHD STUDENTS: | 46 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): | 48 |
| RESEARCH CONTRACTS: | 613 000 € |
| (IN ADDITION TO CHAIRS) | |

ACADEMIC PARTNERS

Europe: University of Stavanger-Norway, DTU-Denmark, University of Liverpool-England, Universidad Politecnica de Valencia-Spain, ETHZ-Switzerland, Politecnico di Milano, Aalto University-Finland, Magdeburg University-Germany, TU Munich, University of Bath-UK, Université de Louvain-Belgique

Asia: Beihang University-China, École Centrale Beijing, City University-Hong Kong, Wuhan University of Technology-China, Chiba University-Japan

America: Northwestern University-Chicago, MIT, Penn State University, Georgia University of Technology, University of Minnesota, UFRJ-Brazil, PUC-Brazil

Africa: ENIT-Tunis, ENIM-Monastir

INDUSTRIAL PARTNERS

Air Liquide, BNP Paribas, Bouygues Construction, Capitaldon, Carrefour, CEA, Danone, Dassault Aviation, DHL, EADS, EDF, Établissement Français du Sang, Faurecia, Hôpital Georges Pompidou, Hôpital Henri Mondor, Lafarge, Lhôtellier, LVMH, PSA Peugeot Citroën, Renault S.A., Safran, Sanofi, Schlumberger, Schneider Electric, Total, Vallourec, Ville de Paris.

CONTACT

www.gi.ecp.fr

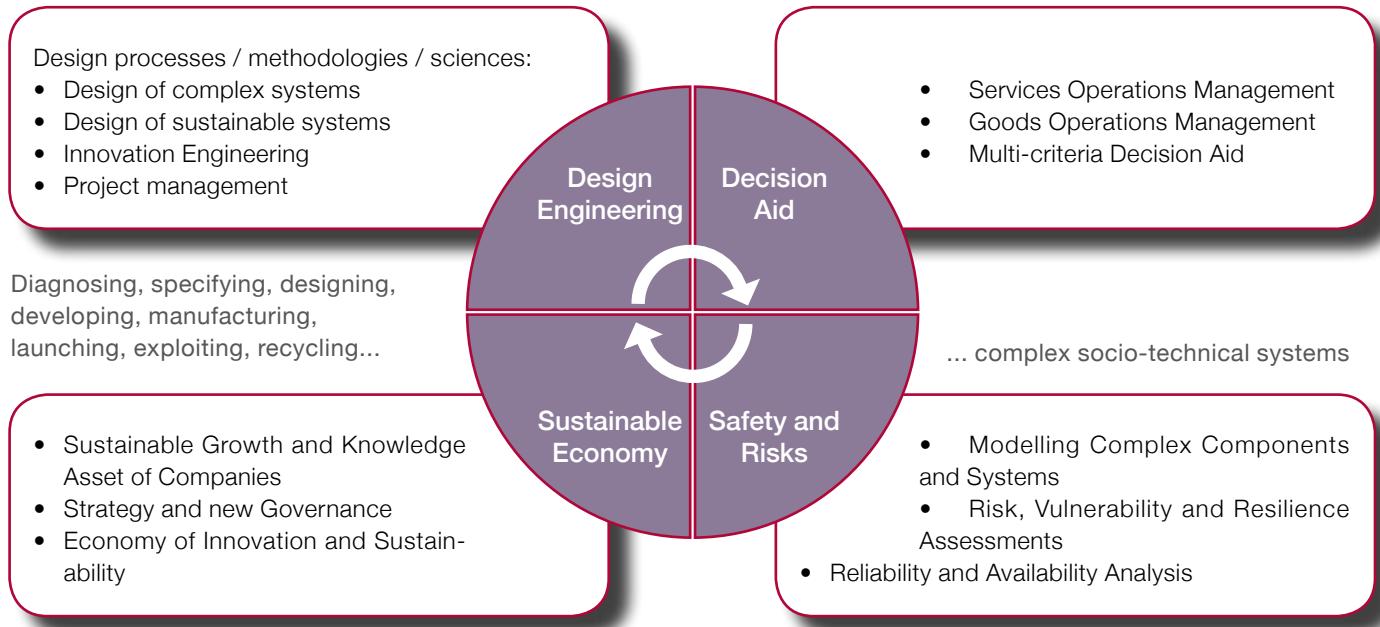
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WE ARE ORGANIZED IN 4 RESEARCH TEAMS:

- **Design Engineering,**
- **Decision Aid,**
- **Safety and Risks,**
- **Sustainable Economy.**



The 4 research teams of the IE department and their research topics

Ten industrial chairs and two research institutes reinforce the 4 research teams.

The 10 industrial chairs are about:

- Sustainable Construction (Bouygues Construction),
- Digital Factory (Dassault Aviation),
- Operational Excellence (BNP Paribas),
- Production Management (Faurecia),
- Supply Chain (LVMH, Sanofi, Carrefour, Safran),
- Electro-mobility (PSA Peugeot Citroën),
- Energy Economy (Capitaldon),
- Design of innovation products (multi companies),
- Systems Engineering (Safran),
- Purchasing in complex projects (Total),
- Systems Sciences (EDF).

The two research institutes for which the department is a founding member are:

- IRT System X (Digital Engineering of Complex Systems)
- PS2E (Paris Saclay Energy Efficiency).

The 10 industrial Chairs associated with IE department, see <http://www.lgi.ecp.fr/pmwiki.php/Main/Chaires>

QUANTUM AND MOLECULAR PHOTONICS LAB LABORATOIRE DE PHOTONIQUE QUANTIQUE & MOLÉCULAIRE LPQM - UMR CNRS 8537 - ENS CACHAN

This team of CentraleSupélec, investigating ultrafast optical and thermal exchanges at the nanoscale, belongs to both LPQM and Institut d'Alembert of the Ecole Normale Supérieure de Cachan and the CNRS.



RESEARCH TOPICS

ULTRAFAST PLASMONICS IN METAL NANOPARTICLES

Noble metal nanoparticles offer remarkable optical properties linked with the plasmon resonance phenomenon. Numerous developments are currently based on these properties, constituting the field of plasmonics. In order to better understand the physical processes involved, it appears relevant to study the dynamics of the optical response subsequent to the excitation of matter by a light pulse. This topic therefore relies on the development of modeling methods adapted to the different time scales involved and on the implementation of ultrafast laser spectroscopy techniques.



PHOTO-INDUCED HEAT TRANSFER AT SHORT TIME AND SPACE SCALES

In this theme we study the optical generation of heat and its transfer at both nanometer scale and ultra-short times, where the classical thermodynamics approaches are no longer valid. Beyond, it is possible to structure matter as to transform a thermal excitation into a coherent radiation. This can be achieved for instance by coupling the phonon-polariton phenomenon to a photonic cavity. This topic is developed in partnership with the EM2C laboratory.



HEAT NANOSOURCES FOR CHEMISTRY AND BIOLOGY

Metal nanoparticles under visible electromagnetic radiation are able to act as nanoscale heat sources due to a series of internal energy exchanges. This conversion process can be employed in various fields, particularly for realizing optical, chemical or biological functions. One can then envisage materials or devices whose functionality is only activated and controlled by light. Within dedicated partnerships we jointly develop projects targeting biomedical applications (improvement of the adhesion of nanohybrid particles on cancer cells for nano-hyperthermia therapy, plasmonic liposomes for targeted drug delivery, intracellular DNA strand delivery triggered by nanoscale photothermal effect for gene therapy). Beyond, the high local electromagnetic field generated at the plasmon resonance of gold nanoparticles induces the effective ionization of water molecules around, which can be exploited for photodynamic therapy, in conjunction with the photothermal effect.

ULTRAFAST PHOTO-INDUCED MODULATION OF THE NANOPARTICLE OPTICAL PROPERTIES: PHOTONIC APPLICATIONS

Thanks to the localized plasmon resonance phenomenon, stemming from the interaction of an electromagnetic wave and the electrons confined in metal nanoparticles, one can efficiently and very quickly inject energy in the latter by light irradiation. From the series of the subsequent exchange and relaxation mechanisms the optical properties of the composite medium where these nanoparticles are spread are modified in a fast transient way. By playing together with these nanoscale photo-induced modifications and the processing of the composite medium in wavelength-scale structured devices (resonant cavity, photonic crystal), one may conceive optically controlled photonic functions.

KEY FIGURES

| |
|---|
| ENSEIGNANTS-CHERCHEUR : 1,5 |
| INGÉNIEUR DE RECHERCHE : 1 |
| PostDocs: 2 |
| PhD STUDENTS: 2 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): 4 |

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SCIENTIFIC PARTNERS

France: Énergétique Moléculaire et Macroscopique, Combustion (CNRS-ECP); Laboratoire de Chimie Physique (Orsay); Sciences et Ingénierie de la Matière Molle - Physico-chimie des Polymères et Milieux Divisés (ESPCI, Paris); UMR_S728 Université Denis Diderot (Paris 7) – Inserm; Photophysique et Photochimie Supramoléculaires et Macromoléculaires (ENS Cachan); Physicochimie des Electrolytes, Colloïdes et Sciences Analytiques (Paris).

International: Instituto de Optica, Madrid, Spain ; Univ. Sistan & Baluchestan, Iran.

FIELDS OF APPLICATION

Use of metal nanoparticles in therapies against cancer by localized photo-induced hyperthermia, generation of reactive oxygen species, or drug delivery. Application of the transient optical response of nanomaterials in the field of ultrafast photonics and catalysis.

KEY FACTS

EFFECTIVE NANOSCALE PHOTO-GENERATION OF REACTIVE OXYGEN SPECIES

In partnership with the group of R. Pansu at PPSM laboratory in ENS de Cachan, we have demonstrated that in a gold nanorod irradiated by femtosecond light pulses a multiphotonic process enabled by the local field enhancement at the plasmon resonance generates efficiently a local plasma and reactive oxygen species, over a range of several micrometers (Fig. 1). This is very promising for local photodynamic therapy of cancer.

Figure 1. Production of reactive oxygen species by a single gold nanorod irradiated by polarization-controlled femtosecond laser pulses tuned at the plasmon resonance, probed by a fluorescent molecule. From left to right: three different polarization directions. Scale bar: 1 μm .

ORGANIC MICROLASERS

A member of our team is implicated in the experimental investigation of the ray-wave correspondence in organic microlasers of various triangular shapes performed within another team of the LPQM laboratory. This study has been published in 2014.

THERMAL METAMATERIALS

On some materials at the nanoscale heat propagates as an electromagnetic surface wave called surface phonon polariton. The heat thus acquires coherence properties over distances up to and meter and it becomes possible to use the tools of nano-optics to change its propagation. By structuring the material at a sub-wavelength scale, one can then create a material whose thermal properties do not exist in nature. The development of simulation tools based solely on Maxwell's equations of electromagnetism has opened the opportunity to create passive materials with temperature inhomogeneities though at thermal equilibrium. This theme is developed in partnership with the team of S. Volz at EM2C laboratory.

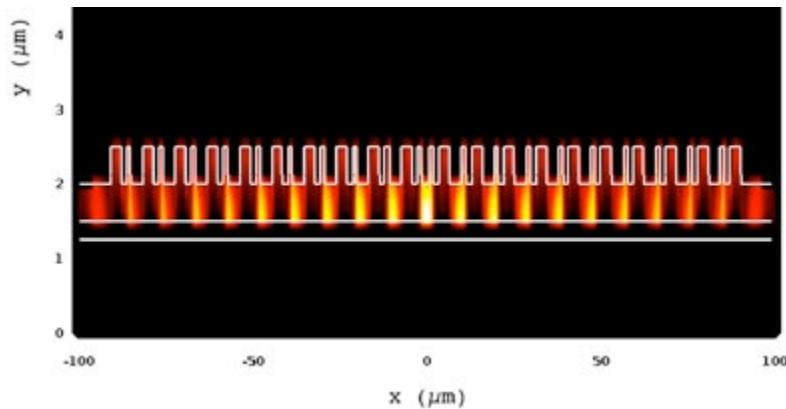


Figure 2. Simulation of heat in a nanostructured thin layer of SiO_2 (the coldest is black, hottest white.) Note that in the structure, although thermal energy is uniformly supplied, the heat distribution is inhomogeneous.

