Communauté
UNIVERSITÉ Grenoble Alpes

PERSYVAL - Lab

SCIENTIFIC Overview

2012-2016

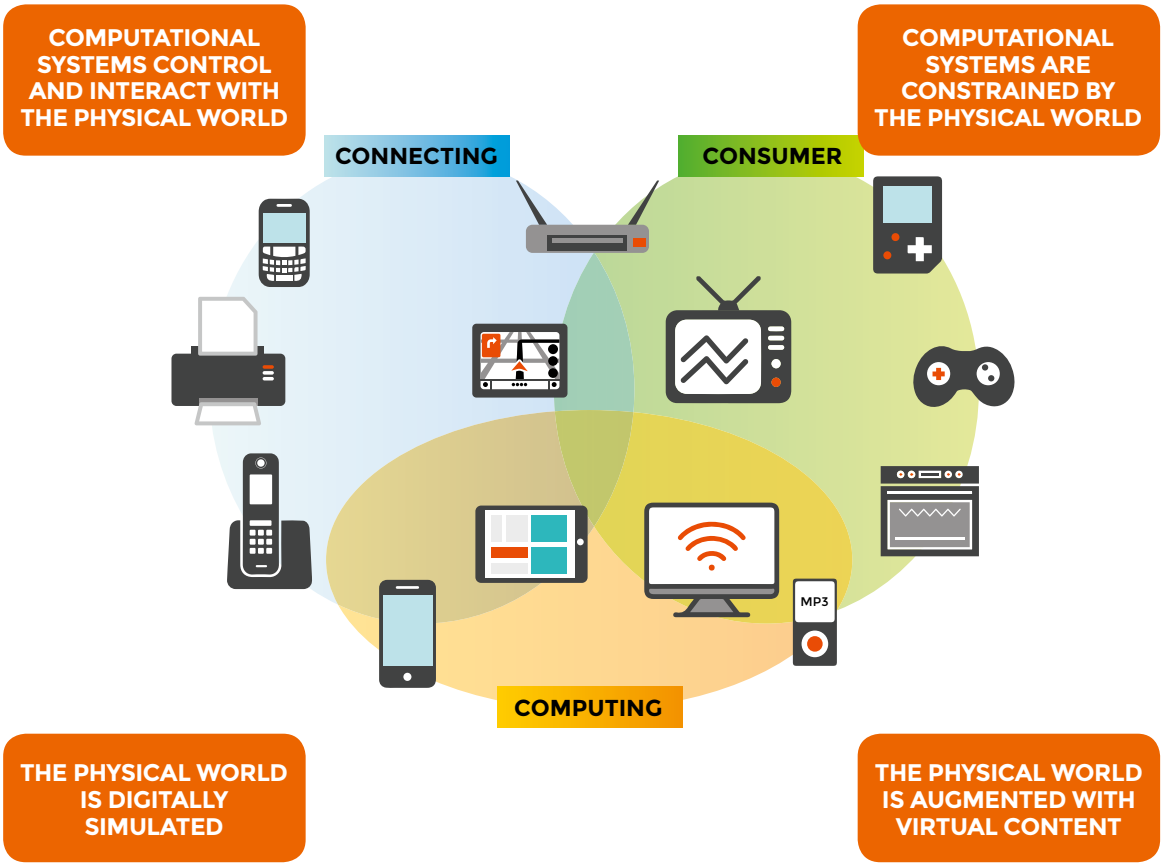
CONTENTS

* This work has been partially supported by the LabEx PERSYVAL-Lab (ANR-11-LABX-0025-01) funded by the French program Investissements d'Avenir

PERVASIVE SYSTEMS AND ALGORITHMS AT THE CONVERGENCE OF THE PHYSICAL AND DIGITAL WORLDS

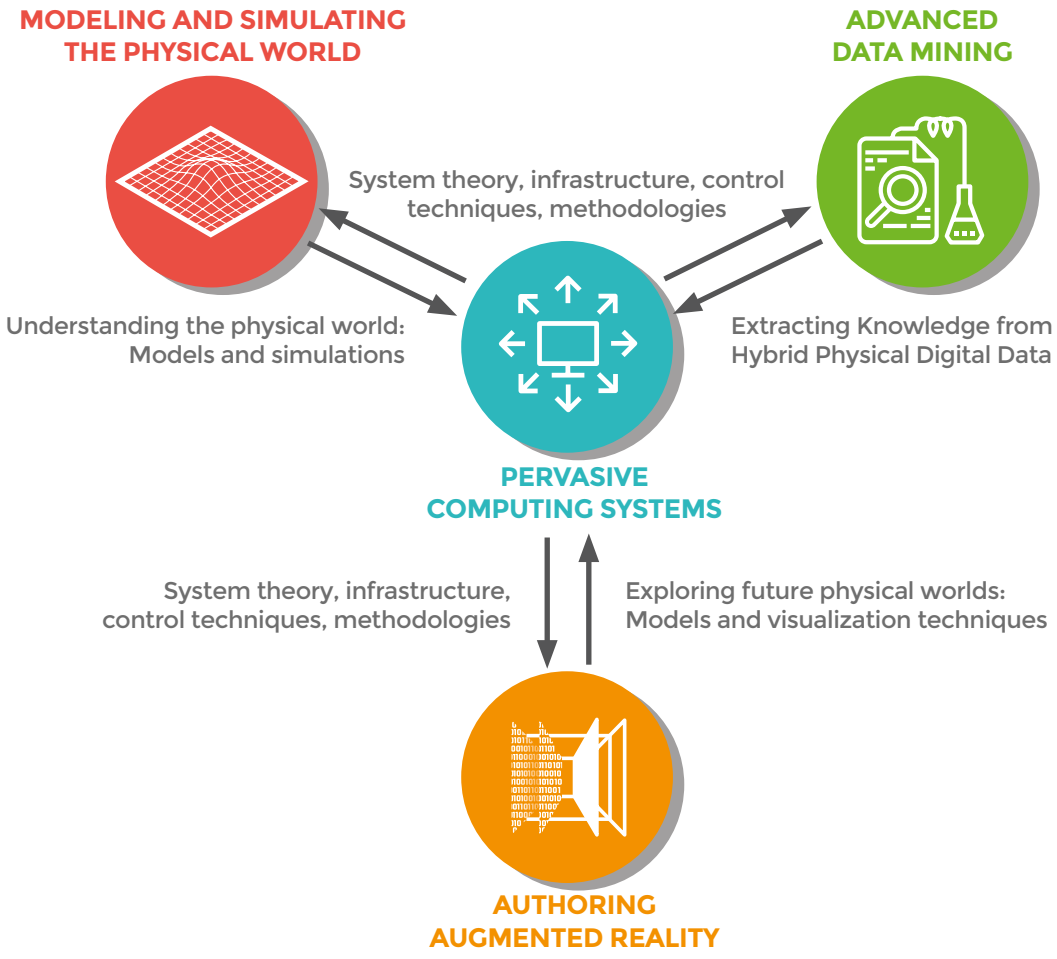
PERSYVAL-Lab federates 800 researchers and academics from 10 laboratories in Grenoble working on computer science, hardware architecture, signal processing, control and mathematics towards a common scientific goal: build secure, reliable and efficient cyber-physical systems. The target applications meet major societal challenges, such as smart spaces, energy management and medicine (collaboration with Labex CAMI).

FOUR TYPES OF INTERPLAY BETWEEN THE PHYSICAL AND DIGITAL WORLDS



PERSYVAL-lab promotes a holistic approach for developing an ambitious scientific program focused on four research tracks conducted by integrated multi-disciplinary small and effective teams: AAR (Authoring Augmented Reality), ADM (Advanced Data Mining, PCS (Pervasive Computing Systems) and SIM (Modeling and simulating the physical world).

A COHERENT RESEARCH AGENDA



The produced results will take the form of mathematical tools, algorithms, software, devices and demonstrators. They will be gathered into a common platform that will be transversely used and fed by the research projects, and will serve as a showcase of PERSYVAL-lab.
A first step towards this showcase is the PerSCiDO-Grenoble_Alpes platform for sharing research datasets: https://persyval-platform.imag.fr/

For education, PERSYVAL-lab promotes the development of multidisciplinary lab-oriented courses, in order to train students to address the challenge of designing ubiquitous computing devices of the future. PERSYVAL-lab provides financial and human support for the development of innovative educational platforms. To attract in Grenoble excellent master and PhD students on PERSYVAL-lab topics, 10 master grants and 5 PhD grants are funded every year through master and doctoral competitive scholarship programmes.

GOVERNANCE

EXECUTIVE BOARD AND COMMITTEES

Direction board

Scientific director: Marie-Christine Rousset
Project Manager: Anne-Laure Bernardin
Co-director (Education): Emmanuel Witrant
Co-director (Communication and Platforms): Brigitte Bidegaray
Co-director (International): Erwan Lanneau
Co-director (Valorisation): Philippe Béliard

Executive Committee (coordinators of the research tracks)

AAR: Gérard Bailly (GIPSA-lab), Laurence Nigay (LIG)
ADM: Massih-Reza Amini (LIG), Pierre Comon (GIPSA-lab)
PCS: Alain Girault (Inria), Alain Kibangou (GIPSA-lab)
SIM: Laurent Desbat (TIMC-IMAG), Christophe Picard (LJK)

Executive Committee Enlarged to the directors of the 10 partners laboratories

CEA: Thierry Collette
GIPSA-lab: Jérôme Mars
G-SCOP: François Villeneuve
Inria: Patrick Gros
Institut Fourier: Thierry Gallay
LIG: Eric Gaussier
LJK: Stéphane Labbé
TIMA: Salvador Mir
TIMC-IMAG: Olivier François
Verimag: Florence Maraninchi

SCIENTIFIC COMMITTEES

Local Scientific Committee

- Gérard Besson, CNRS, IF, ERC
- Georges-Henri Cottet UGA, LJK, IUF Président
- Jean-Pierre Demailly UGA, IF, IUF, French Academy of Sciences
- Radu Horaud, Inria
- Denis Jongmans, UGA, Head of the Doctoral School of Grenoble
- Christian Jutten, UGA, Gipsa-lab, ERC
- David Monniaux CNRS, Verimag, ERC
- Denis Trystram, Grenoble INP, LIG

External Advisory Board

Personalities from the international scientific community:

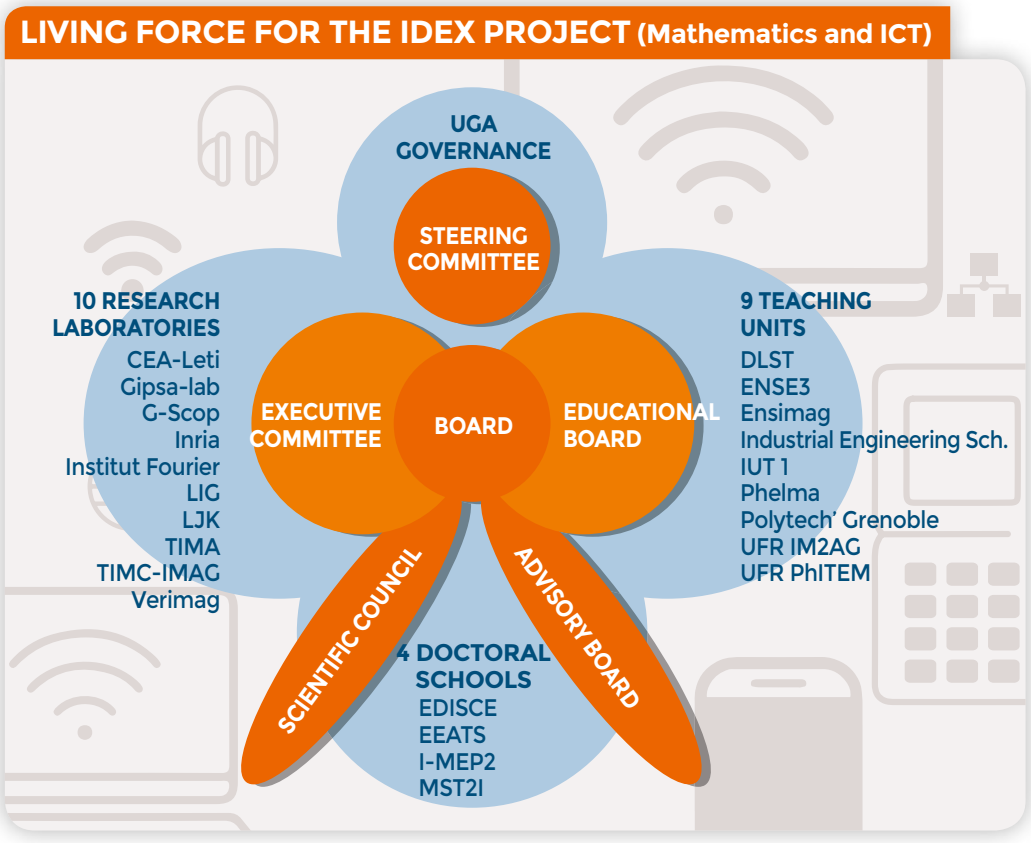
- Gilles Barthe, *IMDEA Software Institute, Madrid*
- Manfred Broy, *Technische Universität München*
- Lothar Thiele, *Swiss Federal Institute of Technology Zurich*
- Jean-Philippe Thiran, *EPFL*

Personalities from the French scientific community:

- Patrick Flandrin, ENS Lyon, *Académie des Sciences*
- Malik Ghallab, *LAAS, CNRS*
- Christine Paulin, *LRI, Paris-Saclay, LabEx Digicosme*
- Emmanuel Trelat, *JLL, Paris 6, IUF*

Figures from the industry:

- Vania Conan, *Thalès*
- Guy Mamou-Mani, *Syntec Numérique*
- Philippe Magarshak, *STMicroelectronics*
- Philippe Wieczorek, *Minalogic*



PERSYVAL-LAB
IN A NUTSHELL

2012-2019

DURATION

12 M€

FUNDING

About 800
permanent researchers
and academics

MEMBERS

Cyber-physical systems, smart spaces, energy management, medicine, etc.

APPLICATIONS

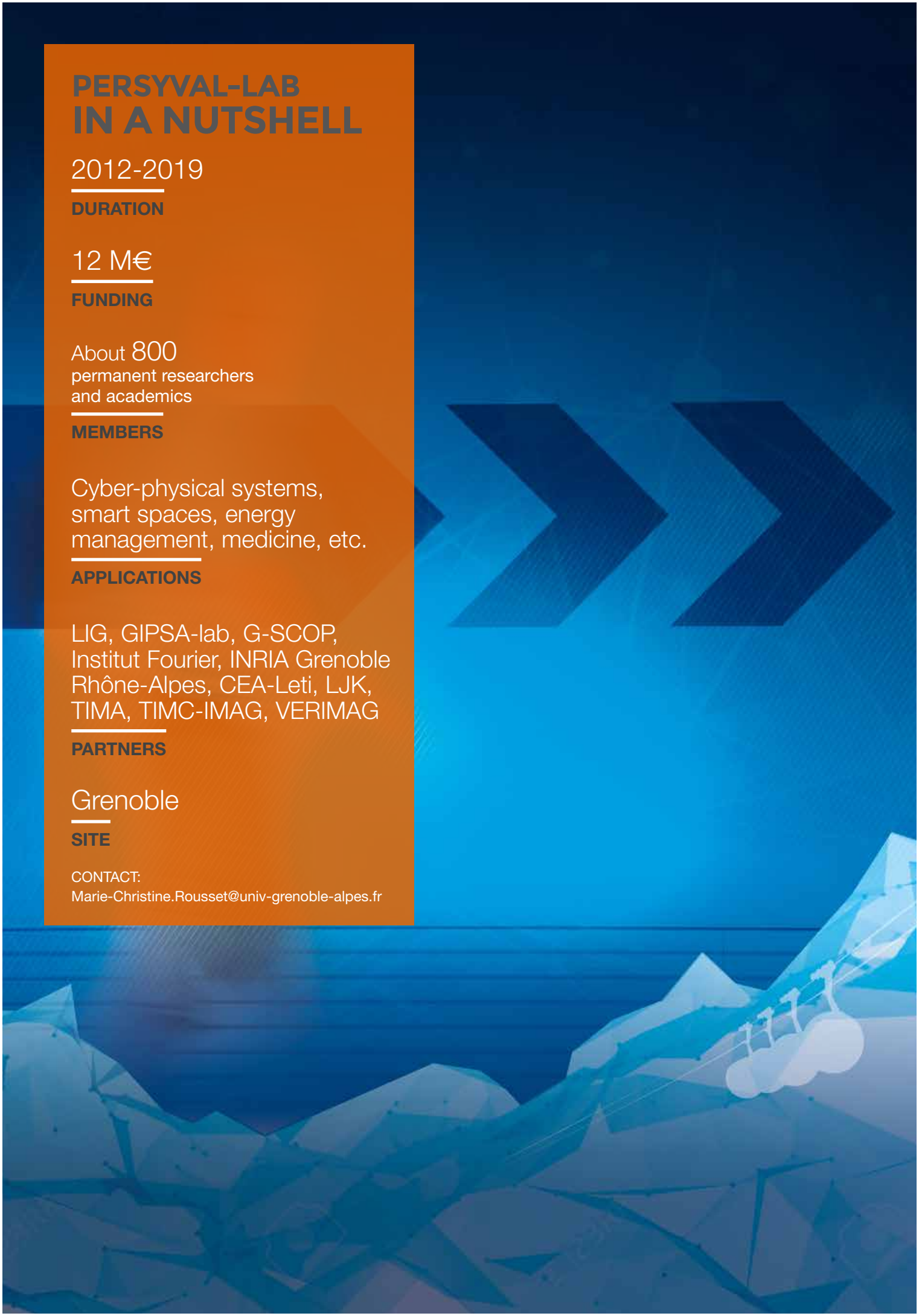
LIG, GIPSA-lab, G-SCOP, Institut Fourier, INRIA Grenoble Rhône-Alpes, CEA-Leti, LJK, TIMA, TIMC-IMAG, VERIMAG

PARTNERS

Grenoble

SITE

CONTACT:
Marie-Christine.Rousset@univ-grenoble-alpes.fr



EDUCATION

Spanning five engineering schools (ENSE3, Ensimag, Industrial Engineering, Phelma and Polytech Grenoble), three university departments (DLST, bachelor studies in science and technology, UFR IM2AG, Computer Science, Mathematics, Applied-mathematics, and UFR PhITEM, Physics, Engineering, Earth, Environment and Mechanics), and a University Institute of Technology (IUT1), PERSYVAL-Lab aims at promoting the development of multidisciplinary lab-oriented courses, in order to train students to address the challenge of designing ubiquitous computing devices of the future. PERSYVAL-Lab provides financial and human support for the development of innovative educational platforms. To attract excellent students interested in research, PERSYVAL-Lab also offers scholarships at the master level.

Master Scholarships

PERSYVAL-Lab has launched in 2012 a scholarship program to attract excellent candidates in the second year of the Master programs at the University of Grenoble in the fields of Computer Science, Automatic Control, Mathematics or Signal Processing. These grants of €8 000 are intended to support excellent students who wish to obtain a master degree in Grenoble and then to apply to a doctoral program within one of the laboratories associated with PERSYVAL-Lab. A maximum of ten grants are allocated per academic year. In 2012, 3 students (out of 13 applicants) have been granted, among which 2 are currently pursuing a PhD at the University of Grenoble. Between 2013 and 2016, 10 students (out of 60 to 78 applicants) received a grant each year and an average of 7 per year continued with Ph.D. studies at UGA, covering a wide spectrum of research topics and origins.

Educational Platforms

PERSYVAL-Lab promotes the development of multidisciplinary lab-oriented courses and exhibitions by supporting the development of innovative educational platforms related to the LabEx themes. A call for projects is organized yearly to promote, federate and mutualize the educational platforms dedicated to experiments. This call supports all the courses in automatic control, computer science, mathematics and signal processing delivered at University of Grenoble. It also supports the PERSYCUP, a yearly event where students from different Universities compete in a robotics challenge.
The candidate projects reinforce existing platforms or propose new ones. Depending on the number of applications, PERSYVAL-lab can support projects up to 30 k€, for a yearly total of about 110 k€. An engineer is also hired to contribute to the technical setup of these projects. 26 projects have been sponsored since 2012, some of them are summarized as follows.

ECloud is a hardware and software platform for cloud computing and distributed applications. The platform architecture is based on 2 Bullion servers, a NETAPP server and the software VMware vCloud standard.

EaZyBoss teaches the basic knowledge of computer architecture for, e.g. operating systems, images processing... It combines hardware circuit design using HDL languages implemented on FPGAs (Field Programmable Gate Array) with low-level software using the embedded processor subsystem based on a multi-core ARM Cortex A9.

Spread allows to experiment with distributed computing infrastructures of various kinds. It permits to build distributed applications but also to work on code distribution, distributed scheduling or even on lower layers, such as routing algorithms or as support infrastructure for sensor network deployment and testing.

Open the hand to move forward

Fablabs

AIR (Ambient Intelligence Room, Polytech Grenoble). Students can borrow from AIR a wide variety of devices ranging from microcontrollers, sensors, game consoles and controllers, multimedia equipments, tablet computers, robots, UAVs... The available tools are: DIY supplies, Makerbot 3D-printer, milling machine, drill press, laser cutting machine and electronics development stations. Noticeable realizations include the robotics platform of telepresence RobAIR, small-scale models of smart house and smart campus, tactile tables.

FabEnsimag (Ensimag) works in close relationship with AIR. Both Fablabs share several equipments and form a network with fabMSTIC. FabEnsimag hosts innovative projects on various topics: internet of things, smart objects, robots, etc.

FabMSTIC (LIG) allows researchers and students to include prototyping in the context of research activity and education programs. FabMSTIC focuses on computer aided design and fabrication, with support for electronic design, mechanical design and microcontroller programming. It is equipped with 3D printers, precision CNC Mill, laser engraver and cutter, vinyl plotter and other tools.

REGIS (Retour d'Effort et Génération d'Images Stéréoscopiques) experiments with new forms of computing. Student work in small groups on topics such as virtual augmentations of the physical environment, new forms of human-computer interactions such as immersive 3D, tangible and gestural interaction, large interactive surfaces and haptic feedback (Phantom Omni).

EDUCATION

Automatic control

PhyAuto (UFR PhITEM) investigates the dynamics of physical system and synthesizing controllers for embedded and computer-controlled systems. The different experiments illustrate several physical principles (fluid mechanics, solid mechanics and electromagnetism) that have a strong impact on modern industrial applications.

Tour Perret 4.0 (IUT) aims at controlling the illumination of the Tour Perret, a symbol of Grenoble built during the universal exposition in 1925. Reduced-size models allow to test the algorithm and students interact with the tower lights using computers, smartphones and digital tablets.

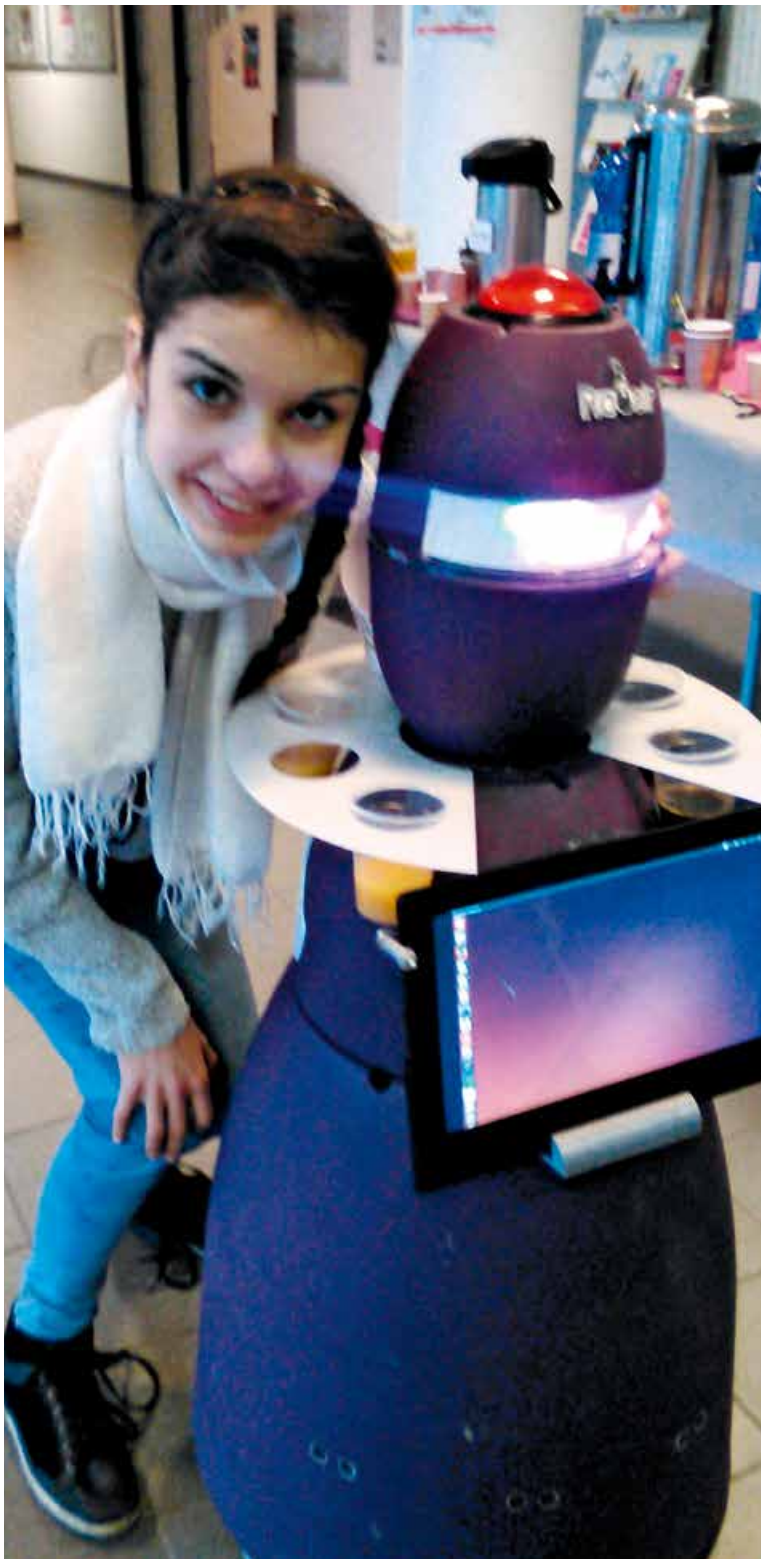
G-ICS Sandbox (GreEn-ER Industrial Control Systems Sandbox) is an industrial communication system learning workshop and a control system cybersecurity exploration lab. Students learn fieldbus and devicebus real-time communication networks and protocols in a “do it by yourself” learning game while testing, comparing and benchmarking control communication chains (device / controller (RTU) / supervisor).

Tournesol is based on 8 photovoltaic sun trackers which follow the sun to maximize the light power on the photovoltaic module. This platform combines physics, mechanics, electronics, computer science, embedded systems, industrial networks and RF communications.

Robotics and vision

Showroom (UFR IM2AG) is dedicated to robotics, simulation and computer graphics. Current and planned activities include autonomous robotics with environmental perception, simulation of a deformable surface and the 3D tracking of its actual shape, real-time tracking and reconstruction of human motion...

Robotics Challenge Persycup is a yearly meeting (since 2015) where students from different universities compete on 3 different robotics challenges. This event attracts a broad audience and presents the findings and dynamism of Grenoble in sciences and technologies, and more particularly in robotics.



Other topics

Caseine is a learning platform in industrial engineering, Mathematics and Computer science. It offers online environments to learn and develop skills for problem solving, auto-evaluation procedures and forums to increase autonomy of students.

Shiny is a framework for web applications of the statistics software R. It provides intuitive and interactive tools to teach particularly difficult concepts in statistics. Shiny is federative for multiple statistics courses at UGA.