PUBLICATIONS

1. Effects of anisotropy and size of polar nano thin films on their thermal conductivity due to surface phonon-polaritons J. Ordonez-Miranda, L. Tranchant, B. Kim et al. *Applied Physics Express*, Vol. 7 Issue 3 (2014)
2. Fresnel-like formulas for the reflection and transmission of surface phonon-polaritons at a dielectric interface J. Ordonez-Miranda, L. Tranchant, S. Gluchko et al., *Physical Review B* Vol. 90 Issue: 15 (2014)
3. Localized lasing modes of triangular organic microlasers C. Lafargue, M. Lebental, A. Grigis, C. Ulysse, I. Gozhyk, N. Djellali, J. Zyss, and S. Bittner, *Physical Review E*, vol. 90, 052922 (2014).
4. Quantized Thermal Conductance of Nanowires at Room Temperature Due to Zenneck Surface-Phonon Polaritons J. Ordonez-Miranda, L. Tranchant, B. Kim, et al., *Physical Review Letters* Vol. 112 Issue: 5 (2014)
5. Thermal conductivity of nano-layered systems due to surface phonon-polaritons J. Ordonez-Miranda, L. Tranchant, Y. Chalopin et al., *Journal of Applied Physics* Vol. 115 Issue: 5 (2014)

HISTORICAL REVIEW

Computational vision is one of the most challenging research domains in engineering sciences. The aim is to reproduce human visual perception through intelligent processing of visual data.

CVC aims at proposing innovative techniques towards automatic structuring, interpretation and modeling of big (visual) data. CVC was established on Sep. 2011 and is also associated with Inria Saclay, Île-de-France unit through a joint project-team (GALEN). Its primary objective is to become a center of international scientific excellence in the field of computer vision, machine learning and medical imaging analysis. The computer vision problems that we work with can be broadly understood as serving the objective of scene understanding. Examples of such problems include:

MACHINE LEARNING & OPTIMIZATION

- **Defining the Score.** We need to specify a form of the score, which is often parametric in nature. Specifically, the likelihood is defined as a parametric function of features extracted from the data. Feature scan dramatically simplify subsequent tasks by eliciting those parts of the low-level signal that are of use for further processing, and removing irrelevant variations. The priors are defined as parametric potentials that capture an expert's knowledge of the problem domain. For example, one such prior can favor random variables that are neighbors in space to take the same or similar labels. The relative score of assigning them the same or a different label will be a parameter of the graphical model.
- **Learning.** We need to estimate the parameters of the model. Typically, this is done by collecting training samples with annotations that represent the ground-truth output of the corresponding input. Ideally, the parameters should be estimated such that the score of the ground-truth output is greater than the score of all other outputs, while avoiding overfitting to the training data.
- **Optimization.** Given the score function whose parameters have been estimated using the training data, we would like to efficiently obtain the most likely output for a previously unseen input. This requires maximizing the score over all possible labelings of the unobserved random variables, which we shall henceforth refer to as inference (in a more restricted sense than visual inference, above).

KEY FIGURES

| |
|---|
| FACULTY RESEARCHERS AND RESEARCHERS: 5 |
| PhD STUDENTS: 17 |
| ADMINISTRATIVE AND TECHNICAL STAFF: 3 |
| RANK A PUBLICATIONS (WEB OF SCIENCE): 22 |
| RESEARCH CONTRACTS: 519 000 € <small>(IN ADDITION TO CHAIRS)</small> |

ACADEMIC PARTNERS

INRIA (FR), École des Ponts-ParisTech (FR), Henri Mondor University Hospital (FR), European Hospital Georges Pompidou (FR), Pitié-Salpêtrière Hospital (FR), Montpellier University Hospital (FR), Stanford University (USA), StonyBrook University (USA), Computer Science Department (USA), University of Pennsylvania (USA), University of California at Los Angeles (USA), Technical University of Munich (DE), University of Lugano (CH), University of Oxford (UK), University College London (UK), University of Oulu (Finland), Ecole Polytechnique de Montreal (CA), International Institute of Information Technology, Hyderabad (IN).

CONTACT

<http://cvn.ecp.fr>
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PARTNERSHIPS AND COOPERATIONS

Digiteo, Medicen, Cap Digital

Bilateral Contracts & Grants with Industry: General Electric Health Care, Siemens Medical Solutions, Intrasense, LLTECH

COMPUTER VISION

- **Object Detection.** Given an image or a video depicting a natural scene, the goal of object Detection is to localize the instances of an object category of interest (such as ‘car’ or ‘person’). The localization is normally represented by a bounding box of the object.
- **Pose Estimation.** Given an image or a video containing an object, the goal of pose estimation is to automatically deduce the pose of the object. For example, the pose of a person is represented by the location, scale and rotation of the head, the torso and the half-limbs.
- **Action Classification.** Given an image or a video containing an object, the goal of action classification is to classify it as positive, that is, the object is performing an action of interest (such as ‘jumping’ or ‘running’), or negative, that is, the object is not performing an action of interest.
- **Semantic Segmentation.** Given an image or a video, the goal of semantic segmentation is to label each pixel or voxel as its semantic class (such as ‘car’, ‘person’, ‘tree’ or ‘road’).

BIOMEDICAL IMAGE ANALYSIS

- **Motion Estimation.** Given a sequence of biomedical acquisitions taken over a period of time, The goal of motion estimation is to determine the pixel /voxel corresponding to each pixel/voxel in the previous time step, which can amount to estimating a non-rigid, potentially infinite dimensional deformation field.
- **Image Registration.** Given two biomedical acquisitions of the same organ obtained from the same or different subjects, the goal of image registration is to establish a point-to-point correspondence between the pixels/voxels of the organ. Similar to motion estimation, the point correspondences do not obey a simple form such as rigid transformations.
- **Image Segmentation.** Given a biomedical acquisition, the goal is to label each pixel/voxel as belonging to a class, such as ‘foreground’ or ‘background’; or different muscle groups.

APPLICATION DOMAINS

- **Complex industrial systems** (automation, optical flow, robotics, non destructive control)
- **Automotive** (computer assisting driving, cruise control, parking assistance)
- **Health** (computer aided diagnosis, computer assisted surgery, image biomarkers)

HIGHLIGHTS OF THE YEAR

- **MICROSOFT RESEARCH FELLOWSHIP**
Pawan Kumar proposal on machine learning was retained for funding in the context of this program.
- **COURSERA**
Pawan Kumar Mudigonda & Nikos Paragios introduced a new MOOC course (MOOC means Massive Open Online Courses) on discrete inference and learning in artificial vision on the Coursera platform with approx. 15,000 student enrollments (<https://www.coursera.org/course/artificialvision>)
- **IBM FACULTY AWARD**
Nikos Paragios, has been awarded a 2014 IBM Faculty Award for his research work on visual analytics and his teaching involvement towards the creation of a novel/innovative curriculum in data sciences bringing together computer science, applied mathematics and statistics.
- **INSTITUT UNIVERSITAIRE DE FRANCE**
Nikos Paragios was appointed as Senior fellow of the Institut Universitaire de France.

LRI is the Laboratory for Computer Science at Université Paris Sud, joint with CNRS the National Center for Scientific Research, INRIA and CentraleSupélec. Founded more than 35 years ago, it has over 250 members, including over than 130 faculty and staff and 88 Ph.D. students. LRI consists of nine research groups, supported by an administrative and a technical staff. Six of the research groups are totally or partially joint with Inria Saclay Île-de-France making it one of the main partners of the laboratory. The laboratory is located on the Moulon plateau in its new connected buildings Ada Lovelace and Claude Shannon.

The research themes addressed by LRI cover a wide spectrum of computer science focused on software ranging from fundamental to applied research: algorithms, combinatorics, graph theory, discrete and continuous optimization, programming, software engineering, verification and proofs, parallel systems, high performance computing, grids, architecture and compilation, networking, databases, knowledge representation and processing, machine learning, data mining, bioinformatics, human-computer interaction, etc. Such diversity is one of the strengths of the laboratory, fostering research at the boundaries across areas, where the potential for innovation is highest.

The laboratory participates in a large number of national and international projects, including those funded by ANR the French National Research Agency, by Digiteo and by the European Union (in particular the KIC ICT Labs from EIT). LRI members participate in many editorial boards of international journals and program committees of international conferences. The laboratory is also highly productive, with over 2000 publications in last five years, and is strongly involved in software production and transfer.

LRI is a partner in Digiteo one of the twelve research networks created by the French government in 2007 and the only one in Information Sciences and Technologies (IST). Digiteo gathers on Saclay plateau 1 200 researchers from 23 laboratories of six founding national research institutions (CNRS, CEA, Inria, Université Paris-Sud, École Polytechnique, CentraleSupélec) and six associate members which joint later (ENS Cachan, Université de Versailles Saint-Quentin-en-Yvelines, Institut Mines-Télécom, Mines ParisTech, ENSTA ParisTech). LRI is also a partner in System@tic Paris-Region a world-class competitiveness cluster with more than 200 industrial, academic and institutional members in the area of complex software and systems.

LRI is strongly involved in the Investments for the Future programs launched in 2010 by the French government. It leads the Equipex Digiscope, the Labex Digicosme, it participates to the IRT SystemX and is very active in the IDEX Paris-Saclay which will give birth in 2014 to the new Paris-Saclay University: it plays an important role in setting the future IST Department in the continuity of Digiteo and leads the projects of the IST Doctoral School and of the computer science master of the Paris-Saclay University.

Stochastic continuous optimization

- Invariance under monotonous transform of optimization objective F
- Invariance under affine transform of search space Ω
- A particular case of information Geometry Optimization
- 100+ Applications to Optimal design, Engineering, e-Science (chemistry, physics, biology)
- Softwares: CMA-ES, ACM-ES

KEY FIGURES

| | |
|---------------------------------------|-----|
| FACULTY RESEARCHERS AND RESEARCHERS: | 130 |
| PHD STUDENTS: | 88 |
| POST-DOCTORANTS : | 1 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 2 |
| INTERNATIONAL PEER-REVIEWED JOURNALS: | 14 |

CONTACT

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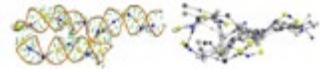
Mail: direction@lri.fr

ACADEMIC PARTNERS

University of Vienna Austria, University of Montreal, Concordia University Montréal, Toronto University, MacMaster University Hamilton, TU Dresden, Pisa University, Milano University, University of Tokyo, Kyoto University, Vrije Universiteit Amsterdam, ETH Zürich Switzerland, Imperial College London, University of Manchester, University of Oxford, University of California at Berkeley, Davis, San Diego, Santa Cruz, City College of New-York, University of Minnesota Minneapolis, Stanford University...

INDUSTRIAL PARTNERS

EDF, Thalès, Télécom, L'oréal, Schneider, Daimler, Dassault, SAP Sirehna, Philips, IBM, Nokia, STMicroelectronics, EADS...



Structural Bioinformatics Methods in machine learning, algorithmics and combinatorics

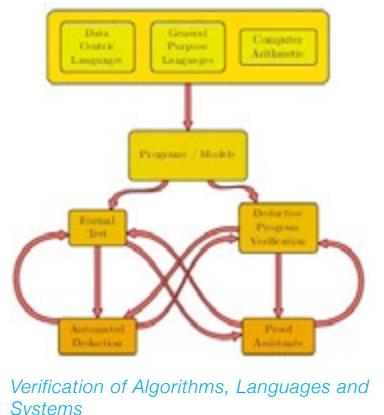
- **Prediction of intermolecular interactions**
 - Protein-protein interactions
 - Protein-RNA docking
- **Bioinformatics for RNA structures**
 - Sequence-structure comparison
 - Design and drawing of structures
 - 3D structure modeling
- **Software:** Varna, GenRGenS...