Science discovery for secondary education students

In January 2016 PERSYVAL-lab organized a week of science discovery for *secondary education* students ("stages de 3ieme"). The college kids spent one week in our University environment learning about the jobs related to research and to the innovation process leading to industrial applications. Organized in a small team (7), the students met with researchers in automatic control, computer science, mathematics and signal processing, who presented their work in a didactic way, highlighting the key challenges and industrial applications for tomorrow's world.

As a guideline during the week, the mornings were dedicated to prototyping a small connected object at Fablab MSTIC. This implied to learn how to concretize an idea, to set the specifications and to actually build the object using the fablab tools. The students came up with a Starwars logo which includes a presence detector and connects to the network to send an email or a text message when an intrudor is detected. Each kid went back home with his/her spying device.

Considering the success of this week and the happiness of the kids in 2016, it was repeated in 2017 and this action is now one of the yearly events of PERSYVAL-lab education board.

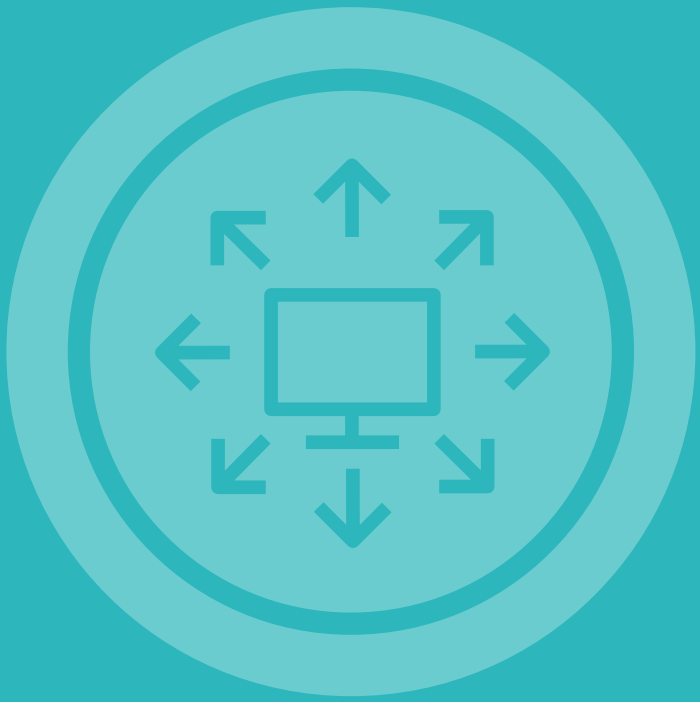
Breakfast with Industry

PERSYVAL-lab also conducts networking activities with industry. In May 2016 PERSYVAL-lab organized a breakfast with industry, in cooperation with the AMIES LabEx and Maimosine, and with the UFR (teaching departments) IM2AG and PhITEM of Université Grenoble Alpes. The goal was to provide potential local industrial partners with an overview of both the research expertise in the 10 laboratories of PERSYVAL-lab and also some of the related educational activities in the Master programs. The participants also discussed the variety of supports for academic/industrial cooperation (local, national and european research projects), and the meeting ended with a networking session.

Education Board

Hacheme Ayasso (GIPSA-lab, UFR PhITEM), Catherine Parent-Vigouroux (Verimag, UFR IM2AG), Laurence Pierre (TIMA, UFR IM2AG), Emmanuel Witrant (GIPSA-lab, UFR PhITEM).

EMAIL: education@persyval-lab.fr



PERVASIVE COMPUTING SYSTEMS

Coordinators

GIPSA-lab:
Alain Kibangou
Inria/LIG: Alain Girault

Scientific committee

CEA-Leti:
Suzanne Lesecq
Inria: Cédric Lauradoux
Inria/LIG: Gwen Salaun, Eric Rutten
Institut Fourier:
Philippe Elbaz-Vincent
LIG:
Bernard Tourancheau
TIMA: Laurent Fesquet, Stéphane Mancini
VERIMAG:
Saddek Bensalem, Stéphane Devisme

The PCS research track aims at designing new strategies for modeling, designing, analyzing, controlling, and synthesizing cyber-physical systems. The work carried out in this research action encompasses high level properties (robustness, security, fault-tolerance, privacy, scalability, optimal resource consumption...) which must be guaranteed using tools from both computation, communication, signal, and control communities.

More specifically, the research that has been carried on thanks to the Persyval & PCS funding has focused on the analysis, design, and implementation of:

- Efficient and certified cryptographic components, security protocols and privacy components, in both hardware and software, for cyber-physical systems vulnerable to various types of attacks or privacy issues.
- Reconfigurable multi-view embedded real-time component-based systems.
- Energy-efficient protocols for short-range capillary IoT networks.
- Scalable protocols for long-range cellular IoT networks.
- Efficient computation platforms (heterogeneous architectures containing FPGA accelerators, stochastic architectures, event-driven sensors/actuators).

PCS PERVASIVE COMPUTING SYSTEMS

> PROJECT-TEAMS

> EXPLORATORY PROJECTS

> PhDs

CASERM

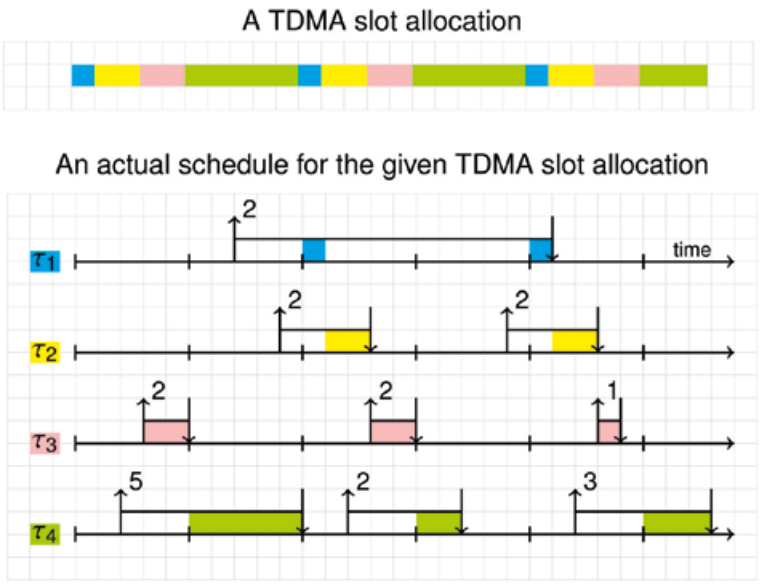
Design and Analysis of Reconfigurable Multi-view Embedded Systems

PCS

The CASERM project-team represents a significant effort towards a Coq-based design and verification method for reconfigurable multi-view embedded systems.

The use of a proof assistant to support such a framework is motivated by the fact that the systems that we target are both extremely complex and critical. In particular, designing and verifying embedded systems requires to handle multiple views of a system (related to e.g. functionality, reactivity, reliability, and resource consumption) as well as their interaction. Multi-view modeling is however still poorly understood, and its support in system modeling or architectural description languages remains unsatisfactory. There is also an increasing need for support of dynamicity and reconfiguration, which were until recently out of the scope of research dealing with critical real-time systems design. This need for support of the dynamical aspects of real-time systems extends to verification: Classically, real-time systems are modeled and analyzed using static analysis. However, when the system to be studied is subject to dynamic reconfigurations, the analysis must be performed following each reconfiguration, hence online. Finally, without even mentioning multi-view and dynamic aspects, there are very few attempts at substantiating research results for real-time systems by mechanically proving and verifying them. CASERM addresses the above mentioned challenges. Case studies and applications will ensure that our formal results apply to real systems.

Website: https://project.inria.fr/caserm



A Gantt chart describing a TDMA (Time Division Multiple Access) schedule.

Main Scientific Results and Ongoing Work

Multi-view modeling:
We plan to design a multiview, reconfigurable architecture description language (ADL) that is able to describe all relevant aspects (such as functional, resource related, reliability) of embedded systems that may evolve. We are also developing techniques for the analysis of architecture descriptions that allow the reuse of viewpoint-specific analysis technology.

Online scheduling of real-time systems:
We are developing new online scheduling algorithms based on learning techniques, so as to achieve so-called "no regret" solutions. For doing so, we introduce meaningful probabilistic constraints in real-time systems and we formulate optimization problems based on those probabilistic constraints.

Certification of real-time systems:
We are developing a formal, modular framework for the analysis of real-time systems in Coq as part of Prosa (http://prosa.mpi-sws.org), a foundational Coq library of reusable concepts and proofs for real-time schedulability analysis.

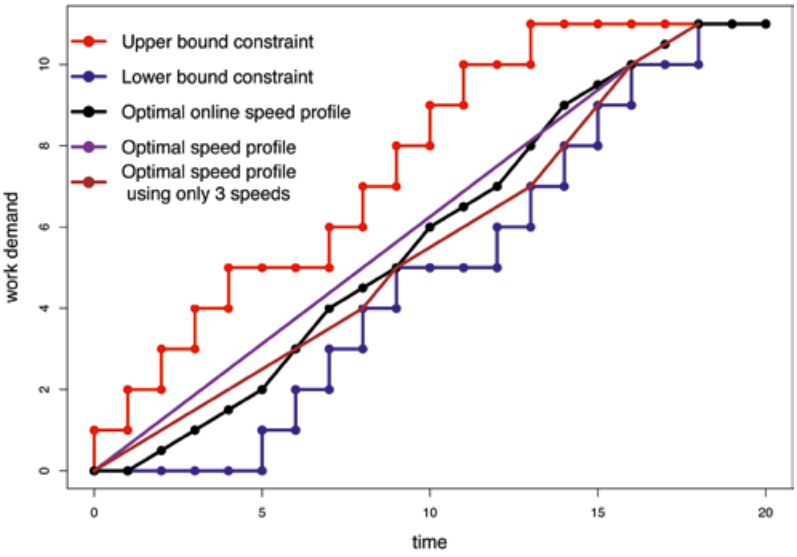
Two PhD theses are currently under way, focusing respectively on online scheduling and certification of real-time systems.

Coordinators

G-SCOP:
Jean-Philippe Gayon
LIG/Inria:
Sophie Quinton (SPADES team), Bruno Gaujal (POLARIS team)
VERIMAG:
Susanne Graf

Valorization

We are in regular contact with tool vendors such as Symtavision and Real-Time-at-Work (RTaW) who are interested by the approach we propose for result certification.



Speed profiles minimizing the energy consumption for FIFO real-time tasks.

Some relevant publications

- Jean-Bernard Stefani. Components as location graphs. In Formal Aspects of Component Software - 11th International Symposium, FACS 2014, Bertinoro, Italy, September 10-12, 2014, Revised Selected Papers, pages 3-23, 2014.
- N. Navet and B. Gaujal. Traité I2C Systèmes Temps Réel, volume 2, chapter Ordonnancement temps réel et minimisation de la consommation d'énergie, chap. 4. Hermès Science, 2006.
- Zain A. H. Hammadeh, Sophie Quinton, Rolf Ernst, Rafik Henia and Laurent Rioux. Bounding Deadline Misses in Weakly-Hard Real-Time Systems with Task Dependencies. In Design, Automation and Test in Europe 2017 (DATE), Lausanne, Switzerland, March 2017.
- Xiaomu Shi, Jean-François Monin, Frédéric Tuong, and Frédéric Blanqui. First Steps Towards the Certification of an ARM Simulator Using Compcert. In J.-P. Jouannaud and Z. Shao, editors, Certified Proofs and Programs, volume 7086 of LNCS, pages 346–361, Kenting, Taiwan, December 2011. Springer.

e-BaCCuSS

Event-Based Control, Circuits and Processing towards Ultra-Low Power Consumption

Mitigating the data-deluge by an adequate sampling

PCS

e-BaCCuSS aims at developing the scientific knowledge and the core technology for event-based circuits, control and signal processing to mitigate power consumption in electronic systems.

Covering applied mathematics, signal processing, control and circuit design, the project-team is developing key technologies such as low-power image sensors, automated design flow for event-based electronic systems or optimal control for high performance power converters.

Our approach follows two complementary techniques:

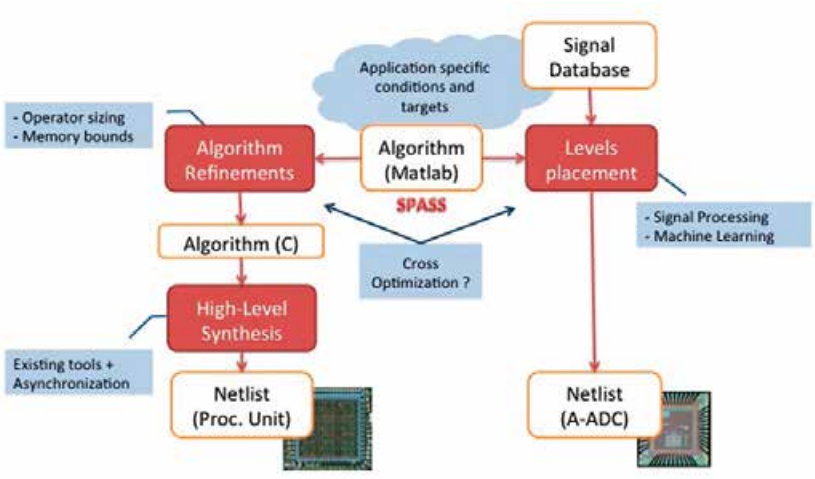
1. sampling signals non-uniformly in order to reduce the dataflow and to produce parsimonious digital signals;

2. designing event-driven circuits in order to only process non-uniform samples each time new data have been produced.

The design paradigm based on synchronizing a digital circuit with a clock is source of useless activity. At the opposite, the event-driven circuits based on local synchronizations are able to mitigate the power consumption by only activating the circuitry when an event appears. In addition, a good way to reduce energy is to rethink the sampling techniques and digital processing chains. Indeed, using the Shannon theory often produces more data than necessary. These useless data induce more computation, more storage, more communication and also more power consumption. We have designed new (parsimonious) sampling schemes and new processing techniques that are able to take advantage of event-based circuits. Drastically reducing the useless data and activity is maybe the Grail of low-power computing.

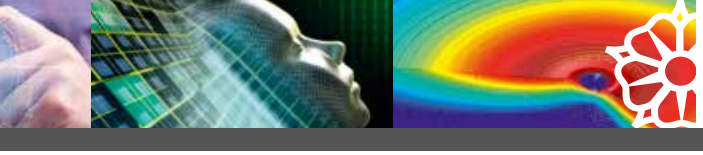
Website:
https://persyval-lab.org/en/sites/e-baccuss

Main Scientific Results and Ongoing Work



ALPS, an automated design flow for Ultra-low power Event-Based Electronic Systems:

Low power electronic systems become essential bricks of our today digital life and are prerequisites for building wireless sensors and actuators of the Internet of Things. The investment involved for designing small dedicated systems can be huge when targeting ultra-low power consumption. In order to quickly benefit from a non-uniform sampling scheme and an event-driven logic, we are developing a specific design flow, called ALPS. This ultra-low power design flow offers the opportunity to first evaluate the system by simulation, then generate an application dedicated ADC (based on a level-crossing sampling scheme), and synthesize (HLS) an event-driven circuit able to process the non-uniform sampled data.



Coordinators

GIPSA-lab:
Christophe Prieur
Inria: Bernard Brogliato
LJK: Brigitte Bidégaray
TIMA: Laurent Fesquet

Event-based Image Sensor for low-power applications:
The CMOS image sensors have been greatly improved during the two last decades, especially in terms of resolution and image quality. At the same time, the power has become a leitmotiv for all the embedded applications including the systems with an embedded camera such as smartphones, sport cams, etc. Nevertheless, the standard reading architecture of image sensors remains unchanged and requires a very power consuming analog-to-digital converter. We have developed an original architecture based on specific sampling and reading techniques able to drastically reduce the dataflow and hence the power. The resulting architecture is an event-based low-power image sensor without analog-to-digital converter. We are currently designing a testchip in AMS 350 nm technology.

High Performance Power Converters:
High performance power converters are today a hot topic because they are spread in a very large panel of electrical equipment. We are developing optimal control for DC-DC converters such as Buck or Ćuk converters.

Valorization

Industrial contact: We have confidential contacts with a small company from the Rhône-Alpes-Auvergne area that designs and manufactures high performance high power converters. It will provide realistic test conditions for some activities of our project-team, with possible extensions to other power converter structures.

Scientific dissemination: We are actively involved in the community on Event-Based Control, Communication and Signal Processing, in particular in the scientific organization and content of the flagship conference on this topic.

Some relevant publications

- Jean Simatic, Rodrigo Possamai Bastos, Laurent Fesquet, **High-level synthesis for event-based systems,** 2nd International Conference on Event-Based Control, Communications, and Signal Processing (EBCCSP 2016).
- Brigitte Bidégaray-Fesquet, Laurent Fesquet, **Levels, peaks, slopes... which sampling for which purpose?** 2nd International Conference on Event-Based Control, Communications, and Signal Processing (EBCCSP 2016).
- Jean Simatic, Abdelkarim Cherkaoui, Rodrigo Possamai Bastos, Laurent Fesquet, **New asynchronous protocols for enhancing area and throughput in bundle-data pipelines,** 29th Symp. on Integrated Circuits and Systems Design (SBCCI 2016).
- Nacim Meslem, Christophe Prieur. **Using the monotone property and sensors placement as basic tools to design set-membership state estimators.** 22nd International Symposium on Mathematical Theory of Networks and Systems, Jul 2016, Minneapolis, United States. pp.403-410, MTNS 2016.
- Fairouz Zobiri, Nacim Meslem, Brigitte Bidégaray-Fesquet. **Event-Based Sampling Algorithm for Setpoint Tracking Using a State-Feedback Controller.** 2nd International Conference on Event Based Control, Communication and Signal Processing (EBCCSP 2016).
- Alexandre Vieira, Bernard Brogliato, Christophe Prieur, **On the optimal control of linear complementarity systems,** IFAC WC 2017.

HEAVEN

HEterogenous Architectures Versatile Exploitation and programmiNg

PCS

As the evolution of programming environments towards heterogeneous programming mainly focuses on CPU/GPU platforms, some hardware accelerators are still difficult to exploit from a general-purpose parallel application.

FPGA is one of them. Unlike CPUs and GPUs, it hosts a circuit tailored for the targeted application. FPGA are extremely energy-efficient compared to CPUs and GPUs. They are obvious building blocks for large scale low-power heterogeneous multicore platforms of the future. The main objective of the HEAVEN project-team is to improve the accessibility of heterogeneous architectures containing FPGA accelerators to parallel application programmers. To improve portability, the project will extend the standard parallel programming environment OpenMP to support FPGA. Improving application portability also means leveraging most of the hardware-specific low-level mechanisms at the runtime system level. We want our solution to be flexible enough to get the most out of any heterogeneous platforms containing FPGA devices depending on specific performance needs, like computation throughput or energy consumption for example.

An important aspect of HEAVEN is to conduct experiments with FPGA accelerators on real-life scientific applications from different domains like signal processing and computational finance.

Website:
https://persyval-lab.org/en/sites/heaven

Main Scientific Results and Ongoing Work

The HEAVEN team is currently working on both the hardware level and the software level. On the hardware level, we assembled a prototype of a heterogeneous multicore platform embedding FPGA. It is composed of a Jetson TX1 board from NVIDIA (hosting a 4 core CPU and a 256 core GPU), linked by a PCIe bus to a Xilinx ZC706 FPGA board (hosting a FPGA fabric). A linux operating system runs on top of this platform (Figure 1).

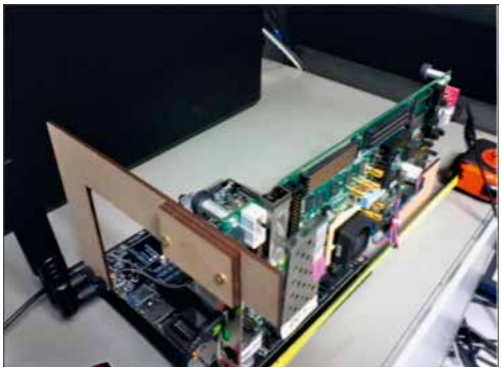


Figure 1: The HEAVEN hardware prototype.

Coordinators

LIG/Inria:
François Broquedis
TIMA: Olivier Muller

We also designed and implemented a software framework that enables some computing kernels of an OpenMP application to run on a wide variety of FPGA boards with very little effort from the application programmer. Our framework includes an extended version of the StarPU [1] heterogeneous runtime system and the AUGH [2] high-level synthesis tool and is completely open-source. Its architecture is depicted on Figure 2.

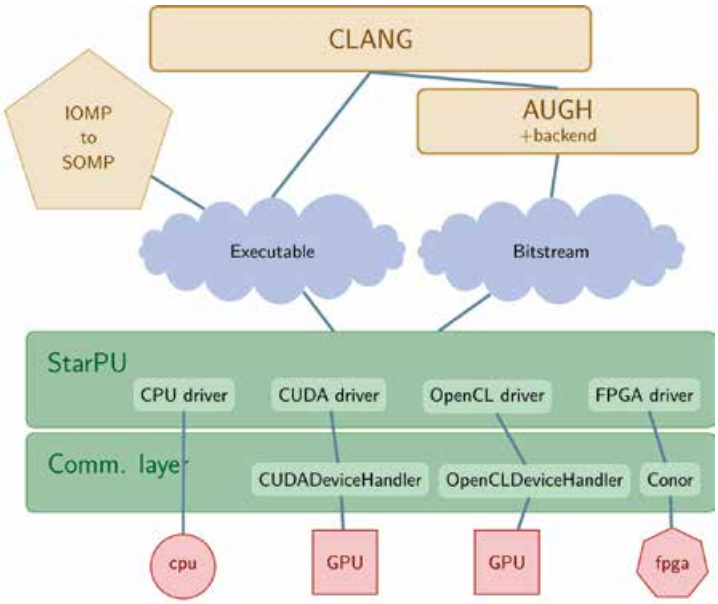


Figure 2: The HEAVEN software stack.

Valorization

Extension of the HEAVEN prototype with FPGA support for StarPU:
We have started a collaboration with the INRIA STORM research group in Bordeaux in charge of maintaining the StarPU heterogeneous runtime system. This will be the basis of future collaborations regarding runtime-level approaches for heterogeneous platforms including FPGA.

Joint Laboratory for Extreme-Scale Computing:
Several contacts have been established both with academic partners (mainly University of Illinois Urbana-Champaign and Barcelona Supercomputing Center) and with industry (Xilinx).

Some relevant publications

- Georgios Christodoulis. Adaptation of a HPC system to FPGA. 2016. Presented at the 5th Workshop of the Joint Lab on Exascale Computing (JLESC).
- Olivier Muller. An OpenMP flow targeting HPC systems with FPGA. 2016. Presented at Workshop on FPGAs for Scientific Simulation and Data Analytics.

References

- Cédric Augonnet, Samuel Thibault, Raymond Namyst, and Pierre-André Wacrenier, **StarPU: A Unified Platform for Task Scheduling on Heterogeneous Multicore Architectures,** EUROPAR 2009
- Prost-Boucle A., Muller O., Rousseau F., Fast and Standalone Design Space Exploration for High-Level Synthesis under Resource Constraints, Journal of Systems Architecture (JSA), Volume 60, Issue 1, January 2014, pages 79-93.

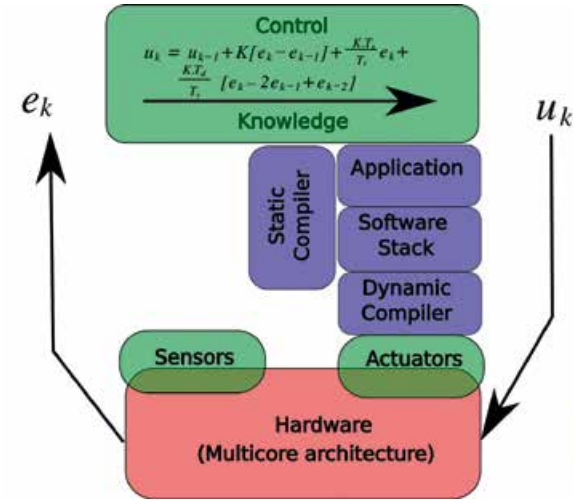
HPES

High Performance Embedded Systems

PCS

The HPES project-team bridges several research domains (Processor Architecture, Compilation, Control Command) to address power consumption for High Performance Embedded Systems in a global way.

Boosting the improvement of the energy performance ratio requires to exploit jointly multicore architectures and the software stack on top of it for code optimization as well as limiting data movements.



The first objective was to make effective a true cross-fertilization by organizing internal meetings and events for cross-cultural teaching, and also by the joint supervision of doctorate and post-doctorate candidates on cross-domain subjects. Such a trans-disciplinary approach has led to a wide variety of results exploiting the interaction between hardware architecture, compilers, applications and the control command theory.

Website: https://persyval-lab.org/en/sites/hpes

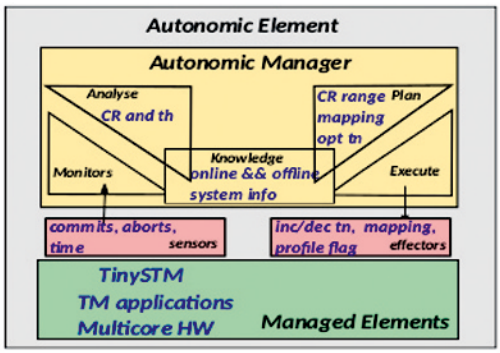
Main Scientific Results and Ongoing Work

Our scientific results cover a broad spectrum ranging from:

- new design of asynchronous system on chips based on AXI bus,
- new data prefetching methods that are more robust to non-uniform memory accesses,
- new control of autonomic parallelism adaptation strategy for software transactional memory,
- software support of global address spaces for distributed memory systems,
- new methodology for performance comparison based on the development of micro-benchmarks,
- code optimization (on GPU, micro controllers, etc) and binary code optimization for Java.

Zoom1: Autonomic Thread Parallelism and Mapping Control for Software Transactional Memory

The Naweiluo Zhou PhD has dealt with autonomic management of thread parallelism and mapping on TinySTM. The main issue addressed in this work is how to identify the trade-off between synchronization and computation among multiple threads and how to reduce thread memory access latency. The underlying scientific approach use control theory in self adaptive system for parallelism.

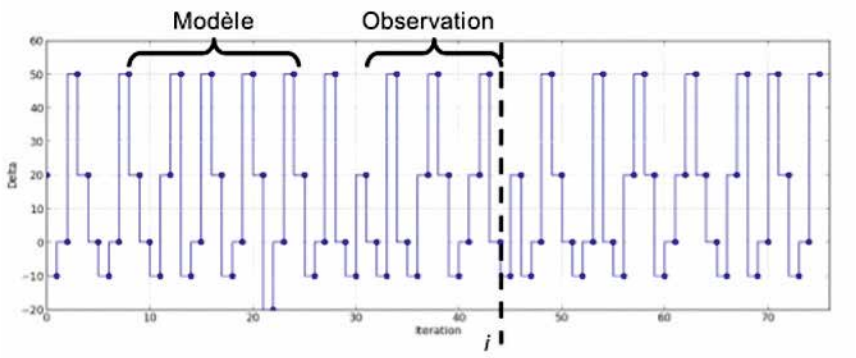


Zoom1: Overview of the feedback control loop used in the Nawailuo's PhD thesis

Coordinators

CEA: Henri-Pierre Charles (LIST), Suzane Lesecq (LETI)
GIPSA-lab: Nicolas Marchand
Inria/LIG: Fabrice Rastello, Jean-François Méhaut
Inria: Eric Rutten
TIMA: Laurent Fesquet, Stéphane Mancini

Zoom 2: Adaptive Data Prefetching for High Performance Processors
In his postdoctorate work, Lionel Vincent has invented a new prefetching mechanism, called **HYP,** based on statistical on-line analysis of access sequences. Hypothesis tests are used to identify complex patterns in the memory access sequence. Metrics are extracted from the statistical procedure to monitor the performance of the prefetcher and to dynamically adapt its parameters. The results obtained with HYP show the adaptive capabilities of the prefetcher. It permits to keep the prediction efficiency high despite the variability of patterns. Experiments have shown an improvement from 25% up to 92%, when compared to the classical SPT. The underlying scientific approach use control theory in self adaptive system for computing architecture.



Valorization

Patent: "Procédé de prédiction d'une donnée à précharger dans une mémoire cache". LESECQ Suzanne, VINCENT Lionel, MANCINI Stéphane, CHARLES Henri-Pierre. (Deposit date: 15/12/2015). Domains: FR- EP, US.

Resulting collaborations:
CIFRE PhD funding with STMicroelectronics on embedded CNN (Convolutional Neural Networks).

New IPL (Inria Projet LAB) project ZEP (ZEro Power computing systems).
https://project.inria.fr/iplzep/fr/news/

New project with JLESC (Joint Laboratory for Extreme Scale Computing).
Using control theory for the regulation of computation w.r.t. energetic and thermal objectives.

Some relevant publications

- Chadi Al Khatib, Claire Aupetit, Cyril Chevalier, Chouki Aktouf, Gilles Sicard, Laurent Fesquet, **"A Generic Clock Controller for Low Power Systems: Experimentation on an AXI Bus",** IFIP/IEEE International Conference on Very Large Scale Integration (VLSI-SoC), October 5-7, 2015, Daejeon, Korea, pp. 307-312.
- Naweiluo Zhou, Gwenaël Delaval, Bogdan Robu, Eric Rutten and Jean-François Méhaut. **"Control of autonomic parallelism adaptation on software transactional memory."** In High Performance Computing & Simulation (HPCS), 2016 International Conference on, pp. 180-187. IEEE, 2016. **(Best paper candidate).**
- Nassim A. Halli, Henri-Pierre Charles and Jean-François Mehaut. **"Performance comparison between Java and JNI for optimal implementation of computational micro-kernels",** ADAPT 2015: The 5th International Workshop on Adaptive Self-tuning Computing Systems, Jan 2015, Amsterdam, Netherlands.
- François Gindraud, Fabrice Rastello, Albert Cohen, François Broquedis. **"A bounded memory allocator for software-defined global address spaces".** ISMM 2016 - 2016 ACM SIGPLAN International Symposium on Memory Management, Jun 2016, Santa Barbara, United States. 2016.
- Venmugil Elango, Naser Sedaghati, Fabrice Rastello, Louis-Noël Pouchet, Jagannathan Ramanujam, et al. **"On Using the Roofline Model with Lower Bounds on Data Movement".** ACM Transactions on Architecture and Code Optimization (TACO), ACM, 2015, 11 (4), pp.67:1 - 67:23.

IoIT

Towards the Internet of Interactive Things: Energy-Efficient Interactive Cyber-Physical Systems

PCS

The Internet of Things (IoT) corresponds to a vision of a world in which billions of objects with embedded intelligence, communication means, and sensing and actuating capabilities will connect over IP (Internet Protocol) networks.

When augmented with a novel user interface, they become Interactive Things with five main properties: they can (i) communicate, (ii) sense physical quantities, (iii) perform actions on the physical world, (iv) execute reasoning or decision making algorithms, and (v) interact with the user. Their potentially large number and communication as well as interaction capabilities open new possibilities to create the Internet of Interactive Things that provides unparalleled means for connecting the physical world with the digital universe. IoIT proposes to make this vision happen by addressing three main challenges:

- Energy-efficient protocols for short-range capillary IoT networks.
- Scalable protocols for long-range cellular IoT networks.
- Novel means for user interaction with Things.

Website: https://persyval-lab.org/en/sites/ioit

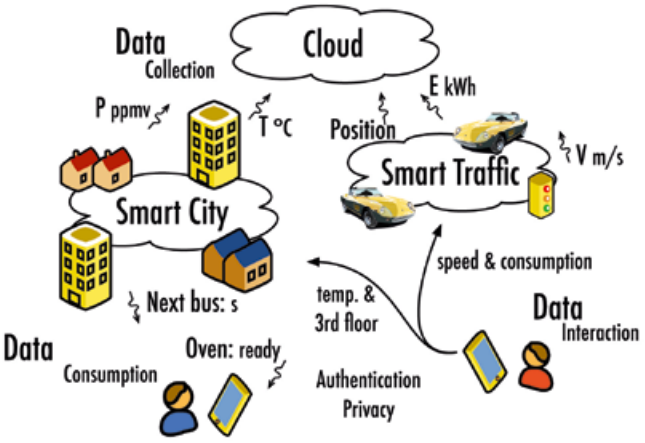
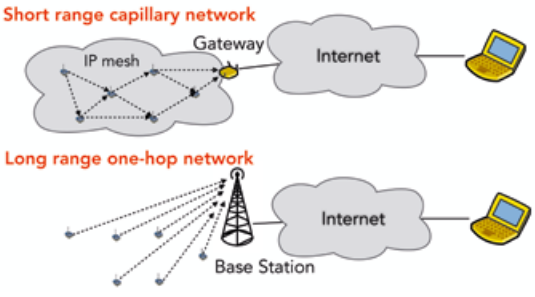


Figure 1: Internet of Interactive Things

Main Scientific Results and Ongoing Work

Comparison of Wireless Networks for IoT:
We have conducted experiments for the comparison of the lifetime that IoT devices may expect from the wireless standards: IEEE 802.15.4e, Bluetooth Low Energy (BLE), IEEE 802.11 Power Saving Mode (PSM), IEEE 802.11ah, and new emerging long-range technologies such as LoRa and SIGFOX. This benchmark of the representative technologies will make the choice of the right solution for a given use case easier.



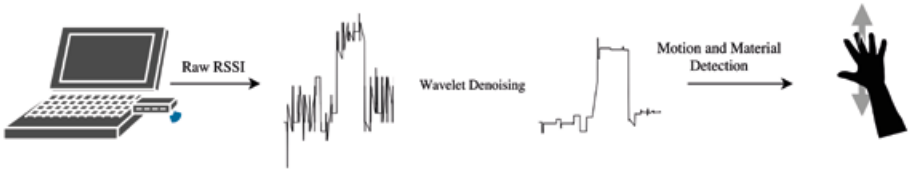
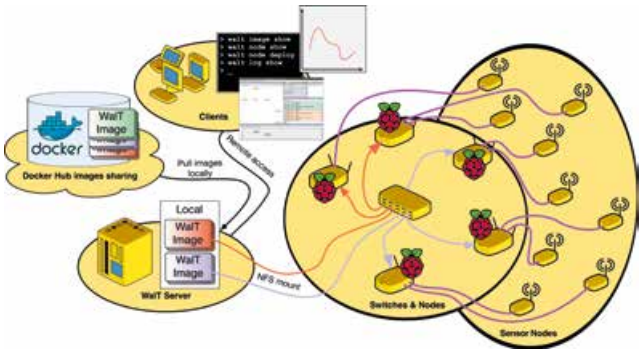


Figure 2: Detecting gestures from wireless signals

Geo-Centric IoT Communications:
We have designed *IP Geocast,* a hierarchical scalable geographical multicast that enables dissemination of data messages to all hosts in a given region.

WalT: a Reproducible Testbed for Reproducible IoT Experiments:
WalT is a reproducible platform to run reproducible experiments based on single-board computers and free software. WalT enables researchers to validate IoT research results in real-world conditions.

Radio-based Interaction Techniques:
We have studied in-air gesture interaction based on wireless signals. We have demonstrated that different materials held by the user while performing a hand gesture influence the Wi-Fi signal in a meaningful way so that it is possible to distinguish between gestures performed with synthetic material, metal dust, and aluminum (Figure 2).



Coordinators

CEA: Michael Maman
LIG: Andrzej Duda (Drakkar team), Céline Coutrix (IIHM team)
VERIMAG: Karine Altisen

Valorization

The research initiated in this project-team has spawned two proposals:

- **TRINITY:** Trusted and Secure Horizontal Interconnection of IoT Enablers and Systems, submitted in April 2017.
- **Use IoT.** A FEDER regional project submitted by a consortium of companies to promote the use of the LoRa technology. Partner involved: LIG-Drakkar.

Some relevant publications

- B. Bonakdarpour, S. Devismes, and F. Petit. **Snap-stabilizing committee coordination.** Journal of Parallel and Distributed Computing, 87:26-42, 2016.
- P. Brunisholz, E. Duble, F. Rousseau, and A. Duda. **WalT: A Reproducible Testbed for Reproducible Network Experiments.** In Proc. of the International Workshop on Computer and Networking Experimental Research Using Testbeds, San Francisco, United States, 2016.
- P. Brunisholz, F. Rousseau, and A. Duda. **DataTweet for User-centric and Geo-centric IoT Communications.** In 2nd Workshop on Experiences in the Design and Implementation of Smart Objects (SmartObjects'16) New-York, USA, pages 146-151, 2016.
- A. Cournier, A. K. Datta, S. Devismes, F. Petit, and V. Villain. **The expressive power of snap-stabilization.** Theoretical Computer Science, 626:40-66, May 2016.
- M. Maman, F. Mani, B. Denis, and R. D'Errico. **Coexistence Evaluation of Multiple Wearable Networks Based on Realistic On-Body and Body-to-Body Channel Models.** In Proc. of the International Symposium on Medical Information and Communication Technology (ISMICT'16), Worcester, USA, 2016.

MicroBayes

Probabilistic Machines for Low-level Sensor Interpretation

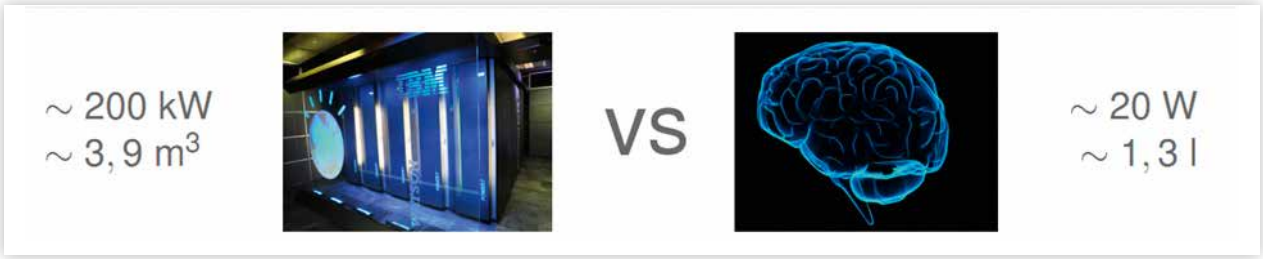
PCS

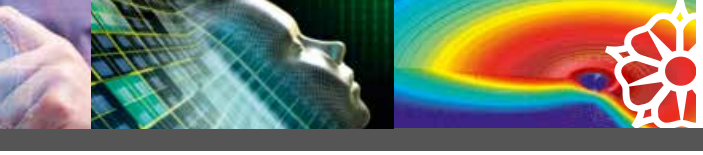
The development of modern computers is mainly based on increase of performances and decrease of size and energy consumption.

This incremental evolution is notable, but it involves no significant modification of the basic principles of computation. In particular, all the components perform deterministic and exact operations on sets of binary signals. These constraints obviously impede further sizable progresses in terms of speed, miniaturization and power consumption. The goal of the MicroBayes project-tem is to investigate a radically different approach to perform computations, namely stochastic computing using stochastic bit streams.

We plan to show that stochastic architectures can outperform standard computers to solve complex inference problems both in terms of execution speed and of power consumption. We will build prototypes of stochastic machines solving the source localization and separation problems found in acoustics.

Website: https://persyval-lab.org/en/sites/content/microbayes





Main Scientific Results and Ongoing Work

The MicroBayes project-team is in the continuation of the European project Bambi (Bottom-up Approaches to Machines dedicated to Bayesian Inference). We have obtained in simulation encouraging results with stochastic machines designed to sample posterior distributions at a very high rate with minimal hardware. More precisely, given a localization problem with 6 sensors, a stochastic machine could produce enough samples to estimate the position given the sensor readings with a precision bellow 2% in a single clock cycle with a minimal power requirement.

A second machine, based on the Gibbs sampling algorithm, was designed to approximate solutions to intractable inference problems. In a starting PhD work, we are investigating a new class of Metropolis algorithm allowing programming the exploration strategy (how to select a new trial sample). The idea is to specify generating sets of the group of isomorphism on the search space to define the search strategies. The goal of this Phd is to synthesize a stochastic machine based on this new principle for an FPGA and to test an experimental setup on two practical inference problems of increasing complexity: the sound localization and the source separation problems.

Coordinators

GIPSA-lab: Laurent Girin
Institut Fourier: Didier Piau
LIG: Emmanuel Mazer
TIMA: Laurent Fesquet

Valorization

The goal of the MicroBayes project-team is to patent architectures and to serve as a basis for the creation of a startup dedicated to the design of stochastic processors.

MICRO BAYES
Rebooting computing

Some relevant publications

- Coninx, A., Bessière, P., and Droulez, J. (2016). **Quick and energy-efficient bayesian computing of binocular disparity using stochastic digital signals.** *International Journal of Approximate Reasoning.*
- Faix, M., Laurent, R., Bessière, P., Mazer, E., and Droulez, J. (2016). **Design of stochastic machines dedicated to approximate bayesian inferences.** *IEEE Transactions on Emerging Topics in Computing* (ISSN: 2168-6750).
- Friedman, J. S., Calvet, L. E., Bessière, P., Droulez, J., and Querlioz, D. (2016). **Bayesian Inference With Muller C-Elements.** *IEEE Transactions on Circuits and Systems,* 63(6):895-904.

SCCyPhy

Security and Cryptology for CyberPhysical Systems

PCS

The main core of this project-team is the analysis, the design and implementation of efficient and certified cryptographic components, security protocols and privacy components, in both hardware and software, for cyber-physical systems vulnerable to various types of attacks or privacy issues with a “secure by design” or “privacy by design” approach.

We also propose to develop a common framework for the protection of software and hardware components and their interaction. The objective is to focus on the complementary protections against various attacks with the goal to give an overall assessment of an embedded application on a secure or privacy component and more generally on cyber-physical components. Due to our various expertises, this trans-disciplinary project-team offers the ideal structure to work on such research with the goal to be a main player in the European landscape.

Website: https://sccyphy.persyval-lab.org/

Main Scientific Results and Ongoing Work

We have obtained a variety of results ranging from:

- the design and cryptanalysis of cryptographic FPGA components based on fast and robust elliptic curve cryptography, with proposal of new arithmetic implementations [1] and new SPA (Simple Power Analysis) attack [2]
- the privacy analysis of widespread methods (based on Bloom filters) with striking results [4,5]. In particular, we have developed a new framework for the modelisation of attackers on Bloom filters and shown vulnerabilities in several software [4]. Our study [5] has also shown that the “Safe Browsing” service of Google had several privacy vulnerabilities which can be used for tracking internet users. This work has forced Google to recently modify the privacy policies in “Google Safe Browsing”,
- solutions to preserve privacy and/or confidentiality of outsourced data using homomorphic encryption. Even if practical implementation of fully homomorphic schemes is still further away, using FPGA [3] we have shown that we can speed-up modular polynomials multiplications used in Ring-LWE (one of the main homomorphic scheme) by a factor of 20 with respect to the best software implementation on high-end CPUs and 3 times faster than previous hardware implementations. Our method also shows enough room for further improvements,
- new techniques [6] based on hidden Markov chains for the evaluation of randomness with the capabilities to identify specific patterns produced by a given non-deterministic random bit generators. Further work on this topic is underway with the aim that such techniques can be integrated in new standards.
- a end-to-end methodology for the evaluation of code robustness in presence of fault injection has been designed. We have proposed a way to characterize probabilistic fault models associated to physical attacks and metrics based on code evaluation, in concordance with a Common Criteria demarch.

Valorization

The project team SCCyPhy has boosted the visibility of the cybersecurity community from Grenoble, with the following resulting collaborations and actions of leadership.

Industrial collaborations:

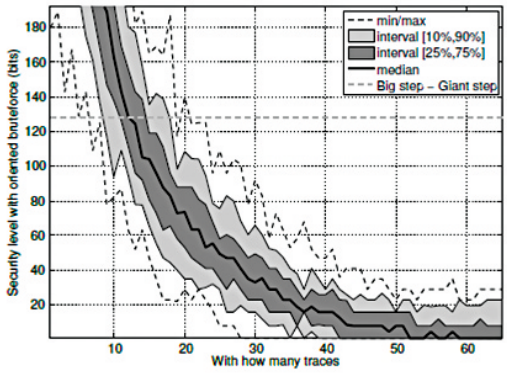
- The project-team is part of the consortium ARAMIS (Robust Architecture for Critical Industrial Control System Infrastructure), led by Atos Worldgrid, selected as a world-class R&D initiative by the French government programme called “Investments for the Future”. It involves the development of an innovative system capable of bringing an unrivalled level of security to existing or new industrial control system architectures. The innovation consists of physically partitioning networks and filtering data exchanges to reject all data flows identified as unauthorised and, thus, potentially malicious. The ARAMIS consortium is composed by key players with a unique expertise in industrial control systems and cybersecurity.
- We are also part of the new Cybersecurity research axis from the IRT Nanoelec of the CEA.

Actions of leadership:

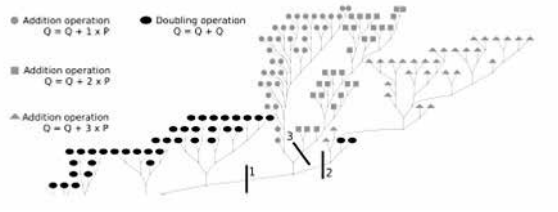
- SCCyPhy is involved in the French RESSI (“Rendez-vous de la Recherche et de l’Enseignement en Sécurité des Systèmes d’Information”) network of academics in cybersecurity and in charge of organizing the RESSI 2017 event.
- SCCyPhy is also present in the rising french Cybersecurity network of the CNRS (pre-GDR “Sécurité informatique”), as well as in the Allistene (“Alliance des Sciences et Technologies du Numérique”) network.

Coordinators

CEA: Jessy Clédière
Inria: Claude Castellucia
Institut Fourier: Philippe Elbaz-Vincent (contact)
TIMA: Régis Leveugle



Bruteforce attack complexity oriented by our power analysis attack with respect to the number of traces (40 attacks against 4 different 256-bit Jacobi quartic curves)



Attack against the m-ary algorithm used in Elliptic Curve Cryptography

Some relevant publications

- Marie-Angela Cornelie; **Implantations et protections de mécanismes cryptographiques logiciels et matériels,** PhD thesis Univ. Grenoble Alpes, April 2016 (https://tel.archives-ouvertes.fr/tel-01377372v1).
- Simon Pontié; **Sécurisation matérielle pour la cryptographie à base de courbes elliptiques,** PhD thesis Univ. Grenoble Alpes, November 2016 (http://tima.imag.fr/publications/files/th/2016/smc_0445.pdf).
- C. Jayet-Griffon, M.-A. Cornelie, P. Maistri, Ph. Elbaz-Vincent, R. Leveugle; **Polynomial multipliers for fully homomorphic encryption on FPGA,** IEEE ReConfig 2015.
- T. Gerbet, A. Kumar, and C. Lauradoux; **The Power of Evil Choices in Bloom Filters,** IEEE/IFIP 45th International Conference on Dependable Systems and Networks (DSN 2015).
- T. Gerbet, A. Kumar, and C. Lauradoux; **A Privacy Analysis of Google and Yandex Safe Browsing,** IEEE/IFIP 46th International Conference on Dependable Systems and Networks (DSN 2016).
- Kevin Layat; **Modélisation et validation des générateurs de nombres aléatoires cryptographiques pour les systèmes embarqués,** PhD thesis Univ. Grenoble Alpes, December 2015 (https://tel.archives-ouvertes.fr/tel-01271983).

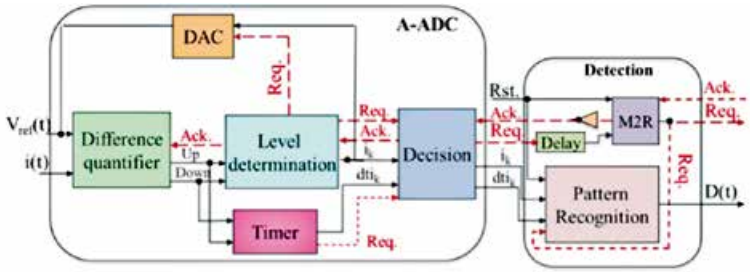
CEE Control and Event-Based Sampling

Coordinators

GIPSA-lab:
Christophe Prieur
Inria: Bernard Brogliato
LJK: Brigitte Bidegaray
TIMA: Laurent Fesquet

The goal is to define new strategies adapted to low consumption to guarantee that a controlled system can exploit non uniform sampling in order to minimize the energy while keeping the control features, namely robustness, precision and stability. The challenges we had to overcome are therefore numerous: filtering algorithms (correctors), controlled systems with non uniform sampling, hardware implementation, choice of an adapted architecture (match between algorithms/architecture/technology), design of a systems with an asynchronous controller, evaluation of the performances in terms of precision and consumption.

Website: http://persyval-lab.org/en/exploratory-project/CEE



Results

We have developed a novel approach for the design of an asynchronous circuit (see the Figure below) for predefined pattern recognition in physiological signals, with a gain of two orders of magnitude compared to uniform processing.
We have also contributed to statistical study of compression for signal with known Hölder regularity, and we have used convex analysis tools and the theory of Lyapunov functions for the simulation of an observer for dynamical systems with impacts. This exploratory project has been continued within the project team E-BaCCuSS.

Some relevant publications

- B. Bidegaray-Fesquet and M. Clausel, Data driven sampling of oscillating signals, Sampling Theory in Signal and Image Processing, 13(2):175-187, 2014.
- L. Fesquet, T. Le Pelleter, A. Darwish, T. Beyrouthy, and B. Bidegaray-Fesquet. Mitigating the data deluge by an adequate sampling for low-power systems, ICCHA5 - Proceedings of 5th International Conference on Computational Harmonic Analysis, 2014.
- A. Darwish, G. Sicard, and L. Fesquet, Low data rate architecture for smart image sensor, Proceedings of Image Sensors and Imaging Systems, Feb 2014.
- A. Tanwani, B. Brogliato, and C. Prieur, On output regulation in systems with differential variational inequalities, IEEE Conf. on Dec. and Cont. (CDC'14), 2014.
- A. Tanwani, B. Brogliato, and C. Prieur, Stability and Observer Design for Lur'e Systems with Multivalued, Non-monotone, Time-Varying Nonlinearities and State Jumps, SIAM J. Control Opt., vol. 52, 2014.

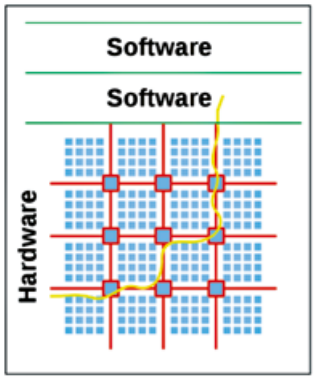
CESyMPA Critical Embedded Systems on Multiprocessor Architectures: Towards a Certifiable HW/SW Solution

Coordinators

TIMA: Stéphane Mancini
VERIMAG:
Florence Maraninchi

Following previous work on hardware design, and critical software design and implementation, we study several approaches for the use of modern hardware architectures including many-core architectures, in critical contexts requiring predictability.

Website: http://www-verimag.imag.fr/PROJECTS/SYNCHRONE/CESYMPA/



Results

We have developed a holistic view of hardware and software for a correct-by-construction compilation chain guaranteeing determinism and predictability.
In particular, we have contributed to more intrinsically predictable hardware elements, and to memory hierarchy for critical real-time systems. CESyMPA has allowed to launch new ambitious projects and collaborations, and has resulted in the CAPACITES collaborative project, studying time-critical applications on Kalray's many-core architecture, a CIFRE collaboration with Kalray on the topic of code generation from synchronous languages for Kalray's architecture, and a CIFRE collaboration with Airbus Helicopter, on the implementation of an embedded application on Kalray's architecture.

Some relevant publications

- Rihani, Hamza and Moy, Matthieu and Maiza, Claire and Davis, Robert I. and Altmeyer, Sebastian. Response Time Analysis of Synchronous Data Flow Programs on a Many-Core Processor. In Proceedings of RNTS 2016.
- Rihani, Hamza and Moy, Matthieu and Maiza, Claire and Altmeyer, Sebastian. WCET analysis in shared resources real-time systems with TDMA buses. In Proc. RNTS 2015.
- Moustapha Lo, Nicolas Valot, Florence Maraninchi, Pascal Raymond. Implementing a Real-Time Avionic Application on a Many-Core Processor. 42nd European Rotorcraft Forum.
- Lionel Vincent, Stéphane Mancini. Closed-loop adaptive and stochastic prefetch mechanism for data array. In DASIP 2014.
- Lionel Vincent, Stéphane Mancini, Suzanne Lesecq, Henri-Pierre Charles. Model Free Adaptive Data Prefetching using Hypothesis Tests. DAC Conference 2016, Work-In-Progress Session.

STAARS Control Techniques for Autonomic, Adaptive and Reconfigurable Computing Systems

Our objective is to build methods and tools for the design of safe controllers for autonomic, adaptive, reconfigurable computing systems. To attain this goal, we propose to combine Computer Science and Control Theory, at the levels of systems infrastructures, programming support, and modeling and control techniques. Particularly, we explore the relationship between the autonomic computing MAPE-K loop and the continuous and discrete control loops.

Website: http://persyval-lab.org/en/exploratory-project/staars

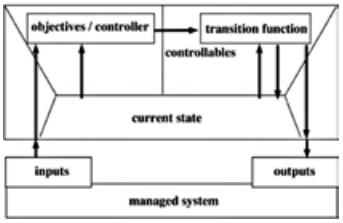
Results

We have identified research topics in collaboration between control theorists and computer scientists. For example, we have proposed a Master internship on the topic of integrating probabilistic choice between solutions of a maximally permissive discrete controller. Other topics include exploring the notion of adaptive discrete control, or identifying control problems in resource management of multi-tier data-centers, or High Performance Computing systems.

We have animated the local community on this multi-disciplinary topic, and have had seminars on topics in control models, programming languages, and adaptive computing infrastructures: interested researchers in Grenoble in Rhône-Alpes can present their work and exchange ideas. These seminars are at a monthly rate or more often. We have organized two workshops on the state of the art in autonomic computing and control, with invited speakers from France and Europe. This project has helped to set up several ANR submissions. The ANR project HPeC (http://hpec.fr/) concerns High Performance embedded Computing: we consider Reconfigurable architectures, based on dynamically partially reconfigurable FPGA, for Autonomous Systems, with a UAV Case Study. We particularly work on the control of reconfigurations, in a layered autonomic loops approach.

Coordinators

GIPSA-lab: Nicolas Marchand
Inria: Eric Rutten
LIG: Gwenael Delaval



Some relevant publications

- Eric Rutten, Nicolas Marchand, Daniel Simon. In R. de Lemos; D. Garlan; C. Ghezzi; H. Giese. Feedback Control as MAPE-K loop in Autonomic Computing. Software Engineering for Self-Adaptive Systems 3: Assurances, Springer, 2016.
- Marin Litoiu, Mary Shaw, Gabriel Tamura, Norha M. Villegas, Hausi Müller, Holger Giese, Eric Rutten, Romain Rouvoy. What Can Control Theory Teach Us About Assurances in Self-Adaptive Software Systems? Software Engineering for Self-Adaptive Systems 3: Assurances, Springer, 2016.

DACRAW Distributed Approach for Cross-Layer Resource Allocation in Wireless Sensor Networks

Wireless Sensor Networks (WSNs) constitute one of the major enabling technologies for the development of the Internet of Things. IEEE 802.15.4e defines TSCH, a new MAC (Medium Access Control) which focuses on ultra-low-power and high reliability, targeting industrial applications. TSCH is named upon its two key principles: Time Slotted operations and Channel Hopping. Our main objective is to provide the means to operate a WSN with TSCH in a fully distributed manner, focusing on MAC and routing.