Integration of Data and Knowledge

Goals: Achieve interoperability of heterogeneous data sources

Scientific contributions:

- Ontology alignment Framework
- Management of mapping evolution between dynamic ontologies
- Logical and numerical approaches for data linking - Linkage rules discovery
- Data fusion based on data quality



Algorithms for networked systems

Goals: Design efficient modeling, control and performance optimization algorithms. Tailored for:

- networked
- distributed systems

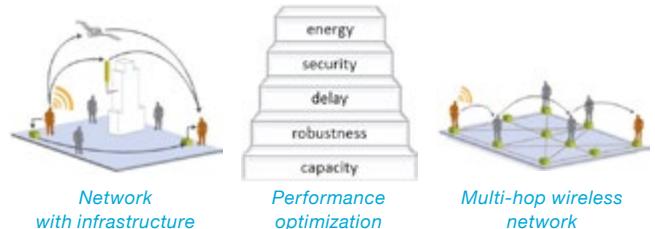
Scientific contributions:

Both theoretical

- Development of new
- Mathematical modeling
- Techniques and proofs

... and applied

- Development of innovative tools
- For the optimal planning ands
- Resource allocation in networks



Objectives: Establish theoretical building blocks for the design and optimization of networked systems, including:

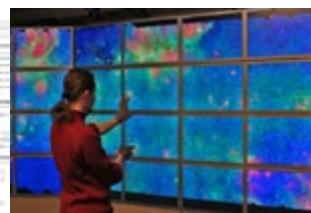
- Algorithmic Game Theory
- Control Theory
- Distributed Algorithms
- Discrete Event Simulation

Interaction off-the-desktop

We create new forms of interaction on devices ranging from mobile phones, tablets and interactive paper to large digital tabletops and wall-size displays. We explore how new paradigms e.g., multi-surface and whole body interaction, can significantly improve the user experience.



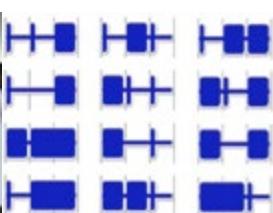
Musink



WILD pan-and-zoom



BiPad



Rhythmic interaction

CATCHING THE INVISIBLE WITH NEW RADAR AND SURVEILLANCE CONCEPTS

SONDRA (CentraleSupélec ONERA DSO Research Alliance) was officially launched on 28 April 2004 in Supélec. The mission of SONDRA is to conduct unclassified basic research in advanced Electromagnetics and Radar domains. As part of its mission, SONDRA contributes also to a better assessment of new technologies that are of interest to overcome various problems related to maritime surveillance in congested water areas, ground and air surveillance, homeland security. The characterization of the environment, whether "natural" or anthropogenic is more and more complicated as we aim at augmenting the sensitivity and performances of the surveillance systems in the current context of increased maritime and air traffics. Radar and EM detection technologies remain of great interest to catch "invisible targets", i.e; target either masked by cloud cover, urban infrastructure, foliage or simply blocked by the horizon line of sight.

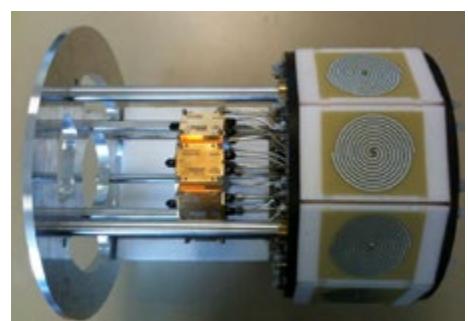
The alliance between the 4 parties offers a unique opportunity of development. NUS and Supelec provide an academic environment, effective at generating new collaborations with academic partners. On the other hand DSO and ONERA are very attentive on transition and experimental validation. The success of SONDRA is probably its capability to carry physics and signal processing research and to systematically register the research projects in a coherent framework leading to concrete actions and real validation, hence taking all attention from overseas stakeholder.

SONDRA contributes to research through 4 scientific areas, propagation and scattering in complex media, phased array antenna, radar signal processing and new radar concepts (MIMO / multistatic radar, passive radar,...). To meet the surveillance needs in 2020 the previous scientific areas are developed as follows:

- **Propagation and scattering in complex media:** to predict the propagation in forested or urban environment; radar is known to propagate though the foliage and inside urban canyons, hence providing unique capabilities for tracking vehicles that are not be visible by optical sensors.
- **Phased array antenna:** to optimize the performance of future sensors on board of new platforms (airship, unmanned airborne vehicle) using distributed and low profile antenna
- **Signal processing:** to better estimate the parameters of the natural environment and maximize the detection performances of existing or future radar or hyperspectral systems,
- **New radar concepts:** to address multistatic and distributed radar sensors suitable for surveillance at low altitude in urban environments, passive radar using existing transmissions(the "green radar"); Multiple Input Multiple Output.

KEY FIGURES

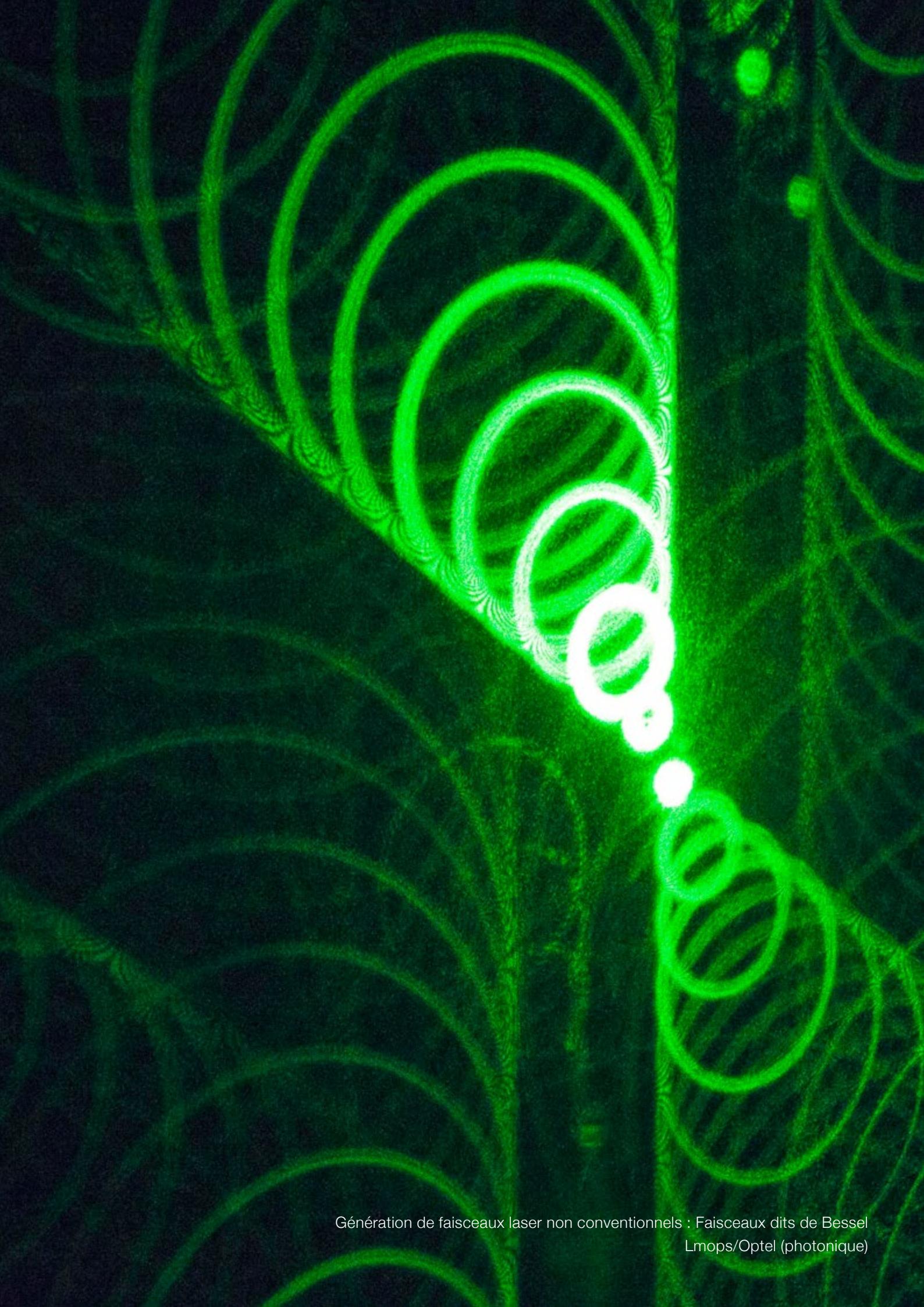
| | |
|---------------------------------------|------|
| FACULTY RESEARCHERS AND RESEARCHERS: | 6 |
| PhD STUDENTS: | 10 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 0,61 |
| INTERNATIONAL PEER-REVIEWED JOURNALS: | 4 |
| RESEARCH CONTRACTS: | 1 M€ |



Antenne CARGESE (Conformal ARray for GMTI
Extended Surveillance)

CONTACT

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Génération de faisceaux laser non conventionnels : Faisceaux dits de Bessel
Lmops/Optel (photonique)

The Lab, co-supervised by CentraleSupélec, UPMC, UPSud and the CNRS, centers on information and power applications. GeePs has a staff of 240 people with more than 100 permanent. It is divided into three departments:

PHEMADIC PIEM E2DC

GeePs was chosen to participate in two advanced research networks in the Paris region: The Physics Triangle and Digiteo, because of a triple approach to research (theory/experiment/ numerical modeling). The departments are partners in the Excellence Initiative (Nano-Saclay and the LaSIPS LABEXs) and interact with many academic and industrial partners at both national and international levels.

PHysics and Electronics of Materials, Devices, Interfaces and Contacts (PHEMADIC)

The “Physics and Electronics of Materials, Devices, Interfaces and Contacts” department has a staff of 21 permanent people (14 researchers and 7 engineers) along with 15 PhD students or post-doctoral researchers.

The main objectives of the department are to develop **innovative characterization tools**, to study **materials and device properties** as well as **interfaces and contacts**. Three main application fields are targeted:

- **Photovoltaics:** silicon solar cells and heterojunctions, multijunctions and III-V-N solar cells, new chalcogenides, SiGeC thin films, perovskites, organics solar cells, PV modules
- **Opto/nanoelectronics:** micro/nanowires, III-V compounds and nitrides, 2D heterojunctions, diamond, UV detectors, mixed valence oxides, Re-Rams, MEMS/NEMS
- **Electrical contacts:** fiability, functionalization, surface modification

A wide range of experimental facilities forming several characterization platforms allow us to investigate fundamental as well as application oriented issues and to efficiently interact with many academic and industrial partners at both national and international levels. We cover the whole scale range of physical and electronic properties from **macroscopic aspects** (large panel of various photocurrent spectroscopies in DC, AC and transient modes, admittance spectroscopies, optical spectroscopies, tribology, fretting, characterization of photovoltaic cells and modules) to the microscopic scale (electron spectroscopies, XPS, UPS, Auger, micro-Raman and micro-luminescence spectroscopies) and down to the **nano-scale** (AFM, conductive probe AFM with the home made extensions Resiscope and Capascope. These characterization facilities are complemented by a long-term **expertise in modeling** that is supported by either commercially available or on in-house developed simulation software.



PHYSICS AND ENGINEERING OF ELECTROMAGNETISM (PIEM)

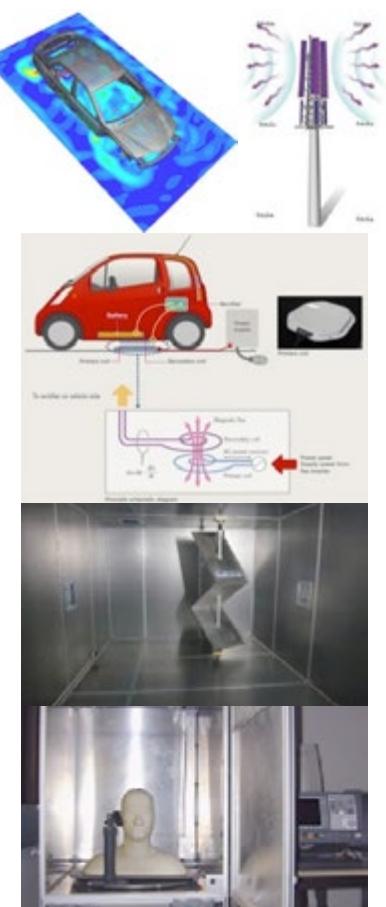
The department “Physics and Engineering of Electromagnetism” includes 25 permanent researchers, 5 engineers and 20 non permanent members (PhD students, post-doctoral researchers) involved in different areas of Electromagnetism. The department covers a wide range of frequencies from static fields to microwaves and THz. It is subdivided into five major topics which extend from behavior laws of materials to complex systems analysis:

- Multiphysics modeling and coupled problems
- Non destructive electromagnetic evaluation of materials and structures
- Electromagnetic compatibility
- Exposition of human beings to electromagnetic fields
- Waves in complex environment

The objectives of the department are to develop new methodologies based on electromagnetic modeling and experimental approaches to :

- Investigate the interactions between electromagnetic fields and natural or artificial media
- Control waves and fields in complex environment
- Build new models for the design of electromagnetic systems and for multi-physics studies

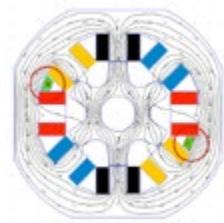
Different experimental facilities are available for basic research or industrial partnership: reverberating chambers (of different sizes), anechoic chambers with two kind of near field probe arrays, a time-reversal reverberating chamber allowing coherent directive and polarized wavefront generation.



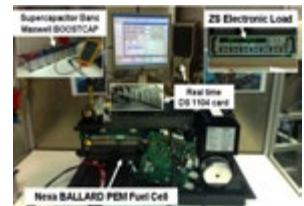
ENERGY, ELECTRONICS, DESIGN AND CONTROL (E2DC)

The department “Energy, Electronics, Design and Control” comprises 34 permanent researchers, 6 engineers and 50 PhD students / post-doc researchers, involved in 5 different areas of Electrical Engineering.

The topic “Actuators and Sensors” is dedicated to electromechanical conversion (magnetic and piezoelectric). Various types of machines are both studied and designed. Optimal methodologies and design tools are developed (analytical models, finite element method, genetic algorithms, space mapping...). Experimental benches are sized to test devices up to 80kW and 15 000 rpm. Studies on the control of such devices are also carried out (sensorless control, use of FPGA...). Fault diagnosis in electrical machines is also the subject of research (specific sensors, non-intrusive fault detection...).



The topic “Microgrid & Power Electronics” focuses on multi-source microgrids and onboard power systems, especially in DC systems mixing HVDC and LVDC buses. Research topics include the integration of local energy production (either controlled - fuel cell, or uncontrolled - solar or wind energy), new types of power consumption (consumer electronics and electric vehicles), the design of reliable connected electronic power converters or systems. In order to interface sources, loads and other grids, the development of optimal power management strategies (taking into account internal or external constraints), and the development of microgrid health monitoring methods are also being investigated.



The topic “Electrical networks” aims at increasing the flexibility of power systems in order to ease the integration of new sources (renewables) and new loads in the electric power system and in distribution grids. The main research areas are (1) network operation (ancillary services, stability), (2) demand flexibility (plug-in vehicles, demand response), (3) DC systems (converter control, interaction between AC and DC grids, HVDC systems), (4) perturbations and protection (harmonics, fault detection), (5) schemes and regulation for economic valuation of the flexibility.



The topic “Mixed-signal integrated circuits and microsystems” integrates many diverse activities on mixed digital and analog electronic systems. Application domains of the studied methods and concepts involve issues from fundamental research, to consumer electronics (telecommunications, civil transportation), high performance electronics (radar, aviation, aerospace, industrial), as well as medical electronics. The main research areas are:

- (1) physics-analog conversion,
- (2) analog electronics design methods,
- (3) analog to digital conversion,
- (4) signal processing and non-ideality compensation.



The “Electrical discharges and arcs” topic pursues both fundamental and industry-oriented research concerning both electrical discharges and arcs at atmospheric pressure and in vacuum. The work can be roughly divided into two broad categories: (1) the study of electrical discharges and arcs from an electrical engineering perspective, where the goal is either to prevent their occurrence or mitigate their effects (high voltage insulation under vacuum and partial discharges in onboard power systems), and (2) their study as a physical or chemical process, where the goal is to use the particular properties of the plasma for some certain objective (surface and gas treatment).

KEY FIGURES

| | |
|--------------------------------------|----------|
| FACULTY RESEARCHERS AND RESEARCHERS: | 35 |
| PHD STUDENTS: | 57 |
| POSTDOCS: | 10 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 17 |
| MAJOR PUBLICATIONS (+PATENTS): | 91 |
| RESEARCH CONTRACTS: | 1 035 k€ |

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RESEARCH TOPICS

Mathematical Tools in Large Dimensions

At the core of the LANEAS research are theoretical advances in large dimensional random matrix theory, free probability theory, game theory and mean field games, stochastic geometry and point processes, communication/information theory.



HIGHLIGHTED PUBLICATIONS

- Couillet, R., F. Pascal, and J. W. Silverstein, "The Random Matrix Regime of Maronna's M-estimator with elliptically distributed samples", *Journal of Multivariate Analysis*, vol. 139, pp. 56-78, 2015.
- Gu, Y., W. Saad, M. Bennis, M. Debbah, and Z. Han, "Matching Theory for Future Wireless Networks: Fundamentals and Applications", *IEEE Communications Magazine*, vol. 53, issue 15, pp. 52 - 59, 2015.
- Couillet, R., and M. Debbah, "Signal Processing in Large Systems: a New Paradigm", *IEEE Signal Processing Magazine*, vol. 30, no. 1, pp. 24-39, 2013.
- Couillet, R., and M. Debbah, *Random Matrix Theory Methods for Wireless Communications*, : Cambridge University Press, 10/2011.
- Saad, W., Z. Han, M. Debbah, A. Hjørungnes, and T. Başar, "Coalitional Game Theory for Communication Networks : A tutorial", *IEEE Signal Processing Magazine*, Special Issue on Game Theory for Signal Processing and Communication, vol. 26, no. 5, pp. 77-97, September 2009.

Antenna Array and Network Signal Processing

Applications of our theoretical tools are made in the discipline of signal processing for large antenna arrays, such as improved detection and localization schemes, robust estimation methods, estimation under stationary noise.



HIGHLIGHTED PUBLICATIONS

- Bianchi, P., W. Hachem, and F. Iutzeler, "A Coordinate Descent Primal-Dual Algorithm and Application to Distributed Asynchronous Optimization", *IEEE Transactions on Automatic Control*, 2014, 2015.
- Abboud, A., R. Couillet, M. Debbah, and H. Siguerdidjane, "Asynchronous Alternating Direction Method of Multipliers Applied to The Direct-Current Optimal Power Flow Problem", ICASSP, Florence, Italy, 2014.
- Yao, J., R. Couillet, J. Najim, and M. Debbah, "Fluctuations of an Improved Population Eigenvalue Estimator in Sample Covariance Matrix Models", *IEEE Transactions on Information Theory*, vol. 59, issue 2, pp. 1149-1163, 02/2013.
- Couillet, R., and W. Hachem, "Fluctuations of spiked random matrix models and failure diagnosis in sensor networks", *IEEE Transactions on Information Theory*, vol. 59, issue 1, 2013.
- Vinogradova, J., R. Couillet, and W. Hachem, "Statistical Inference in Large Antenna Arrays under Unknown Noise Pattern", *IEEE Transactions on Signal Processing*, vol. 61, issue 22, 2013.

KEY FIGURES

| | |
|---------------------------------------|-----------|
| FACULTY-RESEARCHERS AND RESEARCHERS: | 3 |
| PHD STUDENTS: | 6 |
| PostDocs: | 2 |
| INTERNATIONAL PEER-REVIEWED JOURNALS: | 25 |
| RESEARCH CONTRACTS: | 774 915 € |

CONTACT

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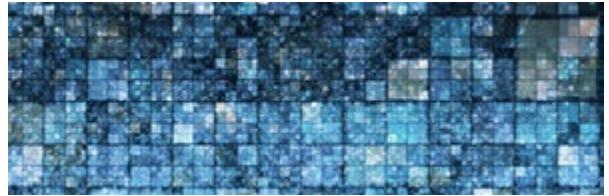
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Data Mining

A growing activity on BigData is taking place in the LANEAS group, with in particular research in random matrix methods for machine learning and sparse principal component analysis, along with distributed storage and caching techniques in networks.



HIGHLIGHTED PUBLICATIONS

- Baştug, E., M. Bennis, and M. Debbah, "A Transfer Learning Approach for Cache-Enabled Wireless Networks", International Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt'15), Mumbai, India, 2015.
- Morales-Jimenez, D., R. Couillet, and M. McKay, "Large dimensional analysis of Maronna's M-estimator with outliers", IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP'15), Brisbane, Australia, 2015.
- Baştug, E., M. Bennis, and M. Debbah, "Living on the Edge: The role of Proactive Caching in 5G Wireless Networks", IEEE Communications Magazine, vol. 52, no. 8, pp. 82 - 89, 2014.
- Katz, G., P. Piantanida, R. Couillet, and M. Debbah, "Joint Estimation and Detection Against Independence", Fifty-second Allerton Conference on Communication, Control, and Computing, Allerton, IL, USA, 2014, 2014.
- Couillet, R., and M. McKay, "Large Dimensional Analysis and Optimization of Robust Shrinkage Covariance Matrix Estimators", Journal of Multivariate Analysis, vol. 131, pp. 99-120, 2014.

Wireless Networks

Multi-cellular multi-user multi-antenna are at the core of the application-oriented research in the LANEAS group, with the performance analysis, precoder design, and topology improvement of multicell massive MIMO, small cells, and heterogeneous networks for the design of 5G.



HIGHLIGHTED PUBLICATIONS

- Björnson, E., J. Hoydis, M. Kountouris, and M. Debbah, "Massive MIMO Systems with Non-Ideal Hardware: Energy Efficiency, Estimation, and Capacity Limits", IEEE Transactions on Information Theory, vol. 60, issue 11, pp. 7112-7139, 11/2014.
- Kammoun, A., A. Müller, E. Björnson, and M. Debbah, "Linear Precoding Based on Polynomial Expansion: Large-Scale Multi-Cell MIMO Systems", IEEE Journal of Selected Topics in Signal Processing, vol. 8, no. 5, pp. 861-875, 11/2014.
- Björnson, E., E. Jorswieck, M. Debbah, and B. Ottersten, "Multi-Objective Signal Processing Optimization: The way to Balance Conflicting Metrics in 5G Systems", IEEE Signal Processing Magazine (Special Issue on Signal Processing for the 5G Revolution), vol. 31, no. 4, pp. 142-148, 2014.
- Hoydis, J., S. ten Brink, and M. Debbah, "Massive MIMO in the UL/DL of Cellular Networks: How Many Antennas Do We Need?", IEEE Journal on Selected Areas in Communications - Large-Scale Multiple Antenna Wireless Systems (2013), vol. 32, issue 2, pp. 160-171, 02/2013.
- Wagner, S., R. Couillet, M. Debbah, and D. T. M. Slock, "Large System Analysis of Linear Precoding in Correlated MISO Broadcast Channels under Limited Feedback", IEEE Transactions on Information Theory, vol. 58, issue 7, pp. 4509 - 4537, 07/2012.