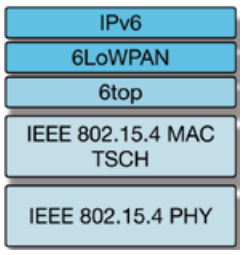
Website: http://drakkar.imag.fr/dacraw

Results

Compute and allocate global schedules of cells that guarantee required properties in a distributed way. Compute suitable paths with a distributed routing algorithm on which to build the aforementioned schedules. Perform neighbor maintenance to discover new nodes and maintain connectivity with nodes of interest, on which we can rely to provide efficient routing.

We have proposed two TSCH slot reservation schemes based on distributed algorithms that are implemented in the 6TiSCH simulator. This project gave us the opportunity to start a fruitful close collaboration through several student internships and master projects that is still very active. Several publications are underway on these aspects.

Also, DACRAW gave birth to the project-team Persyval IoIT: Towards the Internet of Interactive Things Energy-Efficient Interactive Cyber-Physical Systems, integrating new partners: CEA-Leti and LIG-EHCI.



Coordinators

LIG: Olivier Alphand, Franck Rousseau, Bernard Tourancheau
VERIMAG: Karine Altisen, Stéphane Devismes

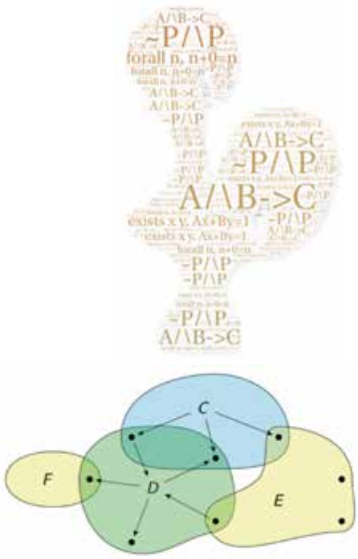
Some relevant publications

- Karine Altisen, Stéphane Devismes, Anaïs Durand, Franck Petit. Gradual Stabilization under τ-Dynamics, Europar 2016, Aug 2016, Grenoble, France.
- Karine Altisen, Stéphane Devismes, Anaïs Durand. Concurrency in Snap-Stabilizing Local Resource Allocation, Journal of Parallel and Distributed Computing, Elsevier, 2016.
- Karine Altisen, Alain Cournier, Stéphane Devismes, Anaïs Durand, Franck Petit. Self-Stabilizing Leader Election in Polynomial Steps, SSS'2014, Sep 2014, Paderborn, Germany. Springer, 8756, pp.106-119, 2014, Lecture Notes in Computer Science.
- Michał Król, Franck Rousseau, Andrzej Duda. Représentation compacte des adresses pour le routage par caractéristiques. AlgoTel 2014, Le Bois-Plage-en-Ré, France, juin 2014.
- Iacob Juc, Olivier Alphand, Roberto Guizzetti, Michel Favre, Andrzej Duda. Energy Consumption and Performance of IEEE 802.15.4e TSCH and DSME, Proc. of the IEEE Wireless Communications and Networking Conference (WCNC), Apr 2016, Doha, Qatar.

CTRC Certified and Configurable Real-Time Components

Coordinators

Inria: Alain Girault
VERIMAG: Susan Graf



The goal of CTRC is the formalization of a certified tool chain for the design and analysis of component-based, reconfigurable, and multi-viewed embedded systems. The typical applications that we consider are found in modern real-time systems such as embedded electronics in cars. Real-time systems embedded in autonomous vehicles do need guarantees that adapt to several modes and configurations of the car. These systems share several key characteristics: they must react under strict real-time constraints, they must be highly reliable and fault-tolerant, their power consumption must remain within strict bounds. These characteristics are those of what we call multi-view systems. Another facet is their complexity, which arises from their size, from their functional complexity, and their heterogeneity. This calls for component-based design and analysis methods. For these reasons, we advocate the use of formal methods and of certification, e.g., using the COQ proof assistant. Despite numerous advances of the formal methods community in that domain, it is still a challenge to guarantee the correctness of complex embedded systems which have to obey simultaneously multiple types of constraints, such as functionality, safety, security, resource usage, reconfigurability.

Website: http://project.inria.fr/ctrc

Results

In a master internship focused on the so-called general event load model, we have formalized activation patterns of software tasks and proved the correctness of the functions used to switch from the time-based view to the event-based view (and conversely) in COQ. This work [1] provides the formal background needed to compare schedulability results based on the general event load model with results based on other activation models.
We have invited a number of renowned researchers and young academics to give talks in Grenoble. These seminars have triggered many interesting discussions on the core topics of CTRC. They have allowed us to build a collaboration with partners in Germany (Björn Brandenburg from MPI-SWS in Kaiserslautern) and Toulouse (Marc Boyer from Onera) on formal proofs for the analysis of real-time systems. It has also permitted to set up the CASERM project-team that has just started.

Selected publication

- Lina Marsso. Formal Proofs for an Activation Model of Real-Time Systems. Master's thesis, University of Grenoble, France, 2016.

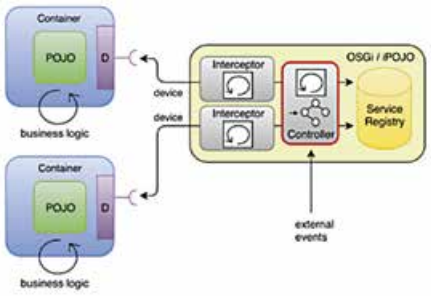
CASE Control techniques for Autonomic Smart Environments

Coordinators

GIPSA-lab:
Stéphane Mocanu
LIG: Vincent Lestideau

The project aims at relating discrete and stochastic control models with middleware platforms applied to smart environments.

Website: http://persyval-lab.org/en/exploratory-project/CASE



Results

In a master internship [1], we have investigated a service-oriented approach to smart home applications control with reactive programming. We have used reactive control models with events and states to coordinate autonomic loops in service-oriented architectures. In Figure 1, we illustrate our approach by integrating a controller based on discrete controller synthesis in an autonomic pervasive environment. The role of the controller is to influence the service-binding criteria of multiple control loops, while respecting logical constraints. In particular, we consider reconfiguration operations of known and dynamic service sets.
In another master internship [2], we have studied the problem of multi-objective optimal reconfiguration of a smart home platform, in which automation devices are connected through a wireless communication protocol, Z-Wave, and controlled by a central controller, USB plug in. This involves methods and tools to design fail-safe controllers for autonomic, adaptive, reconfigurable computing systems by combining Computer Science and Control Theory techniques. For this purpose, it is necessary to access required information over the network, derive out a simplified model of the physical network, and then link it to the User interface application. According to the information achieved, there will be an estimation of the network diagnostics to find some probable solutions for. The final application is in a user media to do installing, maintaining or even optimizing the network and devices.

Some relevant publications

- Armando Ochoa. A service-oriented approach to smart home applications control with reactive programming. Master's Thesis, UGA, Grenoble, France, 2016.
- Ronak Feizimirkhani. Multi Objective Optimal Reconfiguration of a Smart Home Platform. Master's Thesis, UGA, Grenoble, France, 2016.

AEPS Efficient SDP Algorithms for Uncertain Optimization

Many engineering applications (wireless telecommunications, roundoff error analysis) require to solve optimization problems involving a certain degree of uncertainty, either deterministic or stochastic. The aim of this project is to handle such problems by developping, analyzing and applying optimization frameworks based on semidefinite programming (SDP) relaxations.

Website: http://www-verimag.imag.fr/~magron/projects/aeps/index.html

Results

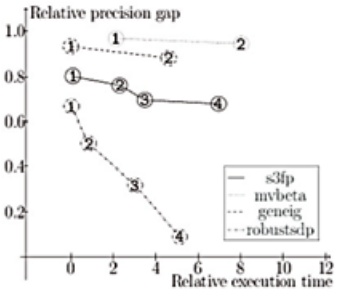
A longstanding problem related to floating-point implementation of numerical programs is to provide efficient yet precise analysis of output errors by solving deterministic uncertain optimization problems. We developed a framework based on semidefinite programming (SDP) relaxations to compute either lower or upper bounds of absolute roundoff errors for certain class of numerical programs. We developed a lower bound framework called "robustsdp" implemented in a software package called FPSDP (github.com/magronv/fpsd). The figure shows how our method compares with others w.r.t. performance (x-axis) and accuracy (y-axis).

We developed an upper bound framework and released two software package called FPBern (github.com/roccaa/FPBern) and FPKriSten (github.com/roccaa/FPKriSten).

An ongoing work aims at doing numerical comparison of average performance obtained while optimizing strongly convex functions with stochastic gradient descent (SGD and mirror descent (MD) algorithms. These numerical results will be obtained through implementation of a practical software package. Furthermore, we propose to analyse the average-case complexity of SGD and MD algorithms. An application of interest is to estimate the efficiency of the MD like algorithm developed by Gaujal and Mertikopoulos to handle stochastic SDP.

Coordinators

Inria/LIG: Bruno Gaujal
VERIMAG: Victor Magron



Some relevant publications

- Victor Magron and Mountassir Farid. Certified Lower Bounds of Roundoff Errors using Semidefinite Programming, submitted to Transactions on Mathematical Software, 2016. preprint available at arxiv.org/abs/1611.01318.
- Alexandre Rocca, Victor Magron, and Thao Dang. Certified Roundoff Error Bounds using Bernstein Expansions and Sparse Krivine-Stengle Representations, submitted to the 24th IEEE Symposium on Computer Arithmetic, 2017, preprint available at arxiv.org/abs/1610.07038.
- Josu Doncel, Nicolas Gast, Bruno Gaujal. A Mean-Field Game Analysis of SIR Dynamics with Vaccination. Submitted to Operations Research Letters, 2016.

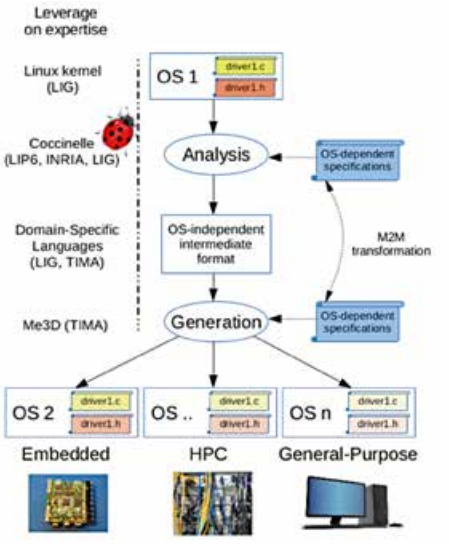
ADP2 Automated Porting of Device Drivers

The device drivers are the main cause of operating system (OS) crashes. However, the overall quality of drivers is quickly improving in Linux. Moreover, Linux has the largest number of supported devices, and these devices are supported until "no user can be found". This project aims to propose an OS-independent implementation of the device drivers, making easier the building of new versions for different OSes. Linux drivers are used as a repository of drivers to extract an OS-independent version. To do so, the extraction process is based on a description of the internal OS API. Then, thanks to the description of another internal API (for a different version of the OS or another OS), the goal is to retarget the OS-independent driver version.

Website: http://lig-membres.imag.fr/palix/research/apd2/

Results

We have defined the internal APIs of Linux involved in the driver code of the selected devices. These internal APIs are described for a particular version. In the case of network devices, the API of the network subsystem is involved, as is the power management API, the memory management API, and the packet management API, among others. As a first step, we study the case of backporting where at least one of this API is different.



Coordinators

LIG: Nicolas Palix
TIMA: Frédéric Rousseau

Some relevant publications

- Hui Chen, Guillaume Godet-Bar, Frédéric Rousseau, and Frédéric Pétrot, Device driver generation targeting multiple operating systems using a model-driven methodology. RSP 2014
- Nicolas Palix, Gael Thomas, Suman Saha, Christophe Calves, Gilles Muller, and Julia Lawall. Faults in linux 2.6. ACM Transactions on Computer Systems (TOCS), 32(2):4, 2014

EDATE Differential Equations: Theoretical and Effective Aspects

Coordinators

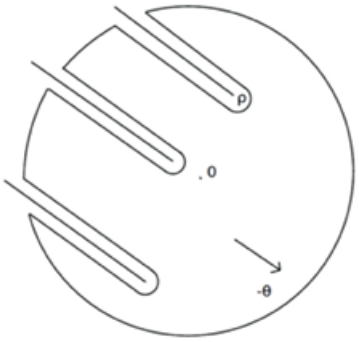
Institut Fourier:
Tanguy Rivoal,
Julien Roques
LJK: Françoise Jung

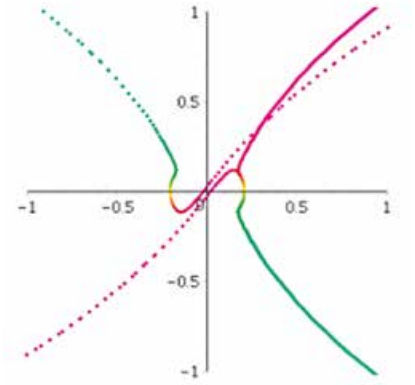
Differential equations are central objects in physics and mathematics. Their theory has multiple facets, making a highly transversal domain, with many different technics. Transversality is at the heart of the project which deals with the effective/algorithmic aspect as well as the theoretical aspect, and the interaction between both.

Website: http://edate2017.sciencesconf.org/

Results

We have made contributions to the following points: Computations of Stokes, monodromy and connection matrices, Computations of differential Galois groups, Effective aspects of p-adic differential equations, Arithmetic and algorithmic properties of values of special functions, in particular *G*-functions and *E*-functions.





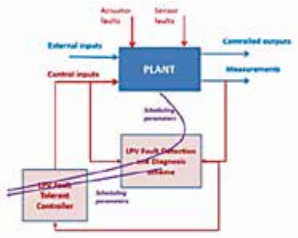
Some relevant publications

- F. Richard-Jung, J.-P. Ramis, J. Thomann and F. Fauvet, New Characterizations for the Eigenvalues of the Prolate Spheroidal Wave Equation, Studies in Applied Mathematics, volume 138, issue 1, January 2017 (pages 3-42).
- Stéphane Fischler and Tanguy Rivoal, *Values of globally bounded G-functions* (2016), preprint, 10 pages.
- Julien Roques. An introduction to difference Galois theory, CRM Series in Mathematical Physics, (2016), 28 pp, to appear.
- Thomas Dreyfus, Jacques-Arthur Weil, Computing the Lie algebra of the differential Galois group: the reducible case (2016), preprint.

LPV4FTC A Linear Parameter Varying approach for Fault Tolerant Control design

Coordinators

GIPSA-lab:
Olivier Sename



The project's objective is to propose a Linear Parameter Varying (LPV) approach to develop an integrated Fault Detection and Diagnosis/Fault Tolerant Control scheme for dynamical systems, following the scheme and to apply it to a Grenoble existing mechatronic testbed, as seen below. The LPV framework is considered as the unified target to synthesize controllers that will be automatically reconfigured in case of the occurrence of actuators and/or sensors degradation/faults. This includes modelling, observer and control design, fault-scheduling.

Website: http://www.gipsa-lab.fr/projet/LPV4FTC/

Results

This project has allowed to reinforce collaborations with CRAN (Nancy) and MTA SZTAKI (Budapest). We have studied the testbed possibilities to do faulty experiments and renew of sensor faults for damper performance evaluation. We have designed several fault estimation algorithms and proposed a LPV fault tolerant control scheme for semi-active suspension control subject to a damper loss of efficiency.
In the setting of 3 co-supervised master projects, we work on a complete definition of the mechatronic benchmark for LPV4FTC project validation and the integration of fault estimation and fault tolerant control algorithms. We plan to design a single estimation-control approach, and to conduct validation and comparison of several approaches.

Some relevant publications

- Juan C. Tudón-Martínez, Sébastien Varrier, Ruben Morales-Menendez, Olivier Sename, Control Tolerante a Fallas en una Suspensión Automotriz Semi-Activa, Revista Iberoamericana de Automática e Informática Industrial RIAI, Volume 13, Issue 1.
- Farhat and D. Koenig. Generalized Luenberger observers for fault detection in switched systems using H-index, 2016 European Control Conference (ECC), Aalborg, Denmark, 2016,
- M.Q. Nguyen, O. Sename, L. Dugard, An LPV Fault Tolerant control for semi-active suspension - scheduled by fault estimation, IFAC-PapersOnLine, Volume 48, Issue 21, 2015.
- M.Q. Nguyen, O. Sename, L. Dugard, A switched LPV observer for actuator fault estimation, IFAC-PapersOnLine, Volume 48, Issue 26, 2015.

BEREKMERI, Mihaly, GIPSA-lab, LIG / BOUCHENAK, Sara, LIG
BOGDAN, Robu, GIPSA-lab / MARCHAND, Nicolas, GIPSA-lab

I. Context and problem statement.

Problem:

Big Data, Big Problems

Vast amounts of data generated daily. We generate more data in one day - 9.6 exabytes - than the past 5000 years combined up to 2003 - 5 exabytes of data.

How do we store the data?
How do we process it?

One of the most popular approaches to processing all this data is the **programming model** called **MapReduce**.
It automatically takes care of:

➢ data partitioning, replication, data consistency, load balancing, fault tolerance, task distribution and scheduling

Challenges:

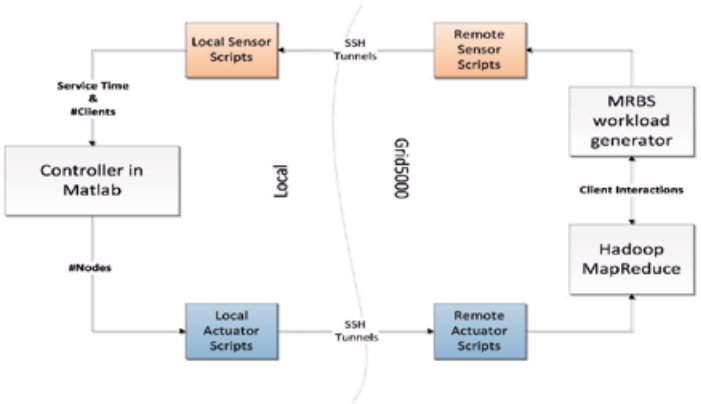
➢ difficult to provision for MR, when faced with a changing workload

➢ complex architecture, many points of contention: CPU, IO, network skews, failures, node homogeneity problems

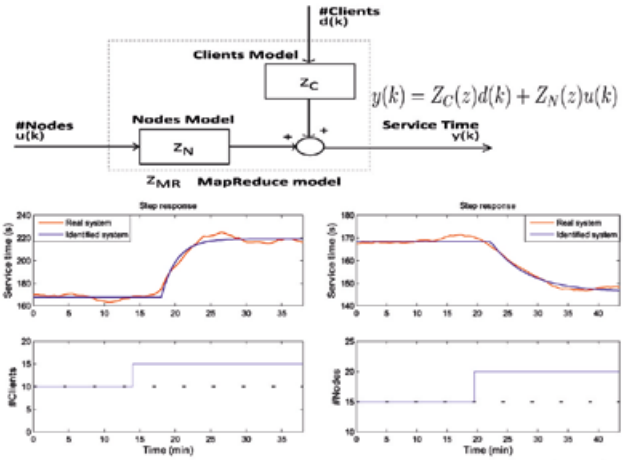
How do we ensure performance, dependability objectives for MapReduce systems?

We take a control theoretical approach to answering these challenges.

II. The experimental setup built

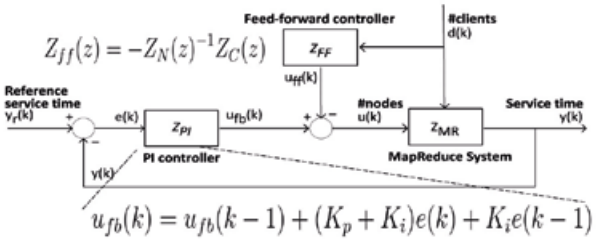


III. Our MapReduce performance model



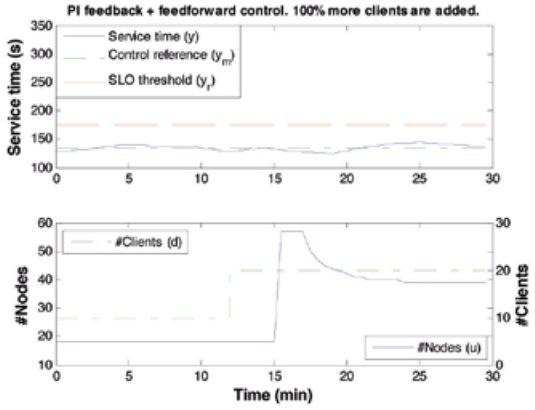
$$Z_C(z) = z^{-8}\frac{1.0716(z+1)}{z-0.7915} \qquad Z_N(z) = z^{-5}\frac{-0.17951(z+1)}{z-0.919}$$

IV. Controlling MapReduce performance



$$u_{fb}(k) = u_{fb}(k-1) + (K_p + K_i)e(k) + K_i e(k-1)$$

V. Experimental results



We've developed the first dynamic performance model for a Big Data MapReduce system, running a concurrent workload and implemented several control strategies. Our approach was validated online on a real 40 node MapReduce cluster, running a data intensive Business Intelligence workload. Our experiments demonstrate the success of the control strategies employed in assuring service time constraints. Furthermore we plan to add new metrics (availability, throughput) to our model, to propose different control strategies for specific workloads and test them in different cloud environments.

MODELING AND VALIDATION OF RANDOM GENERATORS FOR EMBEDDED SYSTEMS

Kévin LAYAT - Institut Fourier
Philippe ELBAZ-VINCENT - Institut Fourier, Cécile DUMAS - CEA-Leti

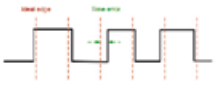
Introduction

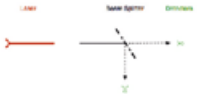
Where can we find randomness?

- Video games, casinos.
- Numerical simulations.
- Cryptography:
  - Key generation.
  - Indistinguability.
  - ...

How to produce random numbers?

- Deterministic generators: Seed + Algorithm.
- Non deterministic generators: physical sources.
  - Jitter / Phase noise.
  - Metastability.
  - Quantum properties.





Evaluation process

Statistical tests

General process (example of Monobit FIPS 140-2):

- We issue an hypothesis $\mathcal{H}_0$ on the model of the source $b_1, \dots b_n$.
  → $\mathcal{H}_0$: (b_i) are random variable (r.v.) independent identically distributed (i.id.) following the Bernouilli distribution with parameter $\frac{1}{2}$.
- We build the statistic of the test $f(b_1, \dots, b_n)$.
  → $f(b_1, \dots, b_{20000}) = \sum_{i=1}^{20000} b_i$.
- We compute the theoretical distribution of the source under the hypothesis $\mathcal{H}_0$.
  → Under $\mathcal{H}_0$ the statistic follows the binomial distribution with parameter $(20000, \frac{1}{2})$.
- We define a decision rule to decide if a sequence fails or passes the test (rejection area, p-value, goodness-of-fit test).
  → Acceptance area: $[9725, 10275]$.

Differentiation problems

Example of 4 sequences with different statistical properties:

Sequence	Pattern				Bias	Dependence	Monobit
	00	01	10	11			
Ex 1	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	0%	No	Pass
Ex 2	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	0%	Yes	Pass
Ex 3	$\frac{1}{9}$	$\frac{2}{9}$	$\frac{2}{9}$	$\frac{4}{9}$	66,6%	No	Fail
Ex 4	$\frac{1}{9}$	$\frac{3}{9}$	$\frac{1}{9}$	$\frac{4}{9}$	66,6%	Yes	Fail

Review :

- Example 2 passes the Monobit test while pattern frequencies are not uniform.
- Examples 3 and 4 fail for different reasons but there is no differentiation in the results of the test.

Adjustments

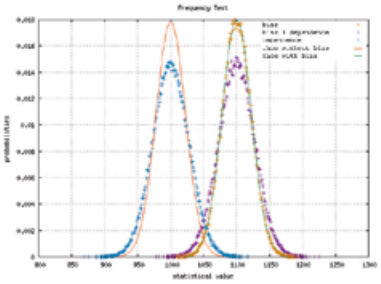
Classical Monobit

- $\mathcal{H}_0$: (b_i) are r.v. i.id $\sim \text{Ber}(\frac{1}{2})$.
- Statistic: $\sum_{i=1}^{20000} b_i$.
- Theory: Binomial $(20000, \frac{1}{2})$.
- Decision: Acceptance region.

Adjusted Monobit

- $\mathcal{H}_0$: (b_i) are r.v. i.id $\sim \text{Ber}(p)$, $p \in [0, 1]$.
- Statistic: $\sum_{i=1}^{20000} b_i$.
- Theory: Binomial $(20000, p)$.
- Decision: Goodness-of-fit test (based on red/green curve depending on the bias).

Results of the adapted test (sequences have the same properties than previously).



Review of adjustments:

- The blue sequence does not have bias but dependance. The test detects it and the sequence fails.
- The orange sequence has bias (taken into account by the test) but the theoretical curve for this bias (in green) matches and the sequence passes the test.
- The purple sequence has bias and dependance. It fails the test that detects both anomalies.

Modeling and certification

The **i.id Model:** is ideal for evaluation (a lot of statistics and convergence theorems) but is it realistic in the case of physical sources (with influence of temperature, magnetic fields, ...)?

Example of other models: Markov chains, Markov processes or brownian motion and Wiener processes.

Starting from a physical source, we want to:

- define the better mathematical model associated to the source.
- define possible anomalies for a generator with respect to the model.
- have certification processes for a physical randomness generation.

we need:

- tests which characterize the mathematical models.
- to exploit statistical properties of the model to test the anomalies.
- to proove the suitability of the model with the physical phenomenon.

Conclusion

- Developing evaluation processes allows to:
  - Better analyse the anomalies of generators.
  - Better understand generator functioning and deduce some parameters.
- In order to improve evaluation we need to increase the knowledge of mathematical models associated to generators.

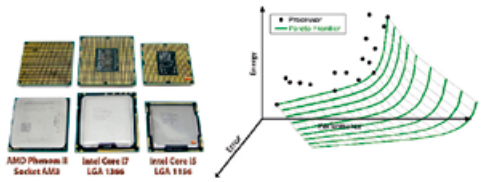
ANR PERSYVAL-Lab

Abhinav Srivastav, Oded Maler & Denis Trystram
CNRS-Verimag & LIG/INRIA

1 Introduction

Motivation

- Evaluation of different alternative solutions based on multi-criteria.
- Problem arises in engineering, economics, social policies, biology, etc.
- **Example:** Design of Processing elements.

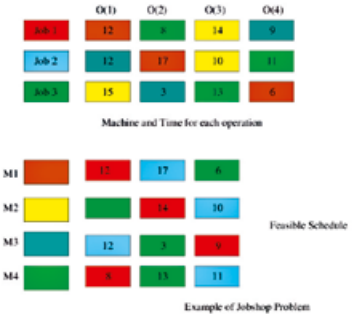


- Computational Accuracy v/s Performance v/s Energy
- Pareto surface in this 3-D space represents the best points of performance, efficiency and error.
- Many opportunity for innovation across the entire system stack.

2 Context

Scheduling

- We are interested in scheduling with *multi-user*.
- Each user expects some degree of *fairness* for his/her set of jobs.
- Scheduling Problem: Jobshop Problem and Online *stretch* minimization problem.



3 General Methodology

- Unfortunately, the size of Pareto frontier is exponential in size.
- Some of these problems, with even single objectives, are NP hard.
- Hence, approximate solutions can be found using:
  - Heuristics: Stochastic local search and Evolutionary Algorithms
  - Approximation Algorithms: ρ-approximation, PTAS, FPTAS, etc.
  - Exact Algorithms: Branch & Bound

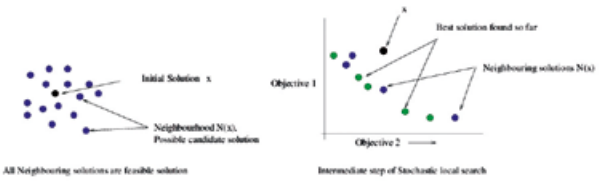
3.1 Methodologies Used

3.1.1 Stochastic Local Search

- Find some approximate (with no guarentee) solutions to the Pareto frontier.
- Like single objective, SLS starts with some initial feasbile solution x..
- Generates all neighbourhood solutions $N(x)$ of x.
- Choose among set of local solutions and proceed iteratively as above.

Open Problems

- Neighbourhood contains local Pareto frontier.
- Which local solution to choose as next point for intensification ?
- How to handle diversity of Pareto frontier in SLS ?
- How to compare two Pareto approximation sets ?



3.1.2 Approximation Algorithms

- In scheduling problem, find solution(s) with good performance guarantees.
- We explore online stretch minimization problem for max stretch and average stretch.

- Stretch of job j is $s_j = \frac{C_j - r_j}{p_j}$, then minimize $\sum s_j$.

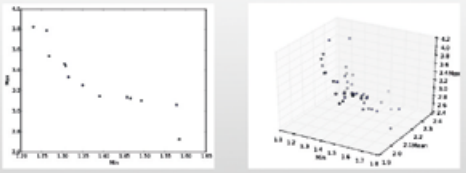
Open Problems

- Is there a algorithm which provide constant bound for sum stretch on single & parallel machines ?
- Is there a algorithm which provide better bound for max stretch than FCFS on single machine ?
- Is there a algorithm which can provided constant bound for both max stretch and sum stretch problem ?

4 Contributions

Stochastic Local Search

- We design an SLS for multi-objective problems.
- Our initial analysis on jobshop problem is presented below, where max, min and average ratio of completion time to ideal completion time (stretch) is shown.



Approximation Algorithms

- We show that Shortest processing time algorithm provided constant bound for sum stretch minimization on single and parallel machines.
- We provide a new algorithm, which uses waiting time, for max stretch minimization on single machine.

5 Future Work

Stochastic Local Search

- Find methods which improves the diversification of Pareto frontier.
- Benchmark testing on other jobshop instances and knapsack problems.
- Comparison with other existing tools like NSGA, SPEA, MOGLS, etc.

Approximation Algorithms

- Use waiting time concept and provide for bound for sum stretch minimization.
- Bi-criteria optimization: Max stretch and Sum stretch.
- Explore other objectives like makespan, flow time together with stretch.

EVENT-BASED CONTROL OF NETWORKS MODELED BY INFINITE DIMENSIONAL SYSTEMS

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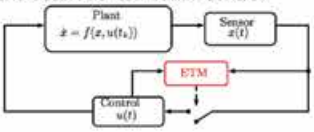
CNRS, GIPSA-Lab, Grenoble[1] CNRS, L2S CentralSupélec, Gif sur Yvette[2]

I.Overview & Objectives

Event-based control is a computer control strategy which aims to use communications and computational resources efficiently by updating control inputs aperiodically, only when needed.

Two components are essential in the framework of event-based control:

1. A feedback control law which has been designed to stabilize the system.
2. A triggering strategy which determines the time instants when the control needs to be updated.



We aim at combining event-based control of finite dimensional systems with boundary control of linear hyperbolic systems.

Motivations:

- New way of sampling continuous time controllers for linear hyperbolic systems.
- Interest of reducing control and communication constraints in infinite dimensional settings.

Key tool:

- Lyapunov techniques.

Several applications in modeling and control of Physical Networks:

- Road traffic.
- Gas pipeline.
- Hydraulic.
- Electrical lines.
- Data/communication.

II. Communication networks under fluid-flow modeling

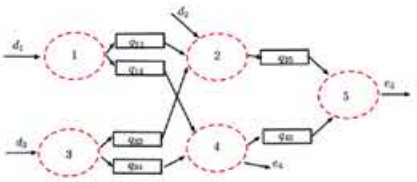


Figure: Example of a compartmental network.

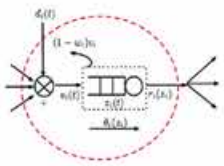


Figure: Compartment: buffer.

Hyp. PDE- ODE

$$\begin{cases} \partial_t q_{ij}(t,x) + \lambda_{ij}\partial_x q_{ij}(t,x) = 0 \\ \dot{z}_i(t) = w_i(t)d_i(t) + \sum_{\substack{k\neq i \\ k\in\mathcal{I}_i}} w_i(t)q_{ki}(t,1) - r_i(z_i(t)) \end{cases}$$

Boundary condition

$q_{ij}(t,0) = u_{ij}(t)r_i(z_i(t))$,

Output function

$e_i(t) = u_i(t)r_i(z_i(t))$

III. Stability issues of Linear coupled hyperbolic PDE-ODEs

$$\left.\begin{array}{l} \left\{\begin{array}{l} \partial_t y(t,x) + \Lambda\partial_x y(t,x) = 0 \\ \dot{Z}(t) = AZ(t) + G_y y(t,1) + B_w W(t) + D\tilde{d}(t) \end{array}\right. \\ \text{with dynamic boundary condition} \\ y(t,0) = G_z Z(t) + B_u U(t) \end{array}\right\} \mathcal{P} \qquad \left.\begin{array}{l} W(t) = \begin{bmatrix} K_z & K_y \end{bmatrix}\begin{bmatrix} Z(t) \\ y(t,1) \end{bmatrix} \\ U(t) = \begin{bmatrix} L_z & L_y \end{bmatrix}\begin{bmatrix} Z(t) \\ y(t,1) \end{bmatrix} \end{array}\right\} \mathcal{C}$$

THEOREM

Let $\underline{\lambda} = \min\{\lambda_{ij}\}_{\substack{i\in\mathcal{I}_0 \\ j\in\mathcal{D}_i}}$. Assume that there exist $\mu, \gamma > 0$, a symmetric positive definite matrix $P \geq I \in \mathbb{R}^{n\times n}$ a diagonal positive matrix $Q \geq I \in \mathbb{R}^{m\times m}$, as well as control gains K_z, K_y, L_z and L_y of adequate dimensions, such that the following matrix inequality holds:

$$M_c = \begin{pmatrix} M_1 & M_2 & M_3 \\ * & M_4 & 0 \\ * & * & M_5 \end{pmatrix} \leq 0$$

with

- $M_1 = (A+B_wK_z)^TP + P(A+B_wK_z) + 2\mu\underline{\lambda}P + (G_z+B_uL_z)^TQ\Lambda(G_z+B_uL_z)$;
- $M_2 = P(G_y+B_wK_y) + (G_z+B_uL_z)^TQ\Lambda B_uL_y$;
- $M_3 = PD$;
- $M_4 = -e^{-2\mu}Q\Lambda + L_y^TB_u^TQ\Lambda B_uL_y$;
- $M_5 = -\gamma I$.

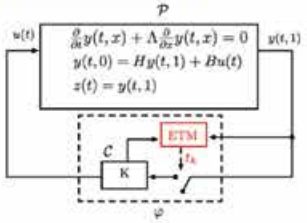
Then, the closed-loop system $\mathcal{P}$ is ISS with respect to $\tilde{d} \in \mathcal{C}_{pw}(\mathbb{R}^+;\mathbb{R}^n)$, and the asymptotic gain (A.g) satisfies

$$\text{A.g} \leq \frac{\gamma}{2\mu\underline{\lambda}}e^{2\mu}.$$

Acknowledgement

This work has been partially supported by the LabEx PERSYVAL-Lab (ANR-11-LABX-0025-01)

IV. Event-based control



Triggering times

$t_{k+1}^u = \inf\{t \in \mathbb{R}^+ | t > t_k^u \wedge \text{some execution rule}\}$

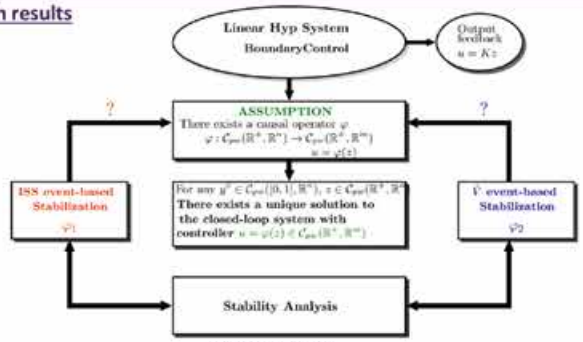
Control function

$$\begin{array}{rcll} u(t) & = & 0 & \forall t \in [t_0^u, t_1^u) \\ u(t) & = & Kz(t_k^u) & \forall t \in [t_k^u, t_{k+1}^u), \quad k \geq 1 \end{array}$$

Boundary Conditions

$$\begin{array}{rcl} y(t,0) & = & Hz(t) + Bu(t) \\ & = & Hz(t) + BKz(t_k^u) \\ & = & (H+BK)z(t) + BK(-z(t) + z(t_k^u)) \\ & = & Gz(t) + d(t) \end{array}$$

V.Main results



Lyapunov function

$$V(y) = \int_0^1 y(x)^TQy(x)e^{-2\mu x}dx$$

$t_0^u = 0, t_1^u = \frac{1}{\min\lambda_i}$ and $\forall k \geq 1$ with $\sigma \in (0,1)$ and $\varepsilon_1(t) = \varsigma_1 V(t_1^u)e^{-\eta t}$

$t_{k+1}^u = \inf\{t \in \mathbb{R}^+ | t > t_k^u \wedge \|BK(-z(t) + z(t_k^u))\|^2 \geq \frac{2\mu\sigma}{\rho}V(t) + \varepsilon_1(t)\}$

Vtriggering times for φ_2

$t_0^u = 0, t_1^u = \frac{1}{\min\lambda_i}$ and $\forall k \geq 1$ with $\sigma \in (0,1)$ and $\varepsilon_2(t) = \varsigma_2 V(t_1^u)e^{-\eta t}$

$t_{k+1}^u = \inf\{t \in \mathbb{R}^+ | t > t_k^u \wedge \dot{V}_{cv} \geq (1-\sigma)\dot{V}_{cont} + \varepsilon_2(t)\}$

THEOREM

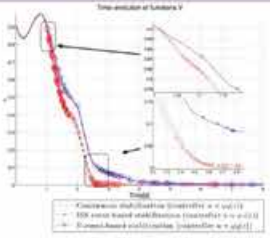
The system $\mathcal{P}$ with controller $u = \varphi_1(z)$ and $u = \varphi_2(z)$ has a **unique solution** and is **globally exponentially stable.** Moreover, for all $t \geq \frac{1}{\min\lambda_i}$,

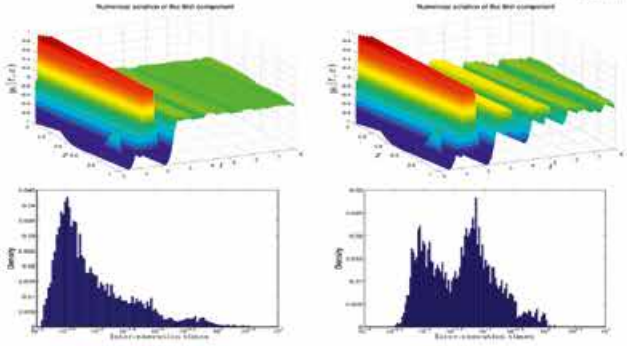
$\dot{V}(t) \leq -2\nu(1-\sigma)V(t) + \rho\varepsilon_1(t)$ and $\dot{V}(t) \leq -2\nu(1-\sigma)V(t) + \varepsilon_2(t)$

respectively.

VI. Numerical Simulations

- IC: $y(0,x) = \begin{bmatrix} 4x(x-1) \\ \sin(8\pi x) \end{bmatrix}$
- $\Lambda = \begin{pmatrix} 1 & 0 \\ 0 & \sqrt{2} \end{pmatrix}$
- $H = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$
- $K = (-1\ 0)$
- $G = H + BK$
- $\|\Delta G\Delta^{-1}\| = 0.7262 \Rightarrow \rho_1(G) < 1$, (GES)
- $Q = \begin{pmatrix} 0.8346 & 0 \\ 0 & 1.1291 \end{pmatrix}$, $\mu = 0.1$, $\nu = 0.1$.
- $\sigma = 0.9$
- $\varepsilon_1(t) = \varepsilon_2(t) = 5 \times 10^{-3}e^{-0.2t}$





ISS event-based:φ_1 $\dot{V}$event-based:φ_2

ANR

PERSYVAL-Lab

Stéphane Durand
Supervised by Federica Garin (GIPSA-Lab) and Bruno Gaujal (LIG)

Game Theory, What is a Game ?

Game Theory
A game is a set of **players** choosing actions to maximize their utilities.
Formally : a game with n players is defined by $(A_i, u_i)_{i=1..n}$, where A_i is the set of possible choices of player i and u_i is an utility function from $A_1 \times \cdots \times A_n$ to $\mathbb{R}$.

Potential Game
A Game is a potential game if there exists a real function V on the state space such that when a player changes its choice, the difference for this function is the same as the difference for the utility of this player:

$$\forall i \in J, \forall x_1 \cdots x_n \in X, \forall x_i' \in A_i,$$
$$V(x_1 \cdots x_i \cdots x_n) - V(x_1 \cdots x_i' \cdots x_n) = u_i(x_1 \cdots x_i \cdots x_n) - u_i(x_1 \cdots x_i' \cdots x_n)$$

V is a **potential function**.

Nash Equilibrium
A Nash Equilibrium (NE) is a stable state x^*. Any unilateral change reduces the utility of the player making the change.

$$\forall 1 \leq i \leq n, \forall y_i \in A_i$$
$$u_i(x_1^*, \ldots, x_n^*) \geq u_i(x_1^*, \ldots, y_i, \ldots, x_n^*)$$

Best Response Function
The best response $\mathbf{br}_i(x)$ is the choice of the player i maximizing u_i when every other player j chooses action x_j.

Thus, the Nash Equilibria are exactly the fixed points of **br**.

Best Response Algorithm
The Best Response Algorithm, or BRA is as follows:

Data: Number of Players n
Game Utilities $(u_i())$
Initial State x
Infinite Sequence of Active Players $R()$
Result: A Nash Equilibrium
$S \leftarrow \emptyset$; `// list of satisfied players`
while $|S| \neq n$ **do**
  $i \leftarrow R()$; `// Pick next player`
  $y \leftarrow \mathrm{br}_i(x)$;
  if $y = x_i$ **then**
    $S \leftarrow S \cup \{i\}$;
  else
    $S \leftarrow \emptyset$;
    $x_i \leftarrow y$;
  end
end
Return x;

Convergence

Theorem
An iterative *one player at a time* best response algorithm always converges to a Nash Equilibrium on a potential game.

In most cases, an algorithm with simultaneous plays will not converge.

On what condition on the **revision set** (sets of simultaneous players) can we guarantee that a partially simultaneous algorithm will converge to a NE?

Separability
The revision set R is separable iff $R = \{r_0 \cdots r_m\}$,
- $\forall i, r_i \setminus \bigcup_{j<i} r_j$ is empty or a singleton
- $\bigcup r_i = J$

Theorem
The simultaneous best response algorithm will converge to a Nash equilibrium with probability one on all games if and only if the revision set R is separable

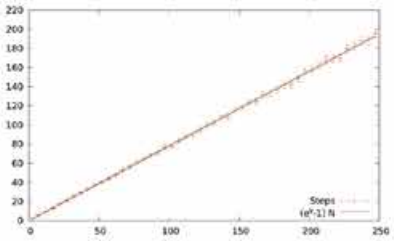
Convergence Speed

Worst Case Complexity
Finding a NE in a potential game is PPAD-complete, we can define a family of games of arbitrary size where finding a NE requires to visit every state.

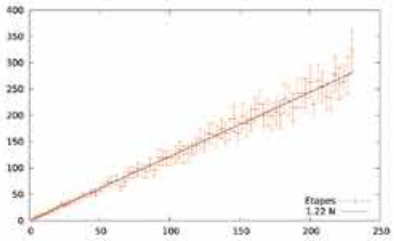
Randomization
A **uniform random potential game** is a game whose potentials are i.i.d. random variables with an arbitrary continuous distribution.

Average Complexity for Fully Random Games
We proved that :
- The average time to reach a NE on a random game, using a round robin sequence is $(e? - 1)n$.
- We can bound the average time using a Bernouilli sequence by $n \log n + Cn$. This bound is tight (experiments show that $C \approx 1.22$).
- BRA is stochastically faster than any iterative algorithm, for any valid sequence.

Simulations



Time Complexity for round robin revision.



Time Complexity for Bernouilli revision.

Independent Players

Definition
In a game, a player is **independent** of another if the difference between any two values of its utility function does not depend on the choice taken by the other.

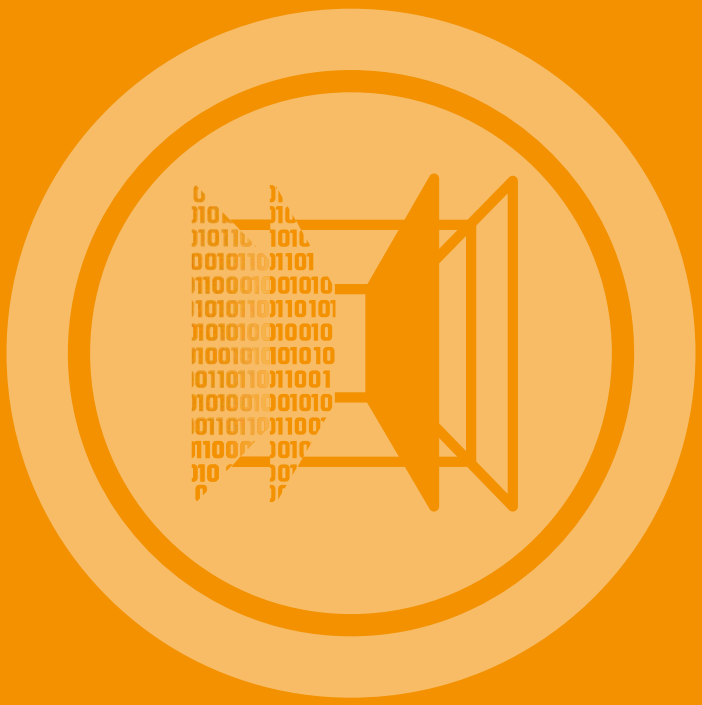
In a potential game, this relation is symmetric.

Properties
- Two independent players acting simultaneously will not interfere, thus their order of play is irrelevant.
- We can replace two or more independent players always acting together by one super-player with a set of choices defined by the Cartesian product of their choices.

Advantages in a Centralized Context
- The number of steps before reaching a NE is linear in the number of super-players.
- The cost of those steps can be shared between the players in the case of concurrent computation.
- This reduces the complexity to $e?M$ where M is the number of super-players.

Distributed Implementation
At each step:
- Each player has a probability to wake up (dependent on its degree).
- Each player that woke up sends a message to non-independent players.
- Each player that woke up and did not receive any message acts.

Any set of players acting at a given time is independent so the convergence is ensured and fast.
Since the probability is only a function of the degree, the probability to play does not go to 0 when the size goes to infinity in a sufficiently sparse dependency graph.



AUTHORING AUGMENTED REALITY

Coordinators

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LIG: Laurence Nigay

Scientific committee

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TIMC-IMAG:
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Augmented Reality (AR) systems seek to smoothly merge physical and digital worlds for the sake of enhanced user interaction. The growing interest for AR is due to the dual need of users to both benefit from computers and stay in contact with the physical world. Although AR systems are becoming more prevalent, we still do not have a clear understanding of these systems and of their impact on the cognitive skills of their users.
The AAR research track aims at designing new strategies for modeling, designing, developing and evaluating augmented reality systems. The goal is to design new forms of interaction between humans and technical systems and to enhance the physical world by adding and interactively controlling dynamic content, usually unseen. The research carried on thanks to the Persyval/AAR funding addresses the following challenges:

- Real-time capture and simulation of the real world
- Representation and editing of virtual prototypes
- Natural interaction with the augmented world

In the AAR research track, we emphasize the diversity of AR systems:

- Systems that enhance interaction between the user and her/his physical environment by providing additional capabilities and/or information.
- Systems that make use of physical objects/actions to enhance the interaction between a user and a computer.

Illustrating this diversity of systems that link the physical and data processing (digital) worlds, the ongoing projects include: robots in human environments, tracking feature points on a leaf during its growth, sensory substitution devices, latency for touch interaction, modeling human activity, personal data visualization, localization/attitude for mobile AR.

AAR AUTHORING AUGMENTED REALITY

> PROJECT-TEAMS

> EXPLORATORY PROJECTS

> PhDs

LBA

The Living Book of Anatomy

AAR

The LBA project-team promotes a new approach to learning anatomy. A large collection of accessible data and applications describing anatomy or other medical knowledge are now available, based on advances in numerical sciences and more specifically to the spread of smart phones and tablets.

However, none of these new services and applications bridges the gap between the user's own body and medical knowledge. The proposed approach relies on evidences that body movements could improve learning of different knowledge by "augmenting" or "enriching" traces in long-term memory. This "embodied" perspective is particularly relevant for learning of functional anatomy as the knowledge to acquire could be specifically related to the learner's body in motion. Exploring this approach requires being able to capture the trainee action (limb movement for instance) and to map it to a model in order to recover relevant related information (for instance the muscles activation), and to render it in a proper way (for instance by superimposition onto the user image using Augmented Reality). A core hypothesis of the LBA project is that the use of Augmented Reality could make the embodiment of knowledge easier by a closer connection between models, knowledge and reality.

Website: https://persyval-lab.org/en/sites/lba

Main Scientific Results and Ongoing Work

The cross-disciplinary approach followed by our project-team has led to significant advances in our scientific programme, by providing the following major results.

Anatomy transfer:
Specific methods have been designed and developed to extend state of the art to real-time deformation and animation of a template model from partial and noisy data of a moving user. These methods have been integrated in a demonstrator named "anatomical mirror" where users can experiment "seeing the inside of their body in action". This demonstrator overpasses the performances of other anatomical mirrors developed worldwide.

Interactive learning:
Tangible interfaces have proved to be useful for memorization by different studies that showed that using a physical object to manipulate a 3D model displayed on a screen improves the memorization in comparison to the use of a mouse. We have developed tangible interaction with an anatomic 3D model projected inside a physical object.

On two groups of 19 volunteers, we have demonstrated that involving trainee gestures during anatomy lessons significantly improves long-term memorization while there is no significant difference for short-term effects.

Coordinators

GIPSA-Lab:
Violaine Cahouet,
Amélie Rochet-Capellan
LIG: Laurence Nigay
LJK/Inria:
Olivier Palombi,
François Faure
TIMC-IMAG:
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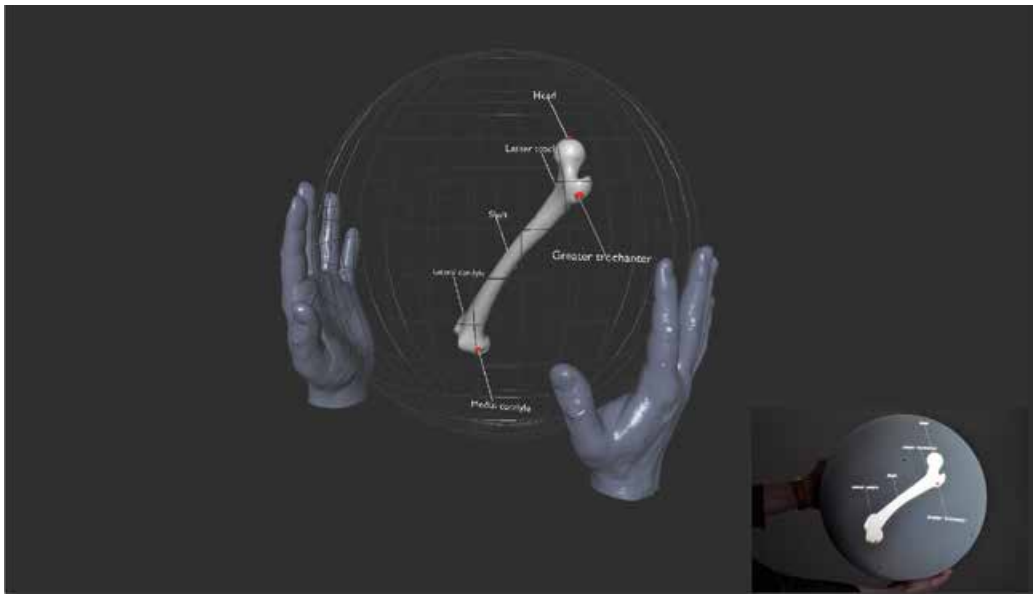


Valorization

- Creation of Anatoscope as a University Grenoble Alpes and INRIA spin-off.
- Installation of the demonstrator “anatomical mirror” in a showroom at INRIA Rhône-Alpes.
- Successful application to ANR generic call 2016 for a new project named An@tomy2020, based on results obtained in the LBA project.

Some relevant publications

- Eric Tatulli, Thomas Hueber. **Feature extraction using multimodal Convolutional Neural Networks for visual speech recognition.** *Proceedings of ICASSP’2017 March 2017,* New Orleans, USA. 2017.
- Mélaine Cherdieu, Amélie Rochet-Capellan, Pascal Perrier, Jocelyne Troccaz, Olivier Palombi. **Move to learn: Can gestures help anatomy learning?** *Spatial Cognition 2016* August 2-5 2016, Philadelphia, USA. 2016.
- Armelle Bauer, Ali-Hamadi Dicko, François Faure, Olivier Palombi, Jocelyne Troccaz. **Anatomical Mirroring: Real-time User-specific Anatomy in Motion Using a Commodity Depth Camera.** *Motion in Games (MIG’16)* october 2016, San Francisco, United States. 2016.
- Armelle Bauer, Florent Paclet, Violaine Cahouet, Ali-HamadiDicko, Olivier Palombi, François Faure, Jocelyne Troccaz. **Interactive visualization of muscle activity during limb movements: Towards enhanced anatomy learning.** *Eurographics Workshop VCBM* september 2014, Vienne, Autriche. 2014.
- Armelle Bauer. **Modélisation anatomique utilisateur-spécifique et animation temps-réel. Application à l’apprentissage de l’anatomie.** Thèse de Doctorat de l’Université de Grenoble, 10 Novembre 2016.

RHUM

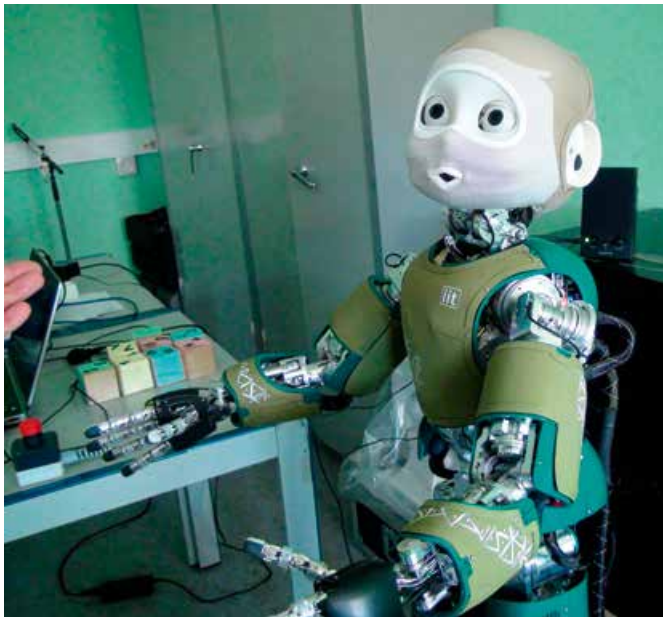
Robots in Human Environments

AAR

Robots offer a unique way to bridge the virtual and physical worlds by augmenting the user experience with digital content through context-sensitive processing of the physical scene, and by acting in the physical world as digital agents.

The RHUM project-team explores new forms of active perception of the physical environment and will author adaptive forms of social communication and interaction between humans and robots, seen as digital agents in the physical world. Learning human-aware and situation-sensitive behaviors is also an important subject studied in RHUM, through on-line and active mining of multimodal data flows.

Website: http://www.gipsa-lab.grenoble-inp.fr/projet/RHUM



Main Scientific Results and Ongoing Work

Learning and adaptation of robots behaviors for social interaction:
Endowing robots with socio-communicative skills for engaging them into effective human-robot interaction (HRI) is a challenging issue. We explore several paradigms for training multimodal behavioral models from human demonstrations: (a) learning by observing human-human interactions and scaling sensorimotor events to the target robot's capabilities [1]; (b) learning from behaviors collected via immersive teleoperation of the robot by human pilots [2]. A particular focus is also given to the evaluation of these HRI behaviors, notably thanks to original online assessment paradigms [3].