TEACHING

The group has been actively providing courses in various academic institutions (all) around the world:

- Inference Methods for Science and Engineering Applications (Master and PhD level: University of Oslo).
- Statistical Signal Processing for Communications (Master level: Coltech, Vietnam).
- Multi-Antenna Technologies (graduate level: ENSEIRB Bordeaux, Université of Avignon, Ecole Polytechnique de Tunisie).
- Random Matrix Theory and its applications to Wireless Communications (Master and PhD level: University of Oslo, University of Aalborg, INRIA, CentraleSupélec, Orange-Labs, Cambridge University).
- Game Theory and its applications to Wireless Communications (Master and PhD level: University of Oulu, University of Oslo, CentraleSupélec, University of Modena).
- Channel Modelling (Master SAR at CentraleSupélec).
- Theoretical Foundations of Mobile Flexible Networks (Master SAR: CentraleSupélec).

ÉQUIPE SYSTÈMES ANALOGIQUES AVANCÉS

ANALOG DESIGN TO DEAL WITH THE INTERACTIONS BETWEEN ELECTRONIC SYSTEMS AND THE PHYSICAL WORLD AROUND US

Advances in scientific instruments, industrial and consumer products have been closely linked to faster, better and cheaper electronic systems. Unmanned Aerial Vehicles (UAVs), self-driving cars, smart buildings are examples of what becomes possible through embedded electronics. However, electronic systems carry out their computing tasks within an abstract, digital world. The interaction between this ideal landscape of ones and zeros and the outside world (ours), the analog world, is handled by analog electronics. The focus of the Advanced Analog Systems Group is to study the interaction of electronic systems with the outside world through modelling and simulation in order to develop innovative solutions for difficult problems such as heat, electromagnetic emissions compliance, actuation, and data acquisition. High-level research on all aspects of analog systems, in partnership with leading companies and CentraleSupélec researchers allows the SANA Group to contribute to the advancement of knowledge of these issues for a wide range of applications.

To achieve this, the research activities of the group are carried out around four axis: Multi-physics systems modelling and optimization, communication systems, imaging and analog to digital converters. This work is carried out in close collaboration with our industrial partners, with the support of members of the GeePs (CNRS UMR8507) ECo2 pole and of the L2S (CNRS UMR 8506) Networks & Telecommunications pole.

Multi-physics systems modelling and optimization has targeted both large (automotive exhaust gas control) and vanishingly small systems (MEMS pressure sensors for aerospace). The objectives are a better understanding of complex phenomena and their interactions through experimentation, mathematical modelling and numerical simulation. We have developed proof-of-concept tools and prototypes. For example, we have developed mathematical models describing accurately non-linear modes in resonant micro-machined structures. Our research has resulted in improved performance and optimized devices.

Communication systems include testability of software defined radios for tactical communications, electromagnetic compatibility (EMC) of equipment installed on a naval platform and power line communication (PLC) systems for aircrafts. As an example of our scope, we have proposed a new way to integrate built-in self-test (BIST) into flexible SDR radio units, at low cost and minimal impact on the normal operation. Another example is the development of a PLC for large aircraft, where a combined know-how on EMC effects, analog electronics and OFDM modulation must be applied to obtain a feasible solution.

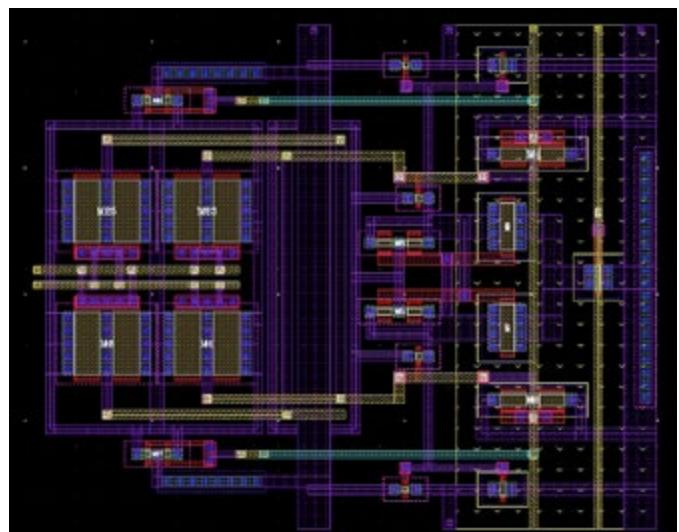


Figure 1 High temperature optimized fast comparator for high-resolution hybrid ADC

KEY FIGURES

FULL-TIME RESEARCHERS: 1

PHD STUDENTS: 8

Pos-Doc: 1

ACADEMIC PARTNERS

UFRJ, CERN, UMONS, HKUST.

CONTACT

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INDUSTRIAL PARTNERS

Thales, EFI Automotive, Melexis, STMicroelectronics, CEA

Research conducted in imaging systems domain targets the development of smart imaging systems. Our objective is to bring feature recognition and image processing capabilities as close to the focal plane as possible. Our approach is twofold: a digital backend using specialized processing units coupled to an analog frontend driving each pixel. To bridge the two parts we are also developing a high-resolution column-parallel analog-to digital converter. With our architecture, we intend to achieve real-time feature extraction of the video stream.

The development of analog to digital converter (ADC) circuits is a transversal axis across all domains and applications of electronic systems, since it's through these that all data acquisition occurs. Accordingly, our team develops three different kinds of circuits: very high speed time-interleaved ADCs, moderate speed high-resolution hybrid ADCs (for high-temperature automotive systems) and high-resolution calibrated column-parallel ADCs (for imaging systems).

HIGHLIGHTS 2015

- New industrial partner for development of high-temperature electronics for automotive systems.
- Two new international cooperation research programs (UMONS and HKUST).
- Graduation of the first PhD "fully minted" within the team (E. Dogaru).
- Start of a new research axis, High Performance Computing using Hardware Acceleration.



A RESEARCH INSTITUTE DEDICATED TO SMART ELECTRIC GRIDS

The RISEGrid Institute (Research Institute for Smarter Electric Grids) was launched jointly by Supélec and EDF (Électricité de France) in December 2012 and is dedicated to the study, modelling and simulation of smart electric distribution grids and their interactions with the whole electric power system.

Research topics cover both theoretical aspects and more applicative and industrial ones. The RISEGrid Institute aims to be in perfect accordance with the strong and challenging evolutions of electric power systems all over the world: opening of electricity markets, development of decentralized production, ubiquitous information and communication means... Research studies carried out in the Institute combine the multidisciplinary aspects of smart grids (power systems, control, information systems of information, telecommunication networks...). In addition, new tools for modelling and simulation of complex systems are deeply investigated.

A FOUR AXIS SCIENTIFIC PROGRAM

ASSESSMENT OF NEW SOLUTIONS FOR SMART ELECTRIC GRIDS

Fast and large development of decentralized electricity production has a great impact on existing distribution networks which were designed in times when dispersed energy resources were marginal.

In such a framework, the goal is to devise new solutions to increase network flexibility, not only for massive integration of decentralized production, but also that of new electricity uses and applications, while still achieving high levels of reliability and security.

OBSERVABILITY OF THE ELECTRIC SYSTEM

The development of new smart and automated functionalities will allow optimizing the whole system, taking advantages of various flexibilities (production, consumer demand side management, storage, electrical grid flexibility).

However, for that purpose it is required to enhance the real time observability of the system components. The current trends rely on the use of smart and innovative signal processing methods or data analysis algorithms.

INFORMATION AND COMMUNICATION SYSTEMS

Information systems and communication means and infrastructures are required for the implementation of new functionalities in smart grids.

The RISEGrid Institute is concerned with the modelling of such systems, considering their strong interactions with the electric network. Interdependencies, quality of service and network reliability are some examples of the topics encountered in this research axis, together with new approaches and tools for simulation:

ADVANCED MODELLING AND SIMULATION

Smart grids are made of numerous interacting subsystems (electrical networks, automated meter management, centralized and decentralized production, demand side management (included smart charging for electric vehicle), storage, information systems, telecommunication network...).

All these subsystems need to be taken into account to obtain a fairly realistic representation of the behavior of the whole system. For that purpose, it is necessary to develop new multi-simulation tools aiming to associate dedicated subsystems simulators. New subsystems and interactions have also to be investigated such as the automated meter management systems or the smart loading of electric vehicles.



*Crédit photos :
EDF, Philippe ERANIAN*

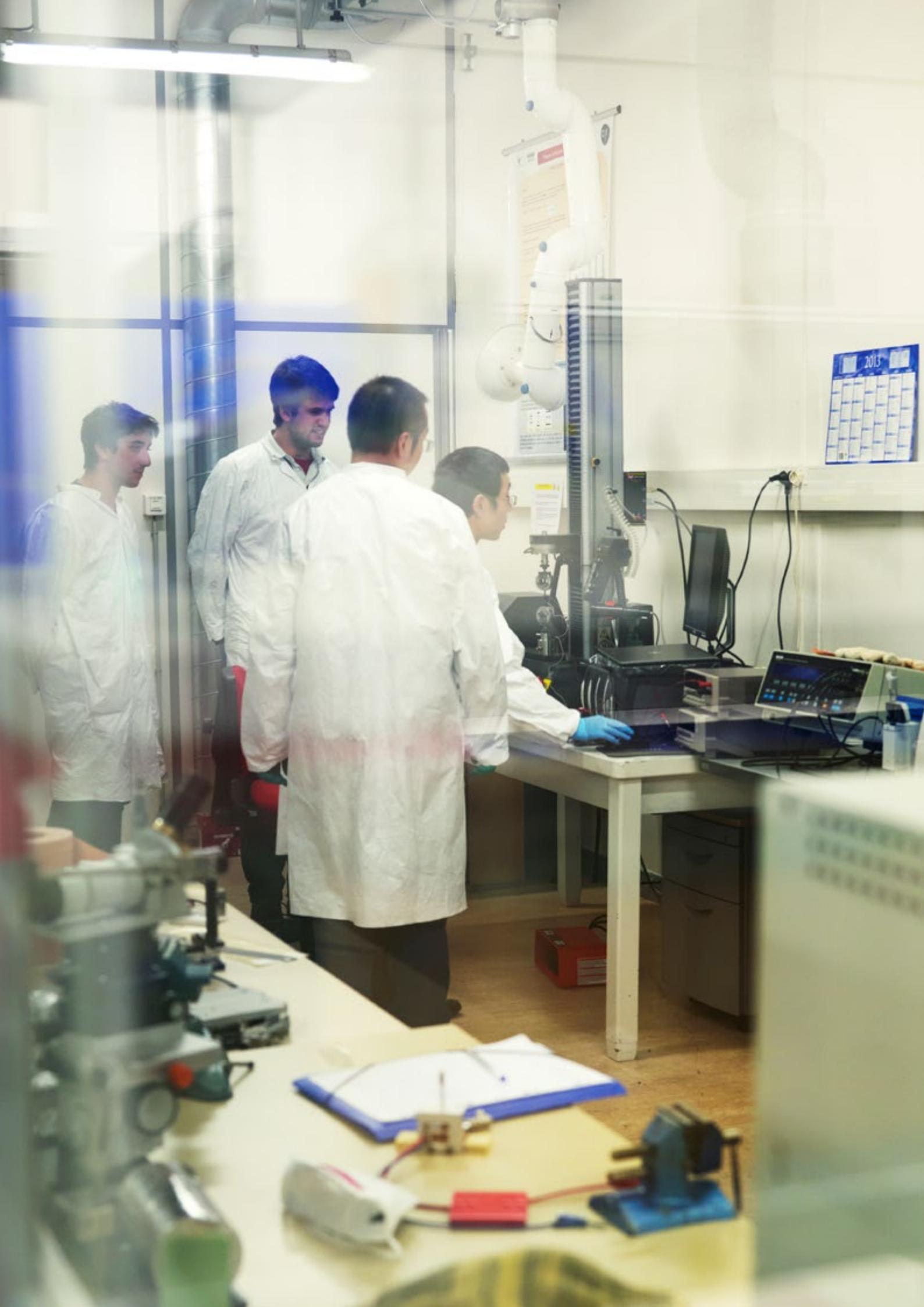
CONTACT

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The signals and systems laboratory is a common research unit between CNRS, CentraleSupélec and University Paris-Sud including more than 200 people. Areas of interest of the unit cover several scientific disciplines. More precisely, we cite - **fundamental and applied aspects of Mathematics** at the origin of the development of signal and image processing, information theory, cryptology and control feedback theory and **applied Physics** including, among others, approaches and methods to describe and predict the evolution of systems at the origin of the theory of electromagnetism. The laboratory is structured in 3 *thematic groups*:

SIGNALS GROUP is interested in statistical modelling and inverse problems. The research topics are change-point detection and failure diagnosis, kernel methods and spectral clustering, multi-variate signal processing, robust statistics, stochastic dynamical systems, time series analysis, algorithm-architecture matching, inverse problems reconstruction, non-destructive control, physical imaging, sparse analysis as well as variational approaches.