The thesis "Acquiring Human-Robot Interaction skills with Transfer Learning Techniques" by Omar Samir Mohammed supervised by Gérard Bailly & Damien Pellier will address the acquisition of new interactive abilities via transfer from previous experiences or abilities already mastered by another robot. We will also investigate the decomposition of tasks into generic sensorimotor abilities and interactive skills. The first application will be transfer learning of cursive writing from drawings (i.e. captioning) between the iCub at GIPSA-Lab and the Baxter at LIG.

Coordinators

GIPSA-Lab:
Gérard Bailly
Inria/LJK:
Pierre-Brice Wieber
LIG: Olivier Aycard

Human-Robot Motion (HRM):
HRM is about controlling how a robot should move among people. In such a situation, it is critical that the robot's motions be both *safe and appropriate* where safe means that the robot should not hurt the people by colliding them and appropriate means that its motion should respect the social and cultural norms that govern people's behavior, e.g. not passing between two people engaged in a conversation. The work done in RHUM has primarily focused on the safety issue. Avoiding collisions with people is a challenge since their future behavior is uncertain and hard to anticipate. This fact actually precludes "absolute" safety meaning that collisions might be unavoidable in specific occasions. Our purpose then is to investigate which safety level can be achieved in a given situation. Considering a biped robot and using tools earlier developed in the team, we have proposed a strategy that allows a biped robot to move in a crowd while maintaining its balance and achieving *Passive Safety,* i.e. should a collision occur, the robot will be at rest [4]. This work was furthered in the RHUM-funded Master internship of Hang Yu [5] that investigated a more sophisticated safety level called *Passive Friendly Safety,* i.e. should a collision with a person occur, the robot will be at rest and the person will be able to avoid the collision if he decides to do. The RHUM-funded PhD of Matteo Ciocca supervised by Thierry Fraichard and Pierre-Brice Wieber that has started in March 2017 will build upon and expand the work done in [5].

Valorization

Several projects complement this action:
- PSPC 1 ROMEO 2 "Développement d'un robot humanoïde assistant et compagnon pour la vie quotidienne" [2012-2017] (LJK-BIPOP) with ALDEBARAN
- H2020 COMANOID "Multi-Contact Collaborative Humanoids in Aircraft Manufacturing" [2015-2019] (LJK-BIPOP) with AIRBUS
- ANR SOMBRERO "Téléopération immersive de robots humanoïdes et apprentissage de modèles de comportements socio-communicatifs" [2014-2018] (GIPSA-CRISSP, LIG-MAGMA, LIP & Lab-STICC) with ALDEBARAN
- Projet Région Rhône-Alpes ARC6 TENSIVE "robots de TEléprésence: Navigation Sociale et Interaction VErbale immersives" [2016-2019] (GIPSA-CRISSP & CITI-CHROMA) with AWABOT & HUMANOO

Some relevant publications

- A. Mihoub, G. Bailly, C. Wolf and F. Elisei, **"Graphical models for social behavior modeling in face-to face interaction",** *Pattern Recognition Letters,* vol. 74, 2016.
- G. Gomez, C. Plasson, F. Elisei, F. Noël, and G. Bailly, **"Qualitative assesment of a beaming environment for collaborative professional activities"** in *European Conf. for Virtual Reality and Augmented Reality (EuroVR),* 2015.
- N. Duc-Canh, G. Bailly and F. Elisei, **"Conducting neuropsychological tests with a humanoid robot: design and evaluation"** in *IEEE Int. Conf. on Cognitive InfoCommunications (CogInfoCom),* 2016.
- N. Bohórquez, A. Sherikov, D. Dimitrov, and P.-B. Wieber, **"Safe navigation strategies for a biped robot walking in a crowd"** in *IEEE-RAS Int. Conf. on Humanoid Robots (Humanoids),* 2016.
- H. Yu, **"Safe Navigation of Biped Robots Subject to Passive Friendly Safety and Balance Constraints",** Master Report, Univ. Grenoble-Alpes, 2016.

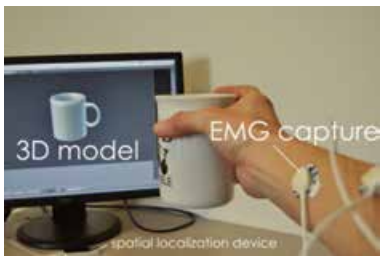
TAPIOCA Physiological tangible interaction: designing artefacts with resizable mixed objects

Coordinators

GIPSA-lab:
Franck Quaine
G-SCOP: Cédric Masclet
LIG: Yann Laurillau
& Céline Coutrix
LJK: Damien Rohmer
& Jean-Claude Leon

This project investigates tangible interactions for experts to better interact with 3D and CAD models in a more natural way, and thus to facilitate the design of such complex models. The focus is on interaction techniques combining tangible interaction based on resizable input interaction devices with muscle-based modalities.

Website: http://iihm.imag.fr/projects/tapioca



Results

We have developed two prototypes that demonstrate the feasibility of resizable input interaction devices and of EMG-based user interaction modalities: a software application (left image) allowing a user to interact with a 3D model through grasping gestures; a resizable slider (right image). A user study of resizable input interaction devices [3] shows that this resizable prototype supports better precision than its small counterpart as long as users do not need to resize it more often than around every 9 seconds. A partnership has been established with the university of Swansea, with a resulting major publication at the ACM CHI conference [4].

Some relevant publications

- Phinyomark, A., Quaine, F., Charbonnier, S., Serviere, C., Tarpin-Bernard, F., Laurillau, Y., Feature extraction of the first difference of EMG time series for EMG pattern recognition. Computer Methods and Programs in Biomedicine 117, 2014, 247 – 256.
- Phinyomark, A., Quaine, F., Laurillau, Y., 2014. The Relationship between Anthropometric Variables and Features of Electromyography Signal for Human-Computer Interface, in: Naik, D.G. (Ed.), Applications, Challenges, and Advancements in Electromyography Signal Processing. IGI Global, Autralia, pp. 325–357.
- Coutrix, C., Masclet, C, 2015. Shape-Change for Zoomable TUIs: Opportunities and Limits of a Resizable Slider. Proceedings of the 15th IFIP TC13 Conference on Human-Computer Interaction (INTERACT'15), 14-18 September 2015, Bamberg, Germany, Springer. 2015.
- Robinson, S., Coutrix, C., Pearson, J., Rosso, J., Torquato, M., Nigay, L., Jones, M. Emergeables: Deformable Displays for Continuous Eyes-Free Mobile Interaction in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'16), May 7-12, San Jose, CA, USA, ACM.

CYPASS Distant creativity by robotic telepresence

Coordinators

GIPSA-lab: Gérard Bailly
G-SCOP: Frédéric Noel

CYPASS aims at assessing the outcomes of creating an environment of collaborative creativity involving distant human agents and physical objects augmented with interaction modalities.

Website: http://www.gipsa-lab.grenoble-inp.fr/projet/CYPASS

Results

We have equipped the MICAL platform with an eye-tracking-enabled Head Mounted Display. New software was developed to integrate this new hardware with the non-autonomous robot of the platform to allow a remote immersive teleoperation interaction loop. A scenario where the human pilot with the HMD interacts with two human partners to reassemble a jigsaw has been studied and evaluated.
The project has shown the importance of gaze within social interaction. It also demonstrates the capacity of a beaming system to replace a remote human pilot as soon as the beaming system reproduces the good interaction modalities within a realistic professional collaborative task. The work done in this project has boosted the H2020 SPARK project on Spatial augmented reality for collaborative creativity, and is related to the collaborative project ARC6 TENSIVE with AWABOT & HUMANOO on immersive teleoperation of telepresence robots.

Some relevant publications

- G. Bailly, F. Elisei, and M. Sauze, Beaming the gaze of a humanoid robot" in *Human-Robot Interaction (HRI),* Portland, OR, 2015, pp. 47–48.
- G. Gomez, C. Plasson, F. Elisei, F. Noël, and G. Bailly, Qualitative assesment of a beaming environment for collaborative professional activities, in *European conference for Virtual Reality and Augmented Reality (EuroVR),* 2015, p. 8 pages.

FIGURINE Expressive Interactive Figurines for Narrative Design

Figurine project targets to provide a storytelling help for narrative design. A narrator wants to share or to construct a story. It can use objects, characters and decor to set the scene. In order to help the narrator visualizing the scene, real objects are manipulated as tangible interfaces. This allows to use every object as part of the stage set and to personalize the decor. The perception system provides a 3D+time representation of the scene, i.e. the position of figurines and stage set over time, annotated with narrator facial expressions and speech. The ultimate goal is to process this representation to produce automatically a 3D movie from the story telling.
The simplicity of this approach allows also children to be narrators and to tell their own stories. The child can imagine his own world, play with the figurines, and then see the movie generated with his creation. More than a playful activity, the generated 3D movie could become a pedagogical help, to support the development of language, social and cognitive skills.

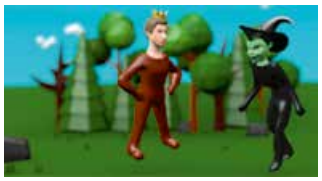
Website: http://team.inria.fr/prima/figurines-project/

Results

We have developed a novel short range perception system for human interaction including new devices like IMU (Inertial Measurement Units). The project was an occasion to gain new experience in printing 3D objects from our shape modeling software (Expressive) and creating clothing for them. We adapted the design to include IMU sensors. We used results of Persyval Lab PhD A. Barbulescu for transferring the facial expressions and head movements of the storyteller onto the animated characters of the figurines. To determine the focus during complex storytelling involving more than one figurine at a time, our current solution uses the audio signal to break down the story into short segments of speech and silence, and a combination of the storyteller and figurine motions to determine the focus in each segment. The experience outcomes from the experimentation with the acquisition system let the Pervasive Team leverage it. This new system is the part the ANR CEEGE proposal that was funded by ANR in 2016. Within this project, an enhanced version of the perception setup will be used to compare techniques for mental modeling of player ability to predict expertise and chess games using short range perception as input.
Figurine projects' work is continued by M. Garcia as part of his PhD thesis "Animation transfer: animating virtual characters by playing and acting". This project has also been a starting point for the CEEGE project (ANR funded since 2016).

Coordinators

Inria/LJK:
Rémi Ronfard
LIG/Inria: Dominique Vaufreydaz



Selected publication

- Adela Barbulescu, Maxime Garcia, Antoine Begault, Laurence Boissieux, Marie-Paule Cani, Maxime Portaz, Alexis Viand, Romain Dulery, Pierre Heinish, Rémi Ronfard, Dominique Vaufreydaz, **A System for Creating Virtual Reality Content from Make-Believe Games,** IEEE Virtual Reality 2017 Los Angeles, California, USA, March 2017.

LOCATE-ME LOcalization teChniques for pedestriAn navigaTion based on inErtial MEasurements in indoor environments

The goal was to investigate the precision of attitude estimation algorithms in the context of pedestrian navigation with commodity smartphones and their inertial/magnetic sensors.

Website: http://tyrex.inria.fr/mobile/benchmarks-attitude/

Results

We have considered typical motions of smartphones when carried by pedestrians. We have used a ground truth obtained from a motion capture system. We have conducted an extensive comparison and experimental analysis of existing algorithms for attitude estimation. Our experiments shed light, for the first time, on the relative impacts of calibrations, noises, bias, motions, magnetic perturbations, and sampling rates when estimating attitude on smartphones (figure 1).

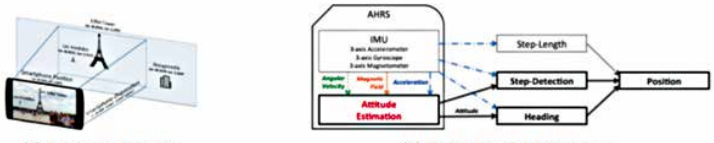
This project has been continued with the ongoing PhD thesis of Thibaud Michel on Mobile Augmented Reality Applications for Smart Cities (figure 2).

Coordinators

Gipsa-Lab:
Hassen Fourati
LIG/Inria: Pierre Genevès

(a) The Smartphone-Frame and Earth-Frame. (b) Method for Estimating Attitude.

Figure 1: Principles of Attitude Estimation.



(a) Augmented Reality (b) Pedestrian Dead-Reckoning.

Figure 2: Applications of Attitude Estimation.

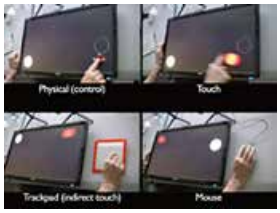
Selected publication

- T. Michel, P. Genevès, H. Fourati, N. Layaida. On Attitude Estimation with Smartphones, International Conference on Pervasive Computing and Communications (PerCom), 2017.

THE TRANSFER OF LEARNING AS HCI SIMILARITY Towards an Objective Assessment of the Sensory-Motor Basis of Naturalness

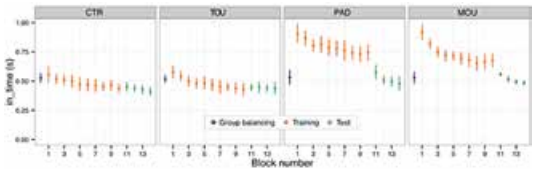
Coordinators

GIPSA-lab:
Amélie Rochet-Capellan
LIG: François Bérard



Human-computer interaction should be natural. However, there is a lack of theoretical background and methods to objectively measure the naturalness of a HCI. We introduce a new experimental paradigm inspired by motor learning research to assess sensory-motor similarity, as revealed by the transfer of learning. We tested this paradigm in an empirical study to question the naturalness of three HCIs: direct-touch, mouse pointing and absolute indirect-touch. It revealed how skill learning transfers from these digital interactions towards an equivalent physical interaction.

Website: http://persyval-lab.org/en/exploratory-project/Similarity



Results

Using a serial target crossing task performed by 28 participants, we observe that the skills learned through training with direct-touch transfer fully to the physical interaction while no skill transfer is observed when training with indirect-touch or mouse pointing. According to our rationale, this means that direct-touch is more similar to the physical interaction at a sensory-motor level. This provides the first empirical and objective correlate of the widely circulated belief that direct-touch is a more natural form of interaction than mouse pointing.
The study was published in the most referenced publication in the field of Human-Computer Interaction: the ACM CHI conference. The cooperation between researchers in the HCI and motor control research fields was pursued in the co-tutoring of Élie Cattan, a PhD student funded by a Persyval grant. The cooperation is pursued in a new ANR project: Anat2020.

Some relevant publications

- Bérard and A. Rochet-Capellan. The transfer of learning as hci similarity: Towards an objective assessment of the sensory-motor basis of naturalness. In ACM Conference on Human Factors in Computing Systems (CHI), pages 1315–1324. ACM, 2015.
- Cattan, E. Rochet-Capellan, A. Perrier, P. and Berard, F. Does Practice Make Perfect? Learning to Deal with Latency in Direct-Touch Interaction. ACM Conference on Human Factors in Computing Systems (CHI). ACM, 2017.

MYSSIV Eye Movement - Sensory Substitution Device - Virtual Immersion

Coordinators

GIPSA-Lab:
Denis Pellerin,
Sylvain Huet
LPNC: Christian Graff

Sensory Substitution Devices (SSDs) aim at compensating impairments in one sensory modality by transmitting through another – functional – sensory channel, information that can no more be perceived. SSDs for visual impairment usually comprise a video camera to obtain spatial information from the user's environment, a computer to process it and actuators to produce tactile or sonic stimuli. Existing SSDs allow navigating in corridors, recognizing objects and patterns such as letters. Our "AdViS" (Adaptive Visual Substitution) setup is being developed within an inter-disciplinary project allying signal and image processing, visual perception, hardware and software architecture, neurosciences and psychophysics. It was initially meant to facilitate navigation for the blind by converting spatial data from a depth camera into audio information [1].

Website: http://www.gipsa-lab.fr/projet/MYSSIV/

Results

In the setting of two master projects, we have improved the ADVIS device to allow the spatial immersion in a virtual environment of a user apprehending the virtual scene through the audio feedback. In another master project, we have also investigated how to exploit the residual eye mobility of certain blind people to restore a perception-action loop involved in natural space perception.

Selected publication

- C. Stoll, R. Palluel-Germain, V. Fristot, D. Pellerin, D. Alleysson, and C. Graff, Navigating from a depth image converted into sound, Applied Bionics and Biomechanics, vol. 2015, ID 543492, 2015.

CARAMBOLE

This project initiates a new collaboration between computer scientists from University of Grenoble Alpes and biophysicists from University Paris Diderot. The objectives are to develop hardware and software to help tracking feature points on a leaf of Averrhoa Carambola during its growth with a multi-camera system and to measure their 3D motion.

Website: http://morpheo.inrialpes.fr/carambole/

Results

A camera set-up has been defined and installed in Grenoble and Paris. In Grenoble, the Kinovis platform (http://kinovis.inrialpes.fr/) has been specialised in both hardware and software for small volumes, high spatial resolutions and very long time scales as specific in our context. The 8 (Grenoble) or 10 (Paris) cameras surrounding the plant are synchronized thanks to a trigger and an Arduino (Grenoble) or a USB system (Paris) programmed to take pictures every k minutes, with k a user-chosen parameter. Calibration is made with a chessboard. For every set of 8 or 10 images, a 3D meshed model is reconstructed using the EPVH algorithm (http://morpheo.inrialpes.fr/~franco/epvh/). A Reeb graph is then computed and embedded inside each mesh to define a one-dimensional spatio-temporal model enabling to analyze the motion of the leaf stem. Dense temporal tracking of the leaf based on feature points is ongoing work. Such tracking will allow for a finer motion analysis, hopefully at a scale of 10 to 100 microns.

The final stages of the project are concerned with the temporal tracking of the plant motion and accurate motion measurement. This should be done by July 2017. We plan to then extend the project to other plants with interesting dynamics, such as avocado *(Persea americana).* A collaboration with biologists from INRA Avignon, Clermont-Ferrand and Montpellier is also planned (ANR project submitted) to apply the same kind of tools at a bigger scale and outdoor for fruit trees and agrosystems. Finally, a new collaboration has recently started with Florence Bertails-Descoubes (Inria Grenoble) in order to use the computed temporally coherent 3D plant models for inverse mechanical modelling.

Coordinators

LJK/Inria: Franck Hétroy-Wheeler

Julien Derr, Laboratoire Matière et Systèmes Complexes, Paris

Left and middle: 3D mesh model of an Averrhoa Carambola leaf with and without texture. Right: approximation of the spine of an Averrhoa Carambola leaf with a Reeb graph, for 70 successive time steps.

IDIG Identifying and understanding the Difference between natural Images and computer-Generated images

The goal of this project is to develop new and effective methods to identify computer generated (CG) fake images that do not reflect real-world scenes. We plan to derive discriminative features, either hand-crafted or automatically extracted, for the purpose of developing a forensic method that can expose both full-sized CG images and CG patches of small sizes. In the second part of this project, we will focus on understanding the main reasons of the difference between natural and CG images. More precisely, we will conduct experiments to investigate the influence of each key element of the rendering algorithm on this difference. With the learned knowledge from the experiments, it would be possible to develop a learning-based post-processing method to improve the realism of a CG image or even a more effective rendering algorithm that can produce visually more pleasing graphical images.

Website: http://www.gipsa-lab.fr/~kai.wang/projet_idig.html

Results

We plan to well accomplish the first part of the project (i.e., identifying CG images) and at least conduct some preliminary work on the second part (i.e., understanding the difference between natural and CG images). We are particularly interested in developing a deep-learning-based forensic method to distinguish between natural and CG images, which would also provide useful insights for understanding their difference. We are also interested in detecting recaptured CG images from LCD screens, which may appear both forensically and visually more plausible. Besides the expected scientific results and the relevant publications, we hope that the project can also have some social impacts in the long term by providing people with a practical tool to expose CG fake images, which can be encountered in their daily life.

Coordinators

Chinese Academy of Sciences, Beijing: Dong-Ming Yan

GIPSA-Lab: Kai Wang

It is often very difficult to distinguish between natural and computer-generated images by human naked eyes. The top image in the figure is a computer-generated image while the middle and bottom ones are pictures taken by digital cameras. The images were downloaded from the Fake or Foto website at http://area.autodesk.com/fakeorfoto.

Selected publication

• K. Wang, A simple and effective image-statistics-based approach to detecting recaptured images from LCD screens, Research Report, 32 pages, January 2017.

DIRECTING VIRTUAL ACTORS BY INTERACTION AND MUTUAL IMITATION

Adela Barbulescu[1,2] Rémi Ronfard[1] Gérard Bailly[2]
IMAGINE, INRIA, Grenoble[1] DPC, GIPSA-lab, Grenoble[2]

Introduction

- **Problem**: lack of a fully automatic system that enables a **user** to create an expressive animation of a chosen **virtual actor.** The obtained performance must maintain the speaking and acting **style** (audio-visual prosody) of the actor.
- We propose a performance-driven approach where the user takes the role of a theater **director** by doing the performance himself and stating the **social attitude** (sneaky, fond etc)
- A **performance** is defined by speech, 3D facial expressions, head and gaze movements.

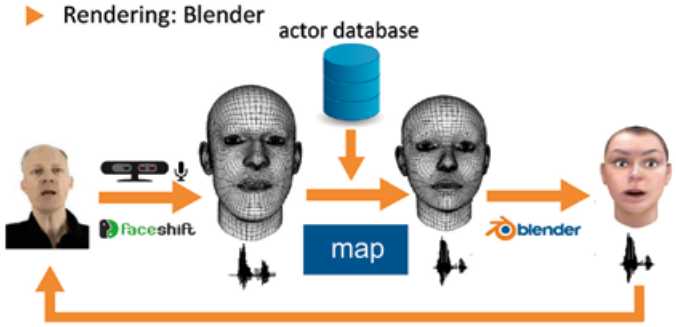
State of the art

- Facial expression **retargeting**
  - modeling: shape interpolation
  - animation: performance-driven (motion capture etc), speech-driven methods [1]
- **Voice conversion:** statistical methods [2]

- **Problems**: identity conversion, audio and visual distance metrics, "blind" data-driven approaches

Our approach

- Modeling and realtime visual data generation: Faceshift
- Audio-visual expressive conversion: joint statistical models of actors (for all attitudes) and attitudes (for pairs of actors)
- Rendering: Blender

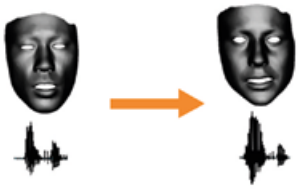


Demonstration loop: features are extracted from director's performance and mapped to an actor's performance. The process is repeated until the desired output is obtained.

Achievements

Audio-visual speaker conversion using prosody features [3]

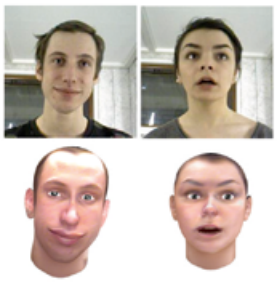
- The work proposes a speaker identity conversion paradigm using speech and visual cues (lip movements, expressions).
- Use of experimental data from 3D BIWI corpus [4]
- Feature conversion framework based on Gaussian Mixture Models.



Conversion is done between any two actors from the BIWI corpus (14 actors in total).

Expressive speech corpus acquisition

- 3D acted corpus of social attitudes
- 1 director and 2 actors performed 35 phrases in 16 different social attitudes (training data)
- The 2 actors also performed a dialog (testing data)



Top: Screenshots from video performances. Bottom: 3D texturized meshes obtained for the same frames. Social attitudes: comforting and scandalized.

Perspectives and future work

- Conversion from neutral to expressive performance for one actor using concatenative synthesis
- Social attitude recognition
- Structured performance conversion between director and actor for a given social attitude

Acknowledgments

This work is supported by the LabEx PERSYVAL-Lab (ANR--11-LABX-0025)

References

[1] Ping, Heng Yu, et al (2013). Computer Facial Animation: A Review. International Journal of Computer Theory & Engineering 5.4
[2] Machado, A. F., & Queiroz, M. (2010). Voice conversion: A critical survey. Proc. Sound and Music Computing (SMC)
[3] Barbulescu, A., Hueber, T., Bailly, G. and Ronfard, R. (2013). Audiovisual speaker conversion using prosodic features. Auditory-Visual Speech Processing.
[4] Fanelli, G., Gall, J., Romsdorfer, H., Weise, T., Van Gool, L. (2010). Acquisition of a 3D audio_visual corpus of affective speech, IEEE Transactions on Multimedia.

Jingtao CHEN[1, 2, 3]
Peter MITROUCHEV[1] Franck QUAINE[2] Sabine COQUILLART[3]
Univ. Grenoble Alpes, CNRS (GSCOP[1], GIPSA[2], INRIA-LIG[3])

How does Virtual Reality influence human behavior during haptic interaction and rehabilitation?

Fatigue evaluation during haptic interaction

Objective

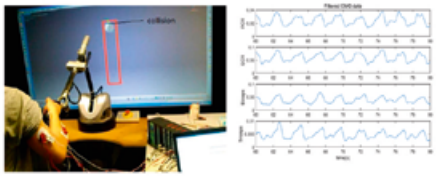
Evaluate the fatigue associated with different disassembly operations simulated with using haptic device

Proposed method

Using **mechanical energy expenditure** to evaluate the **muscle fatigue** [1].