SYSTEMS AND CONTROL GROUP deals with fundamental themes of control feedback theory and their applications. Its activities are carried out in a broad international context. Among the addressed research topics, one can distinguish the following themes:

- Modeling, identification and observation;
- Stability, synchronization, passivity and Lyapunov functions and/or functionals;
- Analysis and control of PDE and systems with delays;
- Robust control, predictive control and optimization;
- Hybrid systems, discrete, sampled, and networked control systems.

In parallel, applications are conducted through academic and industrial collaborations. They concern engineering sciences in general and, in particular, the following themes:

- Energy systems (power systems, smart grids, smart buildings, etc.);
- Mechatronics and Robotics (remote handling, vehicle dynamics, electric vehicles, etc.);
- Aeronautics and Aerospace (missiles, launchers, drones and training flights);
- Life sciences (biology modeling, bioreactors, neurosciences, etc.).

Some of these themes are found within the iCode institute of the University Paris-Saclay and the EC NoE HYCON and HYCON2, on «Hybrid Control» and «Highly Complex and Networked Control».

TELECOMS AND NETWORKS GROUP carries out research in the field of wireless mobile and self-organizing networks, from Physical to Application layers. Its main interests are in cross layer design, coding, modeling and performance evaluation, as well as resource allocation. It also has a strong interest in the connection between communication and energy networks. It is making heavy use of such tools as joint source-protocol-channel coding and decoding, robust image and video compression, distributed source coding, game theory, information theory and stochastic geometry.

KEY FIGURES

| | |
|--------------------------------------|-----|
| FACULTY RESEARCHERS AND RESEARCHERS: | 120 |
| ASSOCIATED RESEARCHERS: | 4 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 11 |
| PHD STUDENTS: | 93 |
| Post-Doc: | 10 |

ACADEMIC PARTNERS

National level: the laboratory cooperates with most of French laboratories of our areas of research.

International level: 58 different countries (38 in Europe, 10 in North America, 3 in South America, 2 in Australia, 4 in Asia, 1 in Africa).

CONTACT

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The laboratory takes part in various types of projects:

7 European projects

- **5G Wireless** (Innovative Architectures, Wireless Technologies and Tools for High Capacity and Sustainable 5G Ultra-Dense Cellular Networks),
- **CONNECT2SEA** (Connecting ICT EU and Southeast Asia Research, Development and Innovation Knowledge Networks);
- **CROSSFIRE** (unCooRdinated netwOrk StrategieS for enhanced interFerence, mobility, radio Resource, and Energy), **EuConNects** (European Conferences on Networks and Communications),
- **IEF-FUTURISM** (Multiple sensor fault tolerant control for management of interconnected, nonlinear systems),
- **NEWCOM#** (Network of Excellence in Wireless COMmunications);
- **IOF-STAMUS**: Statistical models for musical signal processing,
- **TEMPO** (Training in Embedded Predictive Control and Optimization).

2 Projects in the frame of “Programmes d’Investissement d’Avenir”:

- **LABEX DIGICOSME**,
- **IDEX iCODE**

Several ANR Projects: for instance, BYPASS, FIREFLIES, HENIAC, DIONISOS, HONTOMIN, RMT4GRAPH, SURMITO, SYNCHNEURO, WINPOWER

International Associated Laboratory of CNRS (LIA) “Smart Grids” with Canada

CNRS European Research Network on delay systems (DelSys) including 5 European countries;

DIGITEO Chair directed by Professeur Andrea MASSA devoted to the development of new paradigms, approaches, and methodologies and to their application in Electromagnetics.

Different contracts with industrial partners (non-exhaustive list): Alcatel Lucent, Alstom, EDF, IFPEN, Orange, Renault, Safran, SAGEM...

The laboratory takes part in the “PIA” project IEDD “SuperGrid”, in the common institute SUPELEC-EDF “RiseGrid” as well as in the different summer schools **“KIC EICT Labs & Energy”** (European Institute of Innovation and Technology).

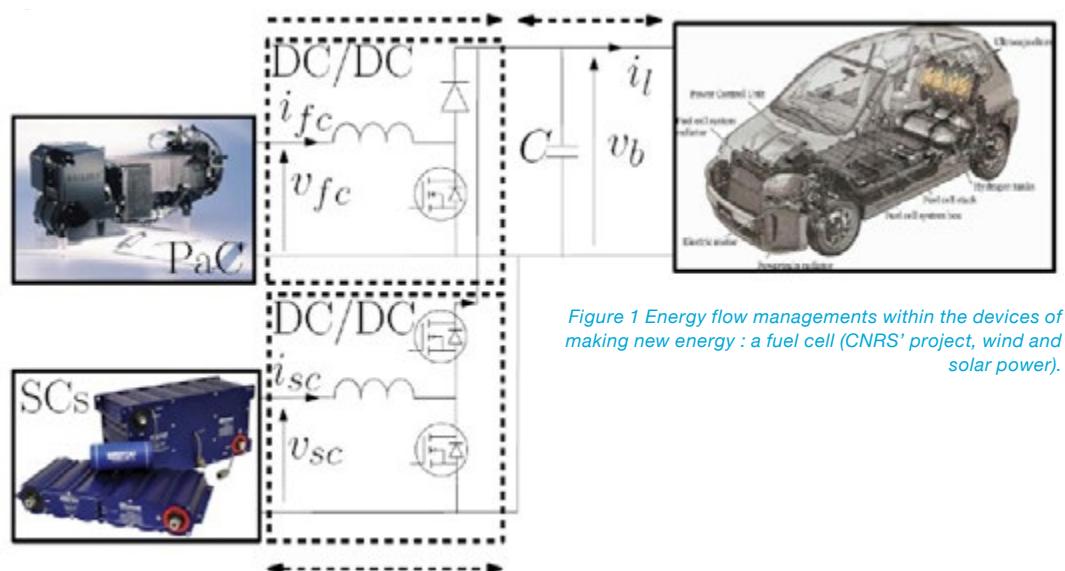


Figure 1 Energy flow managements within the devices of making new energy : a fuel cell (CNRS' project, wind and solar power).



UNITÉ MIXTE INTERNATIONALE 2958 GEORGIA INSTITUTE OF TECHNOLOGY - CNRS

Le Laboratoire international de recherche UMI n° 2958, commun entre le Georgia Institute of Technology (Georgia Tech) et le Centre National de la Recherche Scientifique (CNRS), a été créé en 2006. Ce laboratoire est la première entité UMI située en France. Le site principal de ce laboratoire est situé à Metz sur le campus européen de Georgia Tech, Georgia Tech Lorraine et un site miroir a récemment été mis en place sur le campus de Georgia Tech à Atlanta. Les programmes de recherche se développent avec quatre partenaires associés : Supélec, ENSAM Paris Tech, Université de Franche Comté et Université de Lorraine. Cette recherche collaborative a essentiellement lieu en lien avec les laboratoires suivants : le Laboratoire Matériaux Optiques, Photonique et Systèmes (LMOPS), commun à Supélec et l'Université de Lorraine, le Laboratoire d'Etude des Microstructures et de Mécanique des Matériaux (LEM3) commun à Arts & Métiers ParisTech et l'Université de Lorraine et le Laboratoire Franche-Comté Électronique Mécanique Thermique et Optique - Sciences et Technologie (FEMTO-ST) de l'Université de Franche-Comté et impliquant le CNRS.

THÈMES DE RECHERCHE

Réseaux sécurisés :

Ce thème de recherche regroupe des activités autour de la dynamique des composants lasers et de l'optique non-linéaire. Une des activités de ce thème traite notamment de la sécurisation des communications optiques par l'exploitation de dynamiques chaotiques. Une autre activité concerne l'étude de nouveaux protocoles pour la distribution de clés quantiques (QKD) afin d'améliorer la sécurité, le débit et la distance de transmission. Enfin, une troisième activité est dédiée au développement de nouveaux dispositifs optiques comme des sources de photons utilisant le processus inverse de la génération de troisième harmonique dans les cristaux possédant une non-linéarité.

Matériaux innovants :

C'est le thème majeur de l'UMI n°2958 GT/CNRS qui met en oeuvre les collaborations avec les 3 laboratoires partenaires (LMOPS, LEM3 et FEMTO-ST). Il concerne plus précisément l'étude, la fabrication et le développement de nouveaux matériaux et nano-hétérostructures pour l'électronique et la photonique avec notamment la croissance par OMVCD de semi-conducteurs nitrurés (BalGaN) sur template GaN et/ou substrat Saphir. Une autre partie de ce thème est consacrée à la mise au point de matériaux multifonctionnels, des matériaux «sur-mesure» modélisés puis fabriqués après avoir clairement identifié un besoin, une fonction, avec pour objectif de répondre au mieux aux critères établis, aux propriétés définies afin d'élaborer le matériau qui conviendra le plus justement à la demande formulée. La dernière partie de ce thème se focalise sur la caractérisation des matériaux par ultra-son et le développement de capteurs utilisant ce type d'ondes sonores.

Computer Science :

Ce thème de recherche se décline autour de deux sous-thèmes concernant l'apprentissage situé et la robotique d'une part et l'étude des réseaux de systèmes d'information d'autre part. Ce dernier sous-thème intègre notamment le management des systèmes distribués ainsi que le traitement et le stockage de masses de données.

L'équipe OPTEL du campus de Metz de Supélec, de par son intégration dans le LMOPS, est impliquée dans les thèmes « Dynamique et optique non-linéaire » et « Matériaux innovants ». L'équipe IMS représente, quant à elle, la majorité des forces de recherche impliquées dans le thème « Computer Science ».

ÉQUIPE INFORMATION, MULTIMODALITÉS ET SIGNAL - IMS

L'équipe IMS est composée de 14 enseignants-chercheurs et accueille 6 doctorants. L'équipe se répartit au sein de deux sous-équipes thématiques correspondant aux deux sous-thèmes de l'axe Computer Science de l'UMI n°2958 GT/CNRS.

- **L'équipe MaLis (Machine Learning and Interactive Systems)** s'inscrit dans le cadre du sous-thème « Apprentissage situé et robotique » et est animée par Cédric Pradalier, Professeur assistant à Georgia Tech Lorraine. Elle est constituée de six enseignant-chercheurs de Supélec et de quatre doctorants. Elle regroupe des activités en traitement du signal, apprentissage automatique et représentation des connaissances dont l'objectif est la mise au point de paradigmes de traitement de l'information permettant la mise en situations réelles de machines autonomes. Elle s'investit également dans le développement et le contrôle de robots mobiles pour diverses applications (supports de capteurs, exploration...).

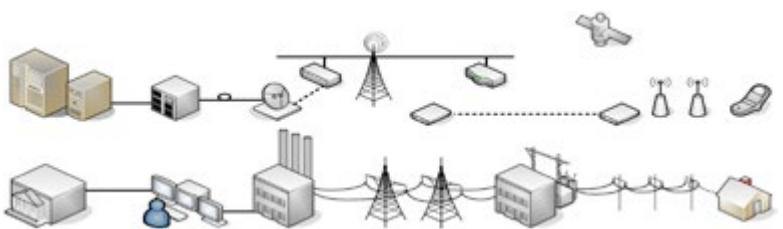
KEY FIGURES

| | |
|---|---------|
| FACULTY RESEARCHERS AND RESEARCHERS (CENTRALE SUPÉLEC): | 25 (14) |
| CENTRALE SUPÉLEC PhD STUDENTS: | 6 |
| PostDocs: | 2 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 1 |
| INTERNATIONAL PEER-REVIEWED JOURNALS: | 4 |

INTERNATIONAL ACADEMIC PARTNERS

University de Mons (Belgique), Université de Augsburg (Allemagne), Università degli Studi Genova (Italie), University College London (UK), Queens University Belfast (UK), University of Zürich (Suisse)...

- **L'équipe IdMad** (Informatique Distribuée et Masses de Données) s'inscrit dans le sous-thème « Étude des réseaux de systèmes d'information » sous la direction de Stéphane Vialle, enseignant-chercheur à Supélec. Elle compte quatre enseignant-chercheurs permanents de Supélec et deux doctorants. Elle développe des travaux dans plusieurs domaines relevant du champ thématique du sous-thème : la compression de flux de masses de données pour le codage notamment d'images hyperspectrales satellites, la co-simulation distribuées de systèmes complexes appliquée en particulier aux problèmes de simulation des réseaux électriques tels que ceux d'EDF (étude réalisée dans le cadre de l'Institut RISEGrid commun entre EDF et Supélec) ainsi que d'escadrilles de drones communicants à travers des réseaux informatiques sans fils (collaboration LORIA) et la conception d'algorithmes et d'outils de développement pour architectures parallèles hybrides dont l'objectif est de développer des algorithmes et des codes parallèles multi-grains pour résoudre des problèmes industriels ou émanant d'autres communautés scientifiques, et à concevoir de nouveaux outils de développement adaptés aux architectures parallèles hybrides et hiérarchiques.



PLATEFORMES DE RECHERCHE

Deux plateformes de recherche mises en place et gérées par Supélec sont mises à la disposition des chercheurs :

- **Smart-Room** : une plateforme d'expérimentation recréant un espace domestique intelligent. Cette plateforme permet de mettre en situation les recherches menées dans les domaines du traitement du signal, de l'apprentissage numérique et symbolique et du calcul distribué. La SmartRoom est composée de trois environnements différents : une salle robotique, équipée de nombreux robots qui peuvent évoluer dans un espace sans obstacle, une partie appartement, équipée de microphones, caméras et d'un mur holophonique qui permet de réaliser des expériences dans un environnement domestique, une partie holophonique, équipée d'un ensemble de haut parleurs permettant de recréer un environnement comprenant des sources sonores virtuelles se déplaçant dans l'espace.
- **InterCell** : un cluster de 256 PCs conçu pour la simulation et le calcul parallèle à grains fins. Il a été co-financé par l'INRIA et la Région Lorraine. L'objectif est de proposer aux chercheurs un système interactif permettant de faire du calcul parallèle en mettant à disposition de l'utilisateur des outils de visualisation et de management d'exécution sans effort de parallélisation qui est réalisée via un framework XXL.



FAITS MARQUANTS

L'année 2013 a donné lieu à la soutenance de deux doctorants (L. Daubigney et E. Klein) et l'arrivée de deux nouveaux doctorants. Cette année a aussi vu le départ d'un enseignant chercheur de Supélec (O. Pietquin) et le passage de l'équipe Malis sous la responsabilité de C. Pradalier, Professeur Associé à GeorgiaTech. L'année 2013 marque par ailleurs la fin du projet Methodeo, projet ANR CSOSG (Concepts, Systèmes et Outils pour la Sécurité Globale) dont le but principal était de mettre au point des méthodologies d'évaluation et de calcul de performance des algorithmes de pré et post traitement utilisées sur les données de vidéo protection. Au niveau du rayonnement international, l'équipe Malis a organisé la conférence SigDial 2013 sur le langage et le dialogue et déposé un brevet en collaboration avec l'université d'Oxford sur la réduction d'artefact périodique dans les signaux bio-médicaux.

ANIMATION DE LA RECHERCHE

L'UMI n°2958 GT/CNRS prend part à de nombreux projets ANR, projets européens, projets industriels et projets soutenus par les collectivités locales, menés avec de nombreux partenaires académiques et industriels. En ce qui concerne plus précisément le thème « Computer Science », il est possible de citer le projet Mardi, ANR CONTINT dont l'objectif est d'étudier l'interaction homme-machine sous l'angle de la mise en situation, et Ilhaire, projet FP7 qui vise à mieux comprendre les mécanismes du rire chez l'humain pour pouvoir le transférer à des avatars numériques. L'équipe IDMaD collabore également avec EDF dans le cadre de l'Institut RISEGrid pour l'étude et le développement des réseaux électriques ainsi qu'avec TOTAL dans le cadre d'une thèse industrielle.

CONTACTS

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Head IDMAD: Stéphane Vialle - stephane.vialle@supelec.fr

Head MALis: Cédric Pradalier - cedric.pradalier@georgiaTech-metz.fr

Le Laboratoire Matériaux Optiques, Photonique et Systèmes (LMOPS) regroupe 60 personnes environ issues de ses deux tutelles qui sont l'Université de Lorraine, et Supélec. Le laboratoire est principalement basé sur le Campus messin de Supélec, avec des antennes à l'Institut de Chimie et Physique de Metz (ICPM), et dans les IUT de Saint Avold et Thionville.

ÉQUIPE OPTIQUE ET ÉLECTRONIQUE POUR LES TÉLÉCOMMUNICATIONS OPTEL

L'équipe OPTEL du campus de Metz de Supélec compte 9 enseignants-chercheurs dont 6 sont membres permanents du LMOPS et membres associés de l'UMI GT-CNRS 2958. Ces enseignants-chercheurs se répartissent au sein de l'Axe 1 «Matériaux Fonctionnels» (2) et de l'Axe 2 «Photonique non linéaire» (4) du LMOPS.

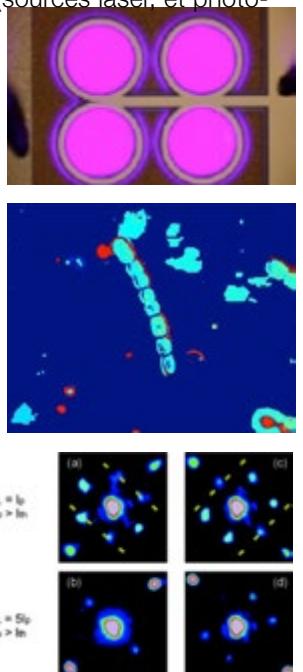
FAITS MARQUANTS

Le LMOPS a été évalué très favorablement (notation A) par l'AERES et est un des laboratoires associés et pilier de l'UMI GT-CNRS 2958. L'année 2013 s'est accompagnée d'une implication du LMOPS dans les programmes d'investissement d'avenir. Ainsi, deux financements pour un projet de recherche AMI d'une part et pour un post doc dans le cadre du programme LABEX Ganex ont pu être obtenus. Le LMOPS est également impliqué dans le Pacte Lorraine dans le cadre du projet Campus International d'Ingénierie en optoélectronique et énergie qui devrait être financé à hauteur de 7,5 M€ d'une part, et d'autre part dans deux projets avec le CEA TECH qui viennent de démarrer avec le recrutement de deux doctorants et deux post docs. Le laboratoire est en outre impliqué en 2013 dans 7 ANR, 1 PEPS, 3 projets européens COST, 1 projet FP7, 3 projets PHC, 3 projets régionaux CPER et 3 projets pilotés par l'Agence de Mobilisation Économique Lorraine. 5 contrats industriels sont également en cours. Côté ressources humaines, le laboratoire a recruté 2 nouveaux enseignant chercheurs à Supélec et vu 3 de ses personnels obtenir des promotions en tant que Professeur des Universités de classe Exceptionnelle. Enfin, le laboratoire vient d'obtenir le label CNRS de par sa participation active à la Fédération de Recherche GI2M.

THÈMES DE RECHERCHE

Matériaux fonctionnels :

Cet axe concerne la conception et l'élaboration de matériaux à fonctionnalités optoélectroniques (sources laser, et photodétecteurs UV, cellules solaires), électroniques (transistors HEMT, diodes Schottky) et thermiques (ignifugation). L'activité des enseignant-chercheurs de Supélec au sein de cette thématique porte notamment sur la conception de nouveaux composants photoniques tels que des miroirs sub-longueurs d'onde, des structures à base d'oxydes transparents conducteurs, des lasers à cavité verticale émettant dans l'UV ou le Moyen Infra-Rouge ou encore des sources lumineuses type LED à cavité résonnante. L'équipe a également obtenu le financement du projet BioCapTech par l'Agence de Mobilisation Économique (AME) du Conseil Régional de Lorraine dont l'objectif est de mettre au point un système optique de détection et de reconnaissance des algues polluantes pour contrôler la qualité des eaux de bassin et lutter contre la prolifération d'algues nocives.



Photonique :

Cette thématique regroupe l'étude de la commutation tout-optique, des circuits optiques 3D, des nouveaux composants électro-optiques, de la génération tout optique de signaux électriques rapides, et de la cryptographie par chaos. Les recherches conduites par les enseignant-chercheurs de Supélec portent plus particulièrement sur l'étude du chaos dans la polarisation de la lumière générée, de la dynamique non-linéaire de lasers à semi-conducteurs pour définir de nouvelles applications de traitement optique de l'information utilisant le chaos, de la conception de guides d'onde reconfigurables basés sur des cristaux photo-réfractifs ainsi que sur l'étude de la formation de patterns optiques, c'est-à-dire de l'auto-organisation d'un faisceau lumineux en une forme spatiale régulière utile pour la réalisation de mémoires optiques adressables.

Contrôle et capteurs optiques :

Ce troisième axe thématique concerne le contrôle optique de matériaux, plus particulièrement par spectroscopie Raman, avec retour et optimisation de leurs conditions d'élaboration, et/ou leurs propriétés fonctionnelles.

Ces trois axes de recherche sont accompagnés par un parc d'équipements de qualité pour l'élaboration (cristaux massifs, fibres cristalline, épitaxie), la caractérisation (optique et électrique) et la modélisation (cluster informatique) de matériaux et composants.

ANIMATION DE LA RECHERCHE

Le LMOPS a prend part actuellement à sept projets ANR (quatre en tant que coordinateur) et un projet européen, menés avec plus de 20 partenaires académiques et industriels : Wide band laser amplifier (ULTRAWIDE, 2010), Long life battery (BATGAN, 2011), UV VCSEL (VESUVE, 2011), *Extreme surface characterization* (MOON, 2011), Photovoltaïque (NOVAGAIN, 2012), Laser UV de puissance (UV CHALLENGE, 2012), Optique non linéaire (TINO, 2012), Ingénierie des contraintes en couches minces (LILA, 2012), Source Terahertz (FP7, COSIT, 2011).

Le laboratoire est coordinateur d'un programme international (ARCUS) financé par les états français et russe ainsi que la région Lorraine. Le LMOPS participe également à des réseaux régionaux (Materialia, Hydreos), nationaux (CMDO+, C'Nano Grand Est, GDR PhoNoMi2) et internationaux (COST* P8, COST MP0702, COST 288 et COST MP0902).