Validated by

Experimental method

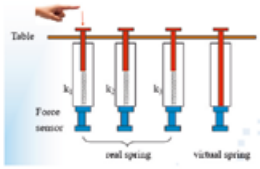


Analyze surface EMG on operators' arm muscles

Motor behavior analysis of pseudo-haptics

Pseudo-haptic experiment

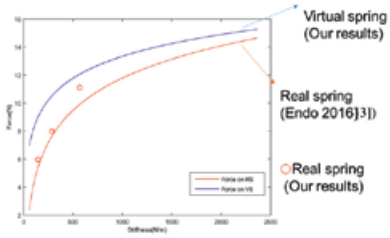
Stiffness discrimination task: **virtual spring vs. real spring**



Subjects' perception results confirm that the experiment induced the pseudo-haptic effect which has been reported in [2]

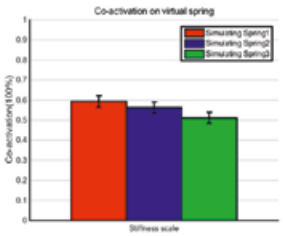
Experiment results and conclusions

Pressing force



Pseudo-haptics can induce the similar force behavior as in real spring

Muscle co-activation



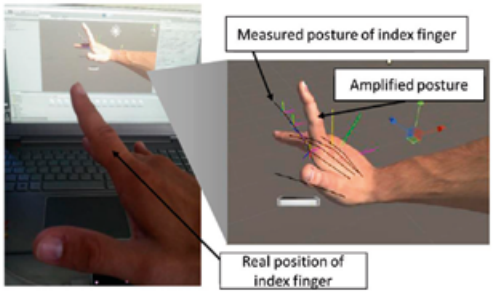
Pseudo-haptics can induce different levels of muscle co-activation

Computer-based rehabilitation for CRPS (Complex Regional Pain Syndrome)

Symptoms of CRPS : Pain, Swelling, Movement disorder…

Proposed solution Computer-based environment based on Leap Motion and Unity

Realized experimental bench



Modify (amplify/decrease) displayed joint motion of patients in order to encourage them to participate in rehabilitation [4,5]

Experiment in Grenoble CHU

Experimental bench

Related publications

- Chen J. , Mitrouchev P. , Coquillart S. , Quaine F.. Disassembly task evaluation by muscle fatigue estimation in Virtual reality environment. The International Journal of Advanced Manufacturing Technology (2017), vol. 88: pp.1523–1533
- Mitrouchev P. , Chen J. , Coquillart S. , Quaine F. Length perception in virtual reality environment. International conference Management and Innovative Technologies (MIT) 2016, pp.56-62

Future work

Pseudo-haptics for rehabilitation

I. Using pseudo-haptic as a static task to avoid the pain in dynamic rehabilitation task
II. Using pseudo-haptic feedback to strengthen patient's deficient muscle

References

[1] Chen J. , Mitrouchev P. , Coquillart S. , Quaine F.. Disassembly task evaluation by muscle fatigue estimation in Virtual reality environment. The International Journal of Advanced Manufacturing Technology (2017), vol. 88: pp.1523–1533
[2] Lécuyer A. , Coquillart S. , Kheddar A. , Richard P. , Coiffet P.. Pseudo-haptic feedback: can isometric input devices simulate force feedback? Proceedings IEEE Virtual Reality 2000, pp.83
[3] Endo H.: Pressing movements and perceived force and displacement are influenced by object stiffness. Physiology & Behavior (2016), vol.163: pp.203–210
[4] Won A.S. , Tataru C.A. , Cojocaru C.M. , Krane E.J. , Bailenson J.N. , Niswonger S. , Golianu B.. Two Virtual Reality Pilot Studies for the Treatment of Pediatric CRPS. Pain Medicine (2015), vol.16: pp.1644–1647
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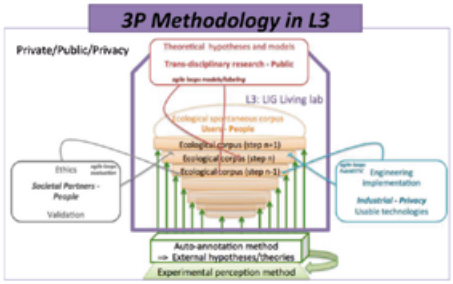
ISAR – INTELLIGENCE IN A SOCIO-AFFECTIVE APPROACH WITH A ROBOT: Speech Primitives for an Expressive Interaction with a Smart Home Robot

Yuko SASA
Supervisors: Véronique AUBERGÉ, LIG and Gang FENG, GIPSA-Lab and Yoshinori SAGISAKA, Waseda University, Tokyo, Japan

Context and Hypothesis

3P Methodology in L3



"Socio-affective glue" as key of a dynamic dialog based on non-dominant altruistic processes
no glue without social role – no social role without glue

graduated prosody levels => robot's only mean of communication and anthropomorphism

1) no speech → 2) pure prosodic mouth noises supposed to be the "glue's" tools → 3) pre-lexicalised cues and interjections/onomatopoeia → 4) commands imitations with supposed "glue" prosody

- Similar communication functions carried by language and more primitive speech cues as pure socio-affective prosody events.
- Understanding interaction process through a damaged communication situation of socio-affective relation (e.g typically elderly) using the primitives cues.

Experiments

external annotations
dialog informational values

auto-annotation

- guided protocol based on ethnomethodology.
- elderly annotate themselves their behaviors, step by step, refering their autobiographical memories.

annotations temporally aligned

same value ??

annotation to be perceptively validated
=> completely external judges

Domus-LIG living-lab

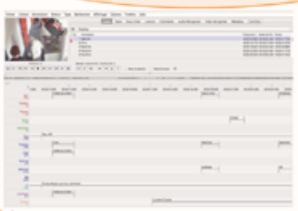
Scenario
controlled and accurate scenario with helpers' assistance to collect a realistic staging

caregivers
Roger Meffreys elderly residence

EmOz : Wizard of Oz interface

smart home automations control
=> 30 voice commands

EEE - Elderly Emox Expressions Corpus
- 24 frail socio-isolated elderly over 75 years old
- total experiments duration: 46:22:42
- 11253 eldery's speech utterances



Emox reactions defined in scripts

theories evaluation

dynamic co-construction of HRI relation

Engineers/researchers controlling Emox & Domus

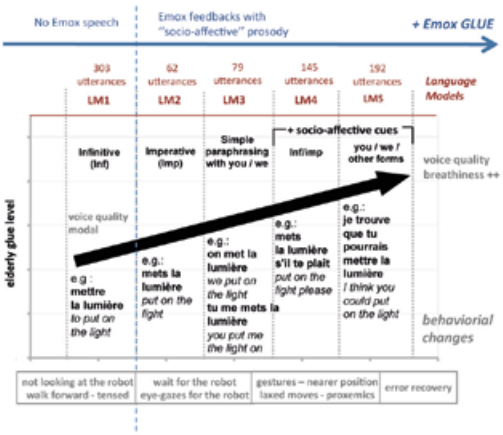
redesign and improvements

new emox

Labelling
aligned descriptive tagging of interactional cues as accurate and objectively measurable as possible
=> not based on any theoretical model

Results & Perspectives

=> ASR recognising the relation statements instead of the words accuracy



Automatic Speech Recognition
Evolutive language model for machine learning

one classical LM vs. multiple glue specific LMs

	LMs						
		6.70%	58.19%	38.10%	14.46%	23.25%	9.39%
		56.25%	25.57%	57.95%	44.32%	56.25%	35.23%
		44.16%	48.72%	13.68%	37.89%	25.64%	16.81%
		44.61%	60.56%	57.54%	22.84%	58.22%	25.75%
		56.22%	60.21%	52.22%	51.62%	18.31%	19.37%
						15.56%	18.11%

Observations:
Multiple LMs seem to be more efficient than the classical single LM but very few data for a machine learning system, so to be extended.

SASI dialog system
Socio-Affective Speech Interaction
(perspectives)
socio-affective dialog bootstrap for interaction training in a adaptive long-life incremental machine learning system

Analysis and evaluation of the "socio-affective glue" degree key points through a global visualisation of micro-dialogue events and temporal organisations.

modified Damerau-Levenshtein algorithm
rule-based : (X) --> (Y) Cost

=> a grammatical edition algorithm's with costs on operators instead of operations

Publications
Y. Sasa, V. Aubergé, F. Aman, "SASI: perspectives for a socio-affectively intelligent HRI dialog system" Interspeech 2017, Stockholm, Suède, 20-24th November, 2017 *(submitted)*
Y. Sasa and V. Aubergé, "Perceived isolation and elderly boundaries in EEE corpus : appeal to communication dynamics with a socio-affectively gluing robot in a Smart Home" 10th World Conference of Gerontechnology (ISG), Nice, France, 28-30th September, 2016
Y. Sasa, R. Magnani, S. Castellanos-Paez, A. Arora, L. Tsvetanou, J. Makonnasse, A. Aithouri-Alyafi, "A Reflective, Adaptive & Communicative Ubiquitous Robot", *Selected for the - Robot Design Competition - of International Conference in Social Robotics (ICSR)*, Paris, France, 26-30th October, 2015.
V. Aubergé and Y. Sasa, "Comment l'interaction rend le robot compagnon en augmentant la réalité sociale : indissociabilité du rôle social et de la glu socio-affective", Journées Nationales de la Robotique Interactive (JNRI), Toulouse, France, 2014.
Y. Sasa and V. Aubergé, "Socio-affective interactions between a companion robot and elderly in a Smart Home context: prosody as the main vector of the "socio-affective glue," presented at the Speech Prosody 7, Dublin, Ireland, 2014.
V. Aubergé, Y. Sasa, N. Bonnefond, B. Meillon, T. Robert, J. Rey-Gomez, A. Schwartz, L. Battista Antunes, G. De Biasi, S. Caffiau, and F. Nebout, "The EEE corpus: socio-affective 'glue' cues in elderly-robot interactions in a Smart Home with the Emoz platform," presented at the 5th International Workshop on EMOTION, SOCIAL SIGNALS, SENTIMENT & LINKED OPEN DATA, Reykjavik, Iceland, 2014.
=> *BEST PAPER AWARD*
Y. Sasa and V. Aubergé, "Caractéristiques prosodiques de la « glu socio-affective » de l'interaction face à face : un robot-compagnon médiateur d'un habitat intelligent pour personnes âgées," published in *Les Cahiers de Linguistiques Françaises* N°31/2014, presented at the 3rd SWIP - Swiss Workshop on Prosody, Genève, Switzerland, 2014.
Y. Sasa, V. Aubergé, A. Rilliard (2013), Audio-Visual micro-expressions within Japanese-French contrast, Proceedings WASSS 2013, Grenoble
Y. Sasa, V. Aubergé, P. Franck, L. Guillaume, S. Mouzahid (2012), Des micro-expressions au service de la macro-communication pour le robot compagnon EMOIX, 54-59, Actes du WACAI 2012, Grenoble

Elie Cattan[1, 2], Pascal Perrier[2], Amélie Rochet-Capellan[2], Francois Bérard[1]
Univ. Grenoble Alpes, LIG[2] - Univ. Grenoble Alpes, GIPSA-lab2[2]

DEFINE

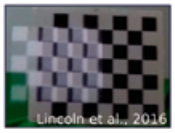
LATENCY

Definition: The delay between a user action and the feedback of this action.

In touch interaction: when the finger is moving, the feedback is late.

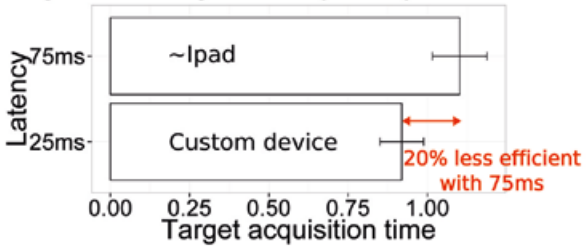
CHALLENGES

Latency is very noticeable in direct interaction



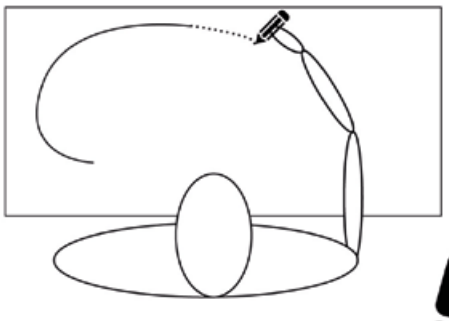
In augmented reality, latency creates a mismatch between virtual and real elements.

Latency, even very low, impacts performances

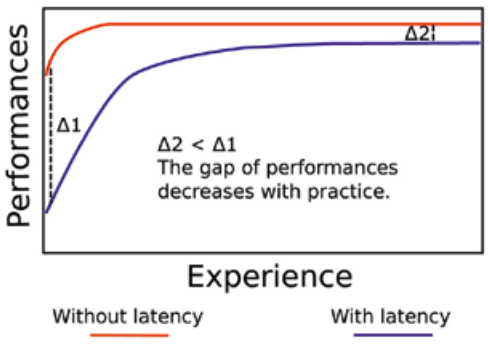


UNDERSTAND

User behaviour with or without latency



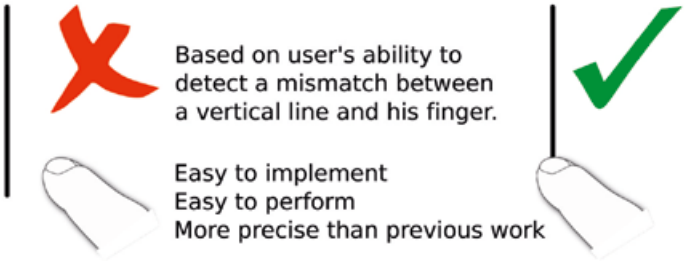
User adaptation to latency



Cattan, E., Rochet-Capellan, A., Perrier, P., and Bérard, F. "Does practice make perfect? Learning to deal with latency in direct-touch interaction". In ACM International Conference on Human Factors in Computing Systems (CHI) (2017)

CONTROL

A new approach to measure the latency



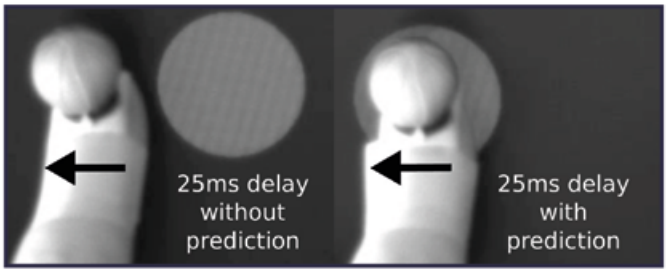
Based on user's ability to detect a mismatch between a vertical line and his finger.

Easy to implement
Easy to perform
More precise than previous work

Cattan, E., Rochet-Capellan, A. and Bérard, F. "A predictive approach for an end-to-end touch-latency measurement". In ACM International Conference on Interactive Tabletops and Surfaces (ITS) (2015).

COUNTERACT

Use prediction to counteract latency



Cattan, E., Rochet-Capellan, A., Perrier, P., and Bérard, F. "Reducing latency with a continuous prediction: Effects on users' performance in direct-touch target acquisitions". In ACM International Conference on Interactive Tabletops and Surfaces (ITS) (2015).

ON ATTITUDE ESTIMATION WITH SMARTPHONES

Thibaud Michel*†‡§¶
Supervisors: Pierre Genevès*†‡¶, Hassen Fourati*†§¶, Nabil Layaïda*†‡¶
*Université Grenoble Alpes, †INRIA, ‡LIG, §GIPSA-Lab, ¶CNRS

Abstract

We investigate the precision of attitude estimation algorithms in the particular context of pedestrian navigation with commodity smartphones and their inertial/magnetic sensors. We report on an extensive comparison and experimental analysis of existing algorithms. We use a precise ground truth obtained from a motion capture system. We test state-of-the-art attitude estimation techniques with several smartphones. Furthermore, we propose a new technique for limiting the impact of magnetic perturbations with any attitude estimation algorithm used in this context.

Attitude

Geo Augmented Reality

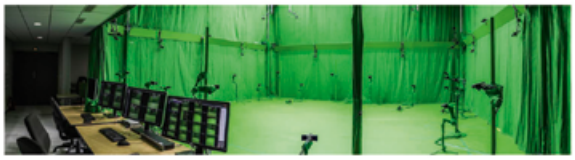
Geo Augmented Reality relies on: smartphone position, smartphone attitude and POIs positions.

Experimental Setup

Motion Lab

126 trials of 2 minutes have been conducted:

- 3 persons with 3 smartphones each.
- 8 typical motions.
- Low and high magnetic perturbations.



Motions

Magnetic Perturbations

Filters

Basic EKF, Sabatini et al. (2006), Choukroun et al. (2006), Mahony et al. (2008), Martin et al. (2010), Madgwick et al. (2011), Fourati et al. (2011), Renaudin et al. (2015), Michel et al. (2016) and from built-in device.

Metrics

The precision error is reported using the Mean Absolute Error (MAE) on:

- Quaternion Angle Difference ($\theta = cos^{-1}(2\langle q_{ref}, q_{est}\rangle^2 - 1)$).
- Euler Angles (Yaw, Pitch, Roll).

Publications

[1] *A comparative analysis of attitude estimation for pedestrian navigation with smartphones*, T Michel, H Fourati, P Geneves, N Layada, International Conference on Indoor Positioning and Indoor Navigation (IPIN), 2015

Results

Overall improvement

During our 126 trials, the proposed filter improves the precision of:

- 100% on Nexus 5
- 300% on iPhones 4S & 5

	iPhone 4S	iPhone 5	LG Nexus 5
Embedded	23.6°	28.6°	12.7°
Existing best	7.1°	8.7°	8.6°
Proposed filter	5.4°	6.5°	5.9°

Calibration

- *Magnetometer* is mandatory.
- *Gyroscope* improves a lot precision.
- *Accelerometer* has a very limited impact.
- *OS-Embedded calibration* is not reliable.

	Mag: No Gyr: No Acc: No	**Mag: Yes** Gyr: No Acc: No	**Mag: Yes** **Gyr: Yes** Acc: No	**Mag: Yes** **Gyr: Yes** **Acc: Yes**	Mag: OS Gyr: OS Acc: No
Proposed filter	82.1°	13.6°	5.9°	5.9°	15.1°

Motions

- There exists a direct correlation between external acceleration magnitude and precision error.
- Filters considering external accelerations do not yield better precision than others.

	AR	Texting	Phoning	Front Pocket	Back Pocket	Swinging	Running Pocket	Running Hand
Embedded	7.1°	5.9°	5.8°	12.7°	13.2°	20.3°	24.4°	62.0°
Existing best and Proposed Filter	4.8°	4.0°	4.4°	4.6°	4.8°	5.3°	6.3°	6.6°

Magnetic Perturbations

- Filters with a detector globally exhibit a better behavior.
- Our technique systematically improved precision compared to their native variant.

	AR	Texting	Phoning	Front Pocket	Back Pocket	Swinging
Embedded	29.0°	24.4°	21.1°	19.8°	37.9°	19.2°
Existing best	16.8°	6.4°	7.3°	8.4°	8.4°	8.9°
Proposed filter	10.6°	5.4°	6.0°	5.8°	7.1°	7.7°

Sampling Rates

- Precision according to sampling rates.

	100Hz	40Hz	10Hz	2Hz
Proposed filter	5.9°	6.0°	14.8°	52.5°

- Sampling rate of our algorithm in a Nexus 5 is more than 10 000 *Hz*.

[2] *On Attitude Estimation with Smartphones*, Michel, Thibaud and Geneves, Pierre and Fourati, Hassen and Layaïda, Nabil, Pervasive Computing and Communications (PerCom), 2017

ANR PERSYVAL-Lab

MEYRON Jocelyn, GIPSA-lab, LJK
Supervisors: ATTALI Dominique, GIPSA-lab MÉRIGOT Quentin, Université Paris-Sud THIBERT Boris, LJK

Abstract

In this work, we are interested in solving multiple non-imaging optics problems. In all the problems we consider, we can recast the problem as an optimal transport problem between a measure supported on the 3D sphere or on the 2D plane and a discrete measure supported on a 3D point cloud for the quadratic cost. We will

1. Show that these problems can be solved using semi-discrete optimal transport,

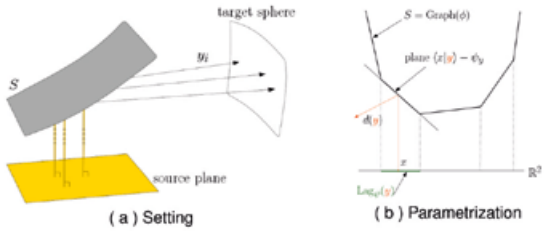
2. Propose an efficient algorithm to solve semi-discrete optimal transport between a measure supported on a triangulated surface and a discrete measure,

3. Prove its convergence,

4. Show numerical results for different optical component design problem.

1. Non-imaging optics and semi-discrete optimal transport

Let us consider the so-called directional reflector problem



(a) Setting (b) Parametrization

[Caffarelli et al, 2008] showed that this problem can be recast as an optimal transport problem between a measure supported on the 2D plane and a discrete measure $\nu = \sum_i \nu_i \delta_{y_i}$ supported on a 2D point cloud $Y = \{y_1, \dots, y_N\}$ for the quadratic cost c. It is well known that semi-discrete optimal transport can be recast as an optimization problem, see [Aurenhammer et al., 1998], [Mérigot, 2010], [Machado et al, 2014]. We can introduce the so-called *Laguerre cells*

$$\mathrm{Lag}_{y_i}(\psi) = \{x \in \mathbb{S}^2 \mid \forall j \in \{1, \dots, n\}, c(x, y_i) + \psi_i \leq c(x, y_j) + \psi_j\}$$

The problem becomes the following: find weights $\psi_1, \dots, \psi_N \in \mathbb{R}$ such that the quantity of mass of the ith Laguerre cell equals the desired amount of mass at y_i namely

$$\text{Find } \psi \in \mathbb{R}^N \text{ such that } \quad G(\psi_1, \dots, \psi_N) = (\nu_1, \dots, \nu_N), \tag{1}$$

where the map $G = (G_1, \dots, G_N) : \mathbb{R}^N \to \mathbb{R}^N$ and G_i is the quantity of mass in the ith Laguerre cell.

Example: Directional reflector

- Reflector parametrized by a maximum of affine functions $\phi(x) = \mathrm{argmax}_i(\langle x \mid y_i \rangle - \psi_i)$ where (ψ_i) denote elevations.
- Cost function: $c(x, y) = \|x - y\|^2$
- Remark: $Lag_{y_i}(\psi) = \mathbb{R}^2 \cap \mathrm{Pow}_{y_i}(\lambda)$. This shows that the problem can also be seen as an optimal transport problem on the plane for the quadratic cost where $\lambda_i = 2\psi_i - \|y_i\|^2$.

In this work, we also discretize the source domain: the sphere is replaced by a triangulation. This allows us to develop a *generic* algorithm in order to solve the optimal transport problem between a measure supported on a triangulated surface in $\mathbb{R}^3$ and a discrete measure supported on a 3D point cloud for the quadratic cost.

2. Damped Newton algorithm

Input:

- A probability measure μ supported on a triangulated surface in $\mathbb{R}^3$
- A measure supported on a point cloud $\nu = \sum_{1 \leq i \leq N} \nu_i \delta_{y_i}$
- A family of weights $\psi^0 \in \mathbb{R}^N$ such that $\epsilon_0 := \min\left[\min_i G_i(\psi^0), \min_i \nu_i\right] > 0$

Output:

- A family of weights ψ^k solving (1) up to η, i.e. $\left\|G(\psi^k) - \nu\right\| \leq \eta$.

While $\left\|G(\psi^k) - \nu\right\| \geq \eta$

- Compute $v^k = -DG(\psi^k)^+(G(\psi^k) - \nu)$
- Determine the minimum $\ell \in \mathbb{N}$ such that $\psi^{k,\ell} := \psi^k + 2^{-\ell} v^k$ satisfies

$$\begin{cases} \min_i G_i(\psi^{k,\ell}) \geq \epsilon_0 \\ \left\|G(\psi^{k,\ell}) - \nu\right\| \leq (1 - 2^{-(\ell+1)}) \left\|G(\psi^k) - \nu\right\| \end{cases}$$

- Set $\psi^{k+1} = \psi^k + 2^{-\ell} v^k$ and $k \leftarrow k + 1$.

Remark: Output weights ψ provide a transport plan: $y \leftrightarrow \mathrm{Lag}_y(\psi)$

3. Convergence of the algorithm

Theorem 1. *Let μ be a measure supported on a triangulated surface S and let $Y = \{y_1, \dots, y_N\}$ be a generic point set with respect to S. Then,*

- *the function G has class $\mathcal{C}^1$ on $\mathbb{R}^N$ and if we denote $\mathrm{Lag}_{y_i,y_j}(\psi) := \mathrm{Lag}_{y_i}(\psi) \cap \mathrm{Lag}_{y_j}(\psi)$, the derivatives of G are given by*

$$\begin{cases} \frac{\partial G_i}{\partial \psi_j}(\psi) = \sum_{\sigma \in \Sigma} \frac{1}{2\|\pi_\sigma(y_i - y_j)\|} \int_{\mathrm{Lag}_{y_i,y_j}(\psi) \cap \sigma} \rho_\sigma(x) \mathrm{d}\mathcal{H}^{d_\sigma - 1}(x) & \forall i \neq j \\ \frac{\partial G_i}{\partial \psi_i}(\psi) = -\sum_{j \neq i} \frac{\partial^2 G_i}{\partial \psi_j}(\psi) & \forall i. \end{cases}$$

- *G is strictly monotone in the sense that*

$$\forall \psi \in K^+, \ \forall v \in \{\mathrm{cst}\}^\perp \setminus \{0\}, \ \langle DG(\psi)v \mid v \rangle < 0.$$

The Damped Newton's algorithm converges in a finite number of steps. Moreover, the iterates of the algorithm satisfy

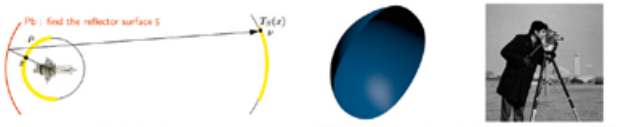
$$\left\|G(\psi^{k+1}) - \nu\right\| \leq \left(1 - \frac{\tau^*}{2}\right) \left\|G(\psi^k) - \nu\right\|,$$

where $\tau^* \in]0, 1]$ depends on μ, ν and ϵ_0.

4. Non-imaging optics and other applications

- The input measure μ is uniform on an hemisphere for point source problems and on a piece of plane for directional problems,
- For each problem, we say how the optical component is parametrized, describe the problem, then we show the surface obtained at the end of the algorithm and finally we do a forward simulation using raytracing given the input measure and the surface.

Far-field reflector: intersection of paraboloids

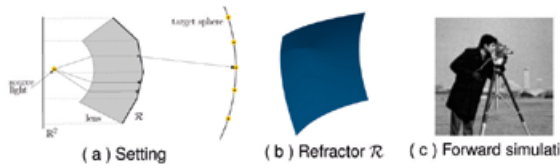


(a) Setting (b) Reflector S (c) Forward simulation

Directional reflector: maximum of affine functions

(a) Reflector S (b) Forward simulation

Directional refractor / lens design: maximum of affine functions



(a) Setting (b) Refractor $\mathcal{R}$ (c) Forward simulation

Other applications of semi-discrete optimal transport:

- Blue-noise sampling on a surface
- Interpolation between two 3D meshes
- Full waveform inversion

Jérémy Wambecke
Supervisors: Georges-Pierre Bonneau (LJK), Renaud Blanch (LIG), Romain Vergne (LJK)

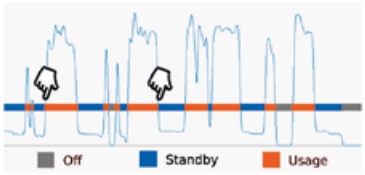
Personal Data

Energy

Physical Activity

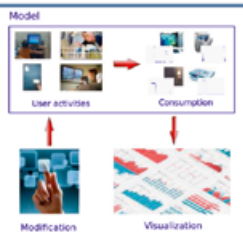
Development of personal informatics allows to reflect on self behavior, to make positive behavior changes. But we need visualization tools to understand the links with behavior.

Modeling



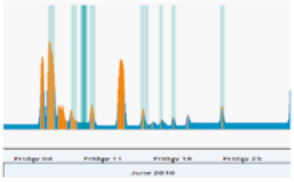
We model the data in 3 layers: raw data (curve), states (colors) and user actions (hands).

What If



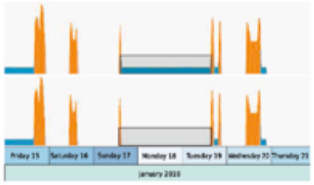
Our principle: allow the user to test scenarios on his data by applying selections of actions and modifications. A feedback is obtained via visualization.

Selection



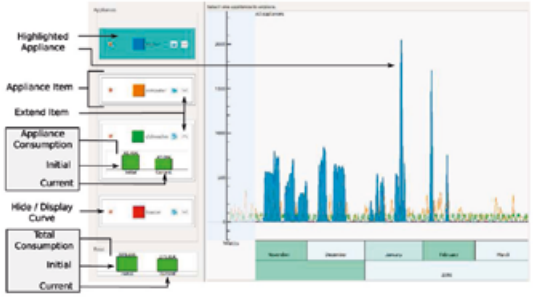
Selection of user actions from criteria based on their properties.
This method allows to explore the space of user actions, to highlight their links with raw data and to modify them.

Modification

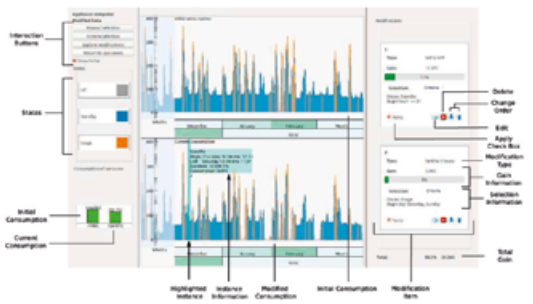


Modifications are applied on user actions, and raw data is computed from the model. The visualization is updated in real time for feedback.

Prototype



We apply our method to home electricity consumption with the development of a prototype.
It is built on two modes, one for all appliances, one to focus and modify an appliance.