PERSPECTIVES

L'objectif majeur du laboratoire est de poursuivre la dynamique engagée en vue de la constitution d'un Pôle en optoélectronique sur la place messine, pour le développement d'activités de recherche de pointe et le développement économique régional, en s'appuyant sur :

- L'intensification de l'implication dans le partenariat avec l'UMI, CNRS-GeorgiaTech-Supelec et avec l'Institut Lafayette,
- Le prolongement et le renforcement des collaborations régionales avec l'Institut Jean-Lamour IJL et le Laboratoire d'Étude des Microstructures et de Mécanique des Matériaux LEM3 dans le cadre de la Fédération de recherche GI2M (Génie Industriel, Mécanique et Matériaux) et du Pôle Scientifique M4 de l'Université de Lorraine,
- Les collaborations nationales et internationales,
- Les collaborations industrielles et activité de valorisation,
- L'interaction avec les deux Pôles de compétitivité lorrains (Materialia et Hydreos) et l'IRT M2P (Matériaux, Métallurgie, Procédés).



KEY FIGURES

| | |
|---------------------------------------|----|
| FACULTY RESEARCHERS AND RESEARCHERS: | 28 |
| PhD STUDENTS: | 24 |
| POSTDOCS: | 2 |
| ADMINISTRATIVE AND TECHNICAL STAFF: | 6 |
| INTERNATIONAL PEER-REVIEWED JOURNALS: | 19 |

PARTENAIRES ACADEMIQUES

ETH (Federal Polytechnic School) Zurich (Suisse), Université de Tsukuba (NIMS) Tokyo (Japon), Université de Canberra (Australie), New Jersey Institute of Technology (États-Unis), Universitat Politècnica de Catalunya (UPC), Fraunhofer Institut Freiburg (IAF), Georgia Tech Atlanta, Université de Bruxelles (VUB), University of Vilnius (Lituanie)...

CONTACTS

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Head OPTEL: Marc Sciamanna
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Tél: +33 (0)3 87 37 85 67 (Jean-Paul Salvestrini)

HYBRID SYSTEM CONTROL - HSC

The aim of the HSC team is to propose algorithms to control large scale network systems. Considering that it is interesting to anticipate on known reference trajectories and disturbances and to take into account constraints and multi objectives, most activities are based on Model Predictive Control. In order to deal with the complexity of the considered systems, hierarchical and distributed control is mainly studied. A special attention is paid to the control of hybrid systems that involve both continuous and logical behaviors. This works are mainly applied to energy management and distributed generation integration. Energy management in buildings so requires to find the trade-off between the energy consumption and the occupants comfort but also to integrate local renewable sources and to respond to grid demands. It is then necessary to control more complex systems that are set up in buildings and to optimize multi objective criteria such as energy, power, comfort, CO₂ emissions and life time.

HIGHLIGHTS 2014

Launch of the Van Gogh project with the Technical University of Delft on Distributed MPC control of Hybrid systems.

FACIAL ANALYSIS SYNTHESIS & TRACKING - FAST

FAST is specialized in expressions and emotion analysis. The goal is to quantify the amount of stress of people with depression, burnout, over-training or post-traumatic disorders. Our core technology is based on 3D deformable models and multi-modal processing (audio, video and context) in order to analyze people face and behavior. With those tools we analyze the gaze, age, gender, identity and expression of unknown people.

HIGHLIGHTS 2014

The team has co-founded two startups (Dynamixyz and 3D Sound Labs), the latest one was created in January 2014.



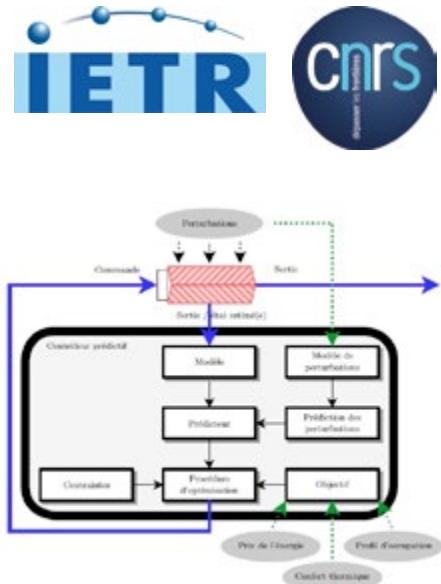
KEY FIGURES (ASH, FAST & SCEE teams)

FACULTY RESEARCHERS AND RESEARCHERS: 8 / 3 / 7

PHD STUDENTS: 5 / 6 / 14

POST-DOC: 1 / 1 / 4

RANK A PUBLICATIONS (SOURCE: WEB OF SCIENCE): 12 / 77 / 22



Light stage

ACADEMIC PARTNERS

HSC: Rennes 1 University, TU Delft.

FAST: Cognac G UMR, Institut de Recherche Biomédicale des Armées, Institut Maupertuis, ENIB

SCEE: Zhejiang University, Patras University, Poznan University, Supcom Tunis, CTTC, KTH, Macquarie University, Lebanese University, Trinity College of Dublin, Technical University of Sofia, INSA Rennes, IRISA, Télécom Bretagne, ESIEE, ENSEA, CNAM, CEA.

INDUSTRIAL PARTNERS

HSC: Delta Dore, EDF Delta Dore, EDF

FAST: 3D Sound Labs, Dynamixyz, Eca Faros, GNFA, Voxygen

SCEE: CEA, Orange Labs, Thales, Teamcast, Enensys, Alcatel, Zodiac

SIGNAL COMMUNICATION & EMBEDDED ELECTRONICS - SCEE

SCEE team is focused on the study of future telecommunication systems (advanced multi-carrier waveforms, 5G, Smart Grids, and green communication) based on the three concepts of Software Radio, Cognitive Radio and Green Radio. To do so expertise spans through the following three research areas:

- Digital Communications and Signal Processing, which includes deep background on digital communications and signal processing for cognitive radio systems (equipments and networks),
- Embedded Systems, that focuses on flexible reconfigurable architectures, security and demonstrators developments
- Sensors for Cognitive Radio, with a focus on spectrum holes (white spectrum) detection.



HIGHLIGHTS 2014

Apart the fact that 2014 was the 10th year of SCEE team (a special day has been dedicated to this event the 27th of June), three events marked 2014: first, SCEE organized the third edition of NextGWin conference held in Rennes. A worldwide panel of 20 top level invited speakers gave a large overview on further green wireless networks and especially 5G. Second, SCEE organized a Spring School of Newcom# Network of Excellence whose topic was based on flexible multi-carrier systems. Third, SCEE was part of ISWCS 2014 conference organization as Chair. Two research projects in which SCEE is partner have been selected for funding by the French national research agency (ANR): SOGREEN (Smart Grids and Cognitive Radio) and ACCENT5 (Device-to-Device Communications for 5G).

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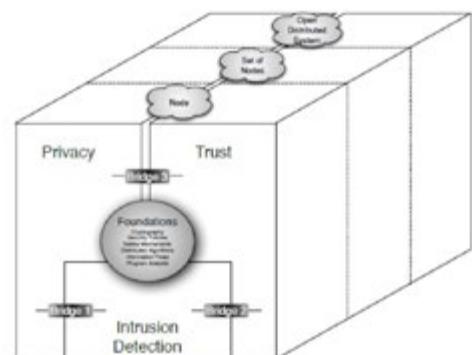
CYBERSECURITY

The long-term ambition is to contribute to build distributed systems that are trustworthy and respectful of privacy, even when some nodes in the system have been compromised.

With this objective in mind, the CIDRE group focuses on three different aspects of security, namely trust, intrusion detection, and privacy as well as on the bridges that exist between these aspects. Indeed, we believe that to study new security solutions one must take into account that it is now a necessity to interact with devices whose owners are unknown. To reduce the risk of relying on dishonest entities, a trust mechanism is an essential prevention tool that aims at measuring the capacity of a remote node to provide a service compliant with its specification. Such a mechanism should allow to overcome ill-founded suspicions and to be aware of established misbehaviors. To identify such misbehaviors, intrusion detection systems are necessary. Such systems aim at detecting, by analyzing data flows, whether violations of the security policies have occurred. Finally, Privacy, which is now recognized as a fundamental individual right, should be respected despite the presence of tools and systems that continuously observe or even control users actions or behaviors.

The CIDRE team considers three complementary levels of study:

- **The Node Level:** The term node either refers to a device that hosts a network client or service or to the process that runs this client or service. Node security management must be the focus of a particular attention, since from the user point of view, security of his own devices is crucial. Sensitive information and services must therefore be locally protected against various forms of attacks. This protection may take a dual form, namely prevention and detection.
- **The Group Level:** Distributed applications often rely on the identification of sets of interacting entities. These subsets are either called groups, clusters, collections, neighborhoods, spheres, or communities according to the criteria that define the membership. Among others, the adopted criteria may reflect the fact that a unique person administrates its members, or that they share the same security policy. It can also be related to the localization of the physical entities, or the fact that they need to be strongly synchronized, or even that they share mutual interests. Due to the vast number of possible contexts and terminologies, we refer to a single type of set of entities, that we call set of nodes. We assume that a node can locally and independently identify a set of nodes and modify the composition of this set at any time. The node that manages one set has to know the identity of each of its members and should be able to communicate directly with them without relying on a third party. Despite these two restrictions, this definition



KEY FIGURES

FACULTY RESEARCHERS AND RESEARCHERS: 12

PHD STUDENTS: 16

POST-DOC: 1

RANK A PUBLICATIONS (SOURCE: WEB OF SCIENCE): 14

ACADEMIC PARTENRS

La Sapienza University, Technische Universität Hamburg-Harburg, Inria, CNRS, INSERM, LAAS, LIRIS, Rennes 1 University, Nantes university, Institut Mines-Télécom, ENS Rennes, ENSI Bourges, ENSI Caen.

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INDUSTRIAL PARTNERS

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remains general enough to include as particular cases most of the examples mentioned above. Of course, more restrictive behaviors can be specified by adding other constraints. We are convinced that security can benefit from the existence and the identification of sets of nodes of limited size as they can help in improving the efficiency of the detection and prevention mechanisms.

- **The Open Network Level:** In the context of large-scale distributed and dynamic systems, interaction with unknown entities becomes an unavoidable habit despite the induced risk. For instance, consider a mobile user that connects his laptop to a public Wi-Fi access point to interact with his company. At this point, data (regardless if it is valuable or not) is updated and managed through non-trusted undedicated entities (i.e., communication infrastructure and nodes) that provide multiple services to multiple parties during that user connection. In the same way, the same device (e.g., laptop, PDA, USB key) is often used for both professional and private activities, each activity accessing and manipulating decisive data.

HIGHLIGHTS 2014

- **Best Paper Award at SAR-SSI 2014**

The supervision of distributed system relies heavily on correlation mechanisms that are responsible for collecting alerts coming from sensors and detecting complex scenarios in the flow of alerts. The problem is that it requires writing complex correlation rules. The work we have performed proposes a technique to generate semi-automatically such correlation rules.

- **ESORICS 2014 Best Student Paper Award**

One approach to protect the privacy of users in personalized recommendation systems is to publish a sanitized version of the profile of the user by relying a non-interactive mechanism compliant with the concept of differential privacy. In a joint work with the LinkMedia Inria team, we have considered two existing schemes offering a differentially private representation of profiles: BLIP (BLoom- and-fLIP) and JLT (Johnson-Lindenstrauss Transform). Our contributions are a theoretical analysis and practical implementations of two attacks tested on datasets composed of real user profiles revealing that joint decoding is the most powerful attack.

Photos :
Direction de la Communication, Direction de la Recherche de CentraleSupélec

Direction artistique et réalisation :
Direction de CentraleSupélec – Mars 2015