User study

We conduct a user study based on 3 tasks:

- Reproduction task for learning, where a target modification has to be applied

- Gain objectives, where the participant has to reach a given gain on an appliance

- Free part (10 min) to study the usage of the system:

Appliance	Total Cons. (cost)	Mean gain (cost)	Mean gain (%)	Mean effort	Total modif.	Different modif.
TV	175	53.03	30.3%	1.8	15	7
Heater	136	28.42	20.9%	1.8	10	4
Computer	116.5	48.35	41.5%	1.7	11	8
Dishwasher	65.5	35.50	54.2%	1.3	13	7
Washing Machine	47.5	19.29	40.6%	1.3	9	4
Tumble Dryer	36	16.63	46.2%	1.3	12	3
Kettle	30	8.22	27.4%	1	6	5
Game Console	17.5	4.78	27.3%	1.3	8	4
Toaster	4.7	0	0%	NA	0	0
Light	3.7	0.08	2.1%	1	2	2

Results show that:

- The learning phase is significant (15 - 20 min) but could be reduced with interface improvements

- The concept (model of data, selections, modifications) is well understood

- Participants could easily use the tool, and thus apply several selections and modifications.

- Our system allows the user to find relevant appliances to save energy on.

MOBILE AUGMENTED REALITY APPLICATIONS FOR SMART CITIES
https://hal.inria.fr/hal-01102797v2/document

TAPIOCA

MOBILE AUGMENTED REALITY

RHUM - ROBOT NINA

ADVANCED DATA MINING

Coordinators

GIPSA-lab:
Pierre Comon
LIG: Massih-Reza Amini

Scientific committee

GIPSA-Lab:
Pierre-Olivier Amblard,
Mauro Dalla Mura,
Anne Guerin,
Bertrand Rivet,
Michele Rombaut
Inria: Jakob Verbeek
Inria/LIG: Nabil Layaida
LIG: Renaud Blanch,
Ahlame Douzal,
Georges Quénot
TIMA: Frédéric Pétrot
TIMC: Olivier François,
Pierre-Yves Guméry

The goal of the ADM research track is to propose new models, algorithms and tools for mining knowledge from the physical world, seen as a planetary sensor network producing distributed flows of digital data. The focus is on online mining of distributed data flows that are digital traces of events, objects, usages or phenomena arising in the physical world. It is crucial to provide automatic tools to analyze those data flows in order to discover relevant information in them, and to do it online so that we can act on the physical world and take appropriate decisions if necessary.

The main challenges that are addressed are related to large scale prediction for data-mining specially the following points:

- Online mining of data streams
- Mining multi-modal data
- Decentralized data mining

ADM ADVANCED DATA MINING

> PROJECT-TEAMS

> EXPLORATORY PROJECTS

> PhDs

DeCoRe

Deep convolutional and recurrent networks for image, speech, and text

ADM

Deep convolutional neural networks (CNNs) and recurrent neural networks (RNNs) have recently yielded breakthroughs in different areas, including object recognition, machine translation, and speech recognition. One of the key distinguishing properties of these approaches, across different application domains, is that they are end-to-end trainable.

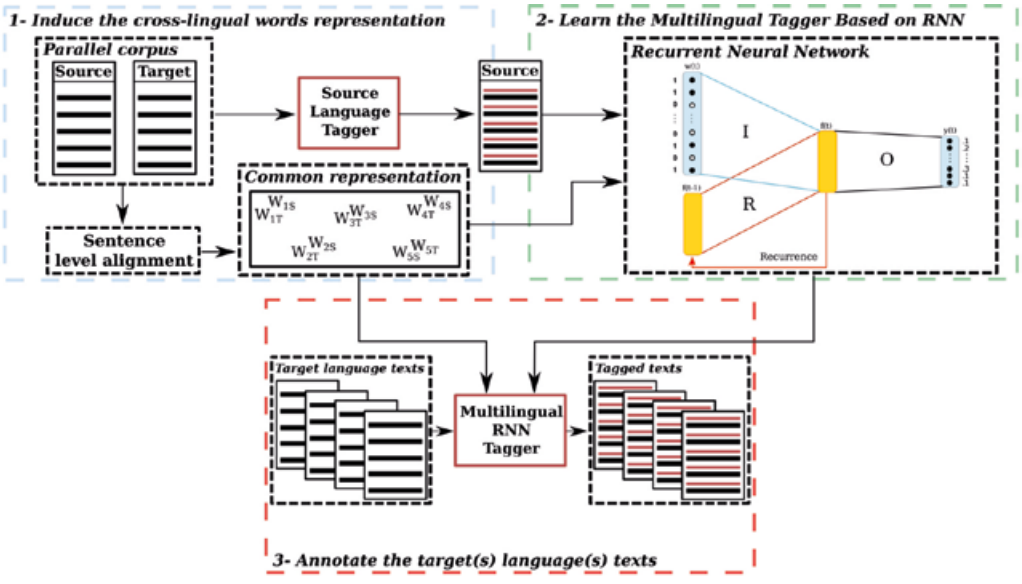
Conventional methods typically rely on a signal pre-processing stage in which features are extracted, such as MFCC for speech, or SIFT for images. In deep end-to-end trainable systems each processing layer (from the raw input signal upwards) involves trainable parameters which allow the system to learn the most appropriate features.

DeCoRe federates researchers from computer vision, machine learning, speech, natural language processing, and information retrieval, to foster collaborative research in this rapidly evolving area which is likely to underpin future advances in these research areas for the next decade.

Website: http://project.inria.fr/decore

Main Scientific Results and Ongoing Work

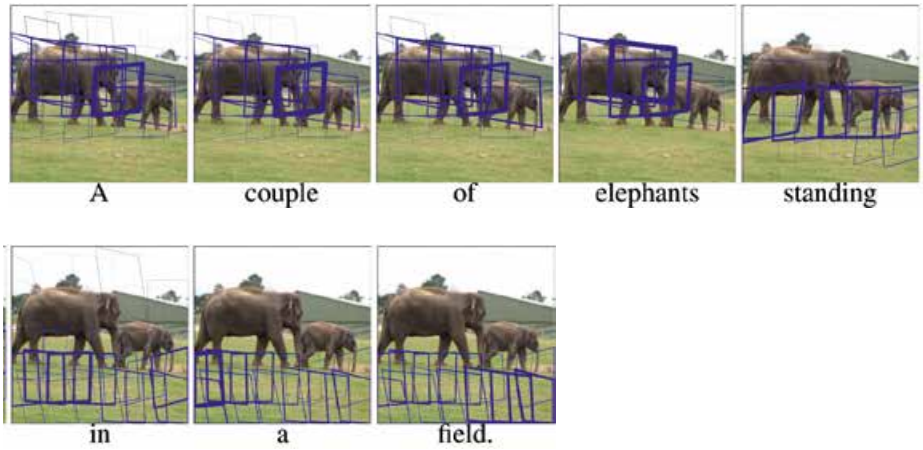
Automatic generation of natural language description of images:
Great progress in automatic generation of natural language image captions has recently been made using encoder-decoder models. These encode the image content using a convolutional neural network into a vector representation. A recurrent neural network decoder takes this vector representation and uses it to sequentially write a natural language sentence conditioned on the image content. We have developed a model based on this encoder-decoder paradigm, which sequentially attends to different image regions as the sentence is produced. This allows us to produce better image captions as local visual appearances can be associated with caption words, instead of having to pass all visual information through a single global image representation. This work has been submitted for publication [3].



Coordinators

GIPSA-lab:
Denis Pellerin
Inria/LJK:
Jakob Verbeek
LIG: Laurent Besacier, Georges Quénot

In another work we have proposed a neural network for cross-lingual projection of annotations in natural language processing [5].



Object recognition and localization:
In a starting PhD work, we are working on object recognition and localization techniques in contexts with many (more than 1,000) object classes and continuous data streams for learning.

Valorization

Research efforts in DeCoRe have already led to two submissions to the 2017 CHIST-ERA call on lifelong learning systems:
- LLAMA: Lifelong Learning Approaches for Multimedia Analysis.
- ADEL2: Autonomous Driving Enabled by Lifelong Learning.

Some relevant publications

- A. Berard, O. Pietquin, C. Servan, and L. Besacier. **Listen and translate: A proof of concept for end-to-end speech-to-text translation.** In NIPS Workshop on end-to-end learning for speech and audio processing, 2016.
- P. Luc, C. Couprie, S. Chintala, and J. Verbeek. **Semantic segmentation using adversarial networks.** In NIPS Workshop on Adversarial Training, 2016.
- M. Pedersoli, T. Lucas, C. Schmid, and J. Verbeek. **Areas of attention for image captioning.** arXiv:1612.01033.
- S. Saxena and J. Verbeek. **Convolutional neural fabrics.** In Advances in Neural Information Processing Systems (NIPS) 29, 2016.
- O. Zennaki, N. Semmar, and L. Besacier. **Inducing multilingual text analysis tools using bidirectional recurrent neural networks.** In COLING, 2016.

KRONOS

Data Mining of Temporal Data

ADM

The tremendous production of data, known as the big data phenomena, has overturned the classical view in science and information technology domains, notably in the statistical machine learning field.

In many real problems, particularly associated with the Internet but not only, massive data streams are continuously produced. This is for example the case of new types of data describing the diffusion of information in social networks (social dynamics), the organization of textual content in blogs (topic models), the various human activities in videos (human action recognition) and the tastes of the users (collaborative filtering) available on the Web. Beyond their sequential nature, the data have generally a complex internal structure, such as those describing the electrical consumption curves, or for which the basic assumption in machine learning stipulating that the observations are identically and independently distributed with respect to a fixed probability distribution is no longer verified. The focus of the Kronos project-team has been to design scalable learning algorithms able to solve complex tasks such as large-scale multi-class classification or signal recovery and to handle data with a possible unknown structure.

Website: http://ama.liglab.fr/Khronos/

Main Scientific Results and Ongoing Work

Large-scale structure-adaptive signal recovery - PhD thesis of Dmitrii Ostrovskii
Our focus is on some problems of high-dimensional statistics where the signal has a local unknown structure, like for instance, in textured image recovery, speech segmentation, and sparse recovery problems in statistical signal processing. In this case, a well-performing linear filter cannot be computed beforehand. We have proposed to use a non-linear filtering that can be estimated from data with a low complexity thanks to the Discrete Fourier transform operator and the l1 norm (Figures 1 & 2). We have provided in [2] a simple sufficient condition, called approximate shift-invariance, for the effectiveness of this procedure, and we have shown that several important statistical models satisfy this condition, most notably nonparametric kernel regression and line spectral signal estimation [3]. We have shown that approximate shift-invariance guarantees that there exists an oracle filter with a good statistical performance, and that the non-linear filter learnt by our procedure has a similar performance to that of the oracle.

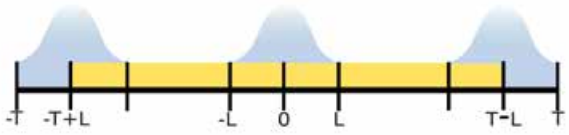


Figure 1: Schematic representation of linear time-invariant filtering. Given a signal on the domain $[-T, T]$, a filter with bandwidth $L \leq T$ can be applied in the central region of the observation domain.

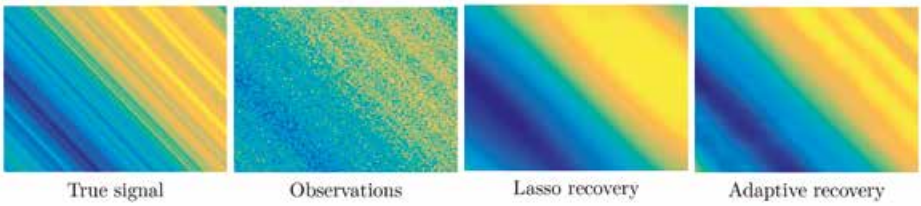


Figure 2: Recovery of a single-index signal $f(t) = g(\theta^T t)$, with unknown index θ, observed in the Gaussian noise. Our adaptive recovery algorithm clearly outperforms the lasso estimator.

Coordinators

CEA: Thomas Burger
LIG: Massih-Reza Amini
LJK: Anatoli Juditsky
TIMC-IMAG: Julie Fontecave

Scalable learning algorithms for distributed collaborative filtering and large-scale multi-class classification - PhD thesis of Bikash Joshi

To avoid the undesirable scaling of the sample complexity with respect to the number of classes, we have designed a new approach based on learning a combination of similarity features between instances and classes, where the similarities are computed by identifying a class with the set of its representative examples. We have studied the consistency of learning with pairs of observations and classes by analyzing the associated dependency graph (Figures 3&4) and shown that a reduction of the initial multi-class classification of examples into a binary classification of pairs of examples and classes allows to learn a single parameter vector with a dimension that does not depend on the number of classes. We have empirically demonstrated that this approach is competitive with state-of-the-art multiclass classification approaches, in particular in terms of the macro F-measure, which gives higher emphasis to the correct prediction of rare classes than the classification accuracy. In addition, the number of parameters the algorithm learns is of order 107 times less than conventional multiclass classification models, which makes the approach appealing for large-scale classification.

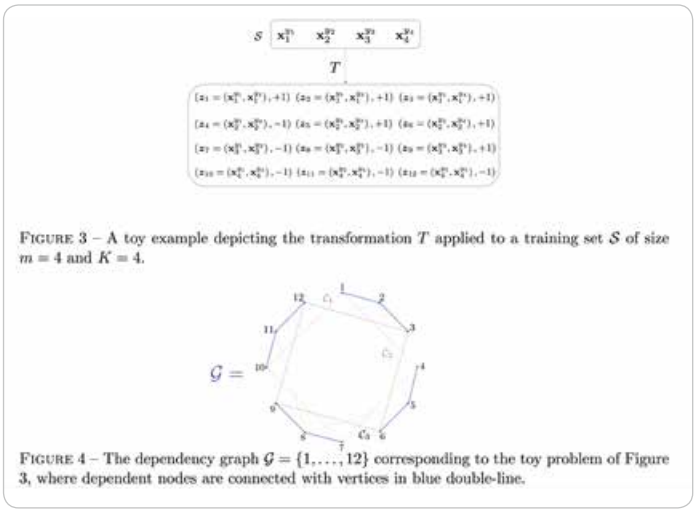


FIGURE 3 – A toy example depicting the transformation T applied to a training set $\mathcal{S}$ of size $m = 4$ and $K = 4$.

FIGURE 4 – The dependency graph $\mathcal{G} = \{1, \ldots, 12\}$ corresponding to the toy problem of Figure 3, where dependent nodes are connected with vertices in blue double-line.

Valorization

Industrial collaborations:
KRONOS was a launching pad for the FUI project Calypso (2015-2017) with Purch and Kelkoo on on-line advertising.

Scientific dissemination:
- Organization in Grenoble of "Conférence sur l'Apprentissage Automatique" Cap 2017 June 28-30 2017.
- In partnership with the Persyvact2 project-team, organization in Grenoble of the international workshop on *Statistical Tools for Data-Mining* May 22-23 2016, and of spring and summer schools on *high-dimensional statistics and optimization for big data* in June 2014, and on *large-scale sparse learning* in April 2015.

Some relevant publications

- Babbar R., Partalas I., Gaussier E., Amini M.-R., Amblard C. **Learning Taxonomy Adaptation in Large-scale Classification.** Journal of Machine Learning Research (JMLR), 17(98):1-37, 2016.
- Ostrovsky D., Harchaoui Z., Juditsky A., Nemirovski A. **Structure-blind signal recovery.** 30th Annual Conference on Neural Information Processing Systems (NIPS), pp. 4817-4825, 2016.
- Harchaoui Z., Juditsky A., Nemirovski A., Ostrovsky D. **Adaptive recovery of signals by convex optimization.** Proceedings of the 28th Conference on Learning Theory (COLT), pp. 929-955, 2015.
- Joshi B., Amini M.-R., Partalas I., Ralaivola L., Usunier N., Gaussier E. **On Binary Reduction of Large-scale Multiclass Classification Problems.** 14th International Symposium on Intelligent Data Analysis (IDA), pp. 132-144, 2015.
- Babbar R., Partalas I., Gaussier E., Amini M.-R. **On Flat versus Hierarchical Classification in Large-Scale Taxonomies.** 27th Annual Conference on Neural Information Processing Systems (NIPS 26), pp.1824-1832, 2013.

OCULO NIMBUS

New statistical models to understand and predict oculometric data

ADM

In vision, the interaction that man has with its environment is realized by a dynamic exploration of visual regions of interest through eye movements. This project-team aims to develop new statistical tools for the analysis of eye movement and multimodal data.

The statistical developed tools are applied in order to: (i) segment spatiotemporal data into comprehensive cognitive phases, (ii) analyze spatiotemporal dependencies for explaining within and between individual differences, and (iii) model ocular fixations with a higher spatial resolution for understanding the functional roles of microsaccades in visual perception. The originality of the project is to capture information from eye movements at different scales: spatio-temporal scale from saccades to micro-saccades (miniature eye movements during multistable perception), cognitive scale from low-level information extraction to high level tasks and usages, and in a multimodality context (joint with electroencephalography, and with mouse tracking).

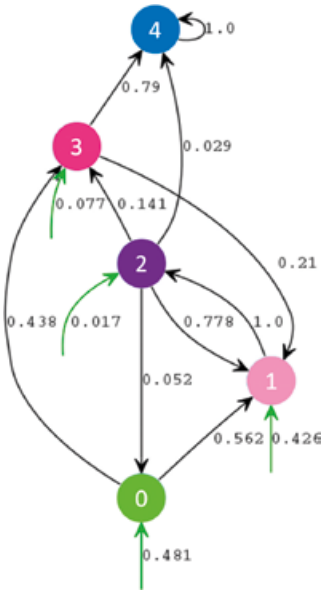
Website:
https://persyval-lab.org/en/sites/oculo-nimbus

Main Scientific Results and Ongoing Work

Scalable inference techniques for spatial point process models - Mélisande Albert's postdoctorate work.
We have focused on semi-parametric models, which involve both a regular parametric part and a non-parametric one. The non-parametric part is often modelled using a Gaussian process, but here we chose to focus on a sparse decomposition approach, which has the potential for better scalability, and is better able to capture abrupt changes in function value. First results have been obtained to validate the use of an adaptive L1 penalty (adaptive Lasso).

Chromatic and luminance information in visual perception - PhD of Camille Breuil
We have conducted an evaluation of the dependence between chromatic and luminance information in images to further analyze the effect of this information redundancy on eye movements. We have found that the estimated amount of mutual information depends on how the images are processed. The most critical step is divisive normalization, a late stage in the processing pipeline. How redundant chrominance and luminance are, may thus depend on the precise definition of these two quantities, explaining some inconsistencies in the literature.

Inference of intertwined phases from oculomotors traces - PhD of Brice Olivier
Oculomotors traces were obtained from experiments, in which subjects had to make some press reviews. In such tasks, reading process and decision making are closely related. We have used Hidden semi-Markov model (HSMM) that showed to be the most powerful tool satisfying all our needs. Indeed, a HSMM is characterized by meaningful parameters such as an initial distribution, transition distributions, emission distributions and sojourn distributions, which allows us to directly characterize a reading strategy. We plan to develop and implement a model for jointly analyzing eye-movements and EEGs in order to improve the discrimination of the reading strategies, and also to define coupled HMM with multimodal observations, to segment cognitive phases, based on using combined eye-tracking and mouse-tracking empirical studies.



Example of a segmentation of a scanpath (top) into cognitive phases estimated by a HSMM with 5 hidden states.
The interpretation of the states in the transition graph (left) is:
state 0 for the initialization,
state 1 for thorough reading,
state 2 for speed reading,
state 3 for normal reading,
and state 4 for confirmation phase (absorbing state).

Coordinators

GIPSA-Lab:
Anne Guérin,
Simon Barthelmé
LJK:
Jean-Baptiste Durand

Functional role of ocular micro-movements - Phd of Kevin Parisot.
At a finer spatio-temporal scale, ocular micro-movements (microsaccades occurring during eye fixations) have been identified as a noise factor facilitating decision making processes during perception. Theoretical models based on stochastic resonance allow for an improvement in the prediction process of decision making. Through a new PhD, we have started to work on explanatory models of these perceptional phenomena in the framework of multistable perception.

Valorization

The study about the functional role of the microsaccades is realized in the framework of the multistable perception. To that end, new collaborations have been initiated: with Jean Michel Hupé (CR-CNRS) at the “Centre de Recherche Cerveau & Cognition” (CERCO, Toulouse), and with Eugenio Rodriguez (Pr.) at the laboratory of “Neurodinámica básica y aplicada”, “Universidad Católica” (Santiago de Chile).

Some relevant publications

- Kristensen, E., Guérin-Dugué, A. & Rivet, B., (2017). **Regularization and a General Linear Model for Event-Related Potential Estimation,** Behavior Research Methods, in press.
- Kristensen, E. & Rivet, B. & Guérin-Dugué, A. (in revision). **Estimate overlapped Eye Fixation Related Potentials: General Linear Model a more flexible framework than ADJAR algorithm,** Journal of Eye Movement Research.
- Quinton, J-C. & Goffart L. (in revision) **A unified dynamic neural field model of goal directed eye-movements.** Connection Science.
- Breuil, C., Barthelmé, S., Guyader, N. (2017). **How redundant are luminance and chrominance information in natural scenes?** Visual Society Conference, VSS2017, Florida, 19-24 may.
- Quinton, J-C. & Goffart, L. (2016). **A neural field model of the dynamics of goal-directed eye movements.** Colloque du GDR BioComp, Lyon, 10-12 octobre.

PERSYVACT2

Structured Models and Algorithmic Methods for Analysing Complex High-dimensional Data in Biomedical Applications

ADM

The Persyvact2 project-team aims at developing cutting edge data science methodologies to analyse large biomedical data generated from neuroscience, genomics, and clinical trial research.

The key structures of biomedical data that Persyvact2 exploit consist of graph structure, repeated experiments and their intrinsic lower dimensional representation. The aim of Persyvact2 is to perform collaborative research by bringing together researchers of different scientific fields of data science such as statistics, machine learning, image and signal processing. Persyvact2 seeks to enhance the international visibility of data science in Grenoble.

Website:
https://persyval-lab.org/en/sites/persyvact2

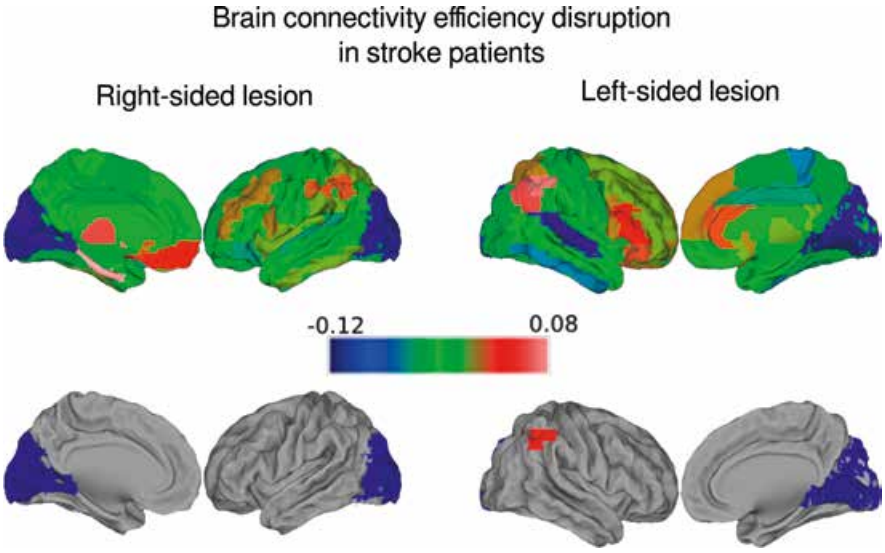
Main Scientific Results and Ongoing Work

Genome Scans

We have delivered the R package pcadapt to look for footprints of natural selection in human genomes [1,2]. It assumes that candidate markers are outliers with respect to how they are related to population structure. Because population structure is ascertained with principal component analysis, the package is fast and works with large-scale data. It can handle missing data and pooled sequencing data. By contrast to population-based approaches, the package handles admixed individuals and does not require grouping individuals into populations. The package has been applied to a large human genomic dataset to find genes involved in adaptation. Another R package to find associations between genomic data and diseases is currently developed by Florian Privé whose PhD is funded by Persyvact2 (https://github.com/privefl/bigsnpr).

Neuroscience

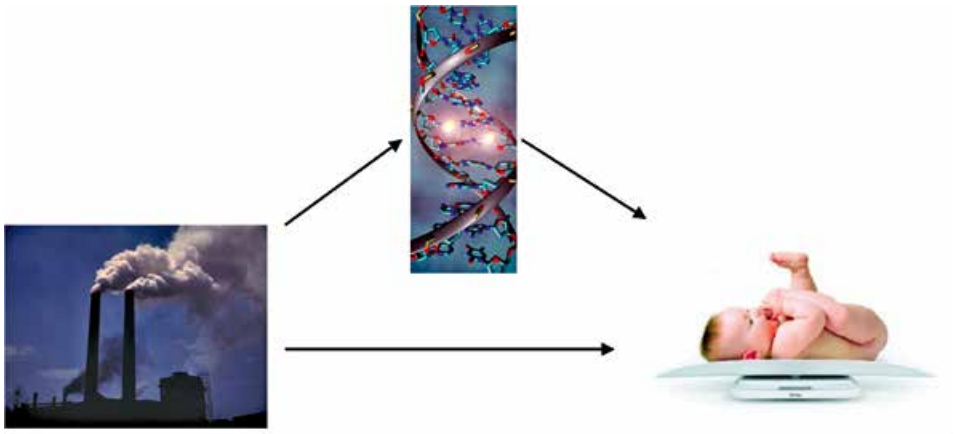
We have constructed a new graph metrics entitled the “hub disruption index”. This metric allows to show that stroke induces a network-wide pattern of reorganization in the contralesional hemisphere [4]. We anticipate that graph modeling and metrics such as the “hub disruption index” can become a useful tool for clinical applications. Karina Ashurbekova is starting her PhD funded by Persyvact2 on the subject of robust graphical modeling with application to brain connectivity.



Coordinators

GIPSA-Lab:
Pierre-Olivier Amblard
LJK:
Adeline Leclercq-Samson
TIMC-IMAG:
Michael Blum

Epigenetic
We are collaborating with epidemiologists from the Grenoble Institute for Advanced Biosciences with whom we organize the Epigenetic & High-Dimension Mediation Data Challenge (June 7-9 2017, Aussois). The objective is to understand if epigenetic mediates the effect of environmental exposures (air pollution) on child health. The Data Challenge in Aussois seeks to evaluate statistical methods of mediation when there are a very large number of potential mediators.



Pharmacokinetic
We focus on stochastic modeling in biology (pharmacokinetic, tumor growth under immunotherapy) based on mixed models. We have developed new optimization algorithms (penalized stochastic EM, stochastic proximal gradient algorithms) to select genes that influence the pharmacokinetic of drugs [3]. In tumor growth modeling, we have proposed an individual-based stochastic model. The PhD thesis of Modibo Diabate, partially funded by Persyvact2, aims at providing estimation procedures for these models.

Valorization

Scientific dissemination
Organization in Grenoble of the international workshop *STATLEARN Statistical Tools for Data-Mining* May 22-23 2016, jointly with the Kronos project-team, and of the *journées MAS (stochastic processes and statistics)* in Grenoble in 2016.

Cross-disciplinary Research
Our project-team has been a leading force for the creation of the Grenoble Data Institute that will be funded by the IDEX Université Grenoble Alpes (2017-2020) through the Cross Disciplinary Research project DATA@UGA. A 3-year junior chair whose research concerns data-science applied to biomedical data will be recruited.

Some relevant publications

- Duforet-Frebourg N, Luu K, Bazin E, Blum MGB (2016). **Detecting Genomic Signatures of Natural Selection with Principal Component Analysis: Application to the 1000 Genomes Data.** Molecular Biology and Evolution. 33:1082-1093.
- Martins H, Caye K, Luu K, Blum MGB, François O (2016) **Identifying outlier loci in admixed and in continuous populations using ancestral population differentiation statistics.** Molecular Ecology 25:5029–5042.
- Ollier E, Samson A, Delavenne X, Viallon V (2016) **A SAEM Algorithm for Fused Lasso Penalized Non Linear Mixed Effect Models: Application to Group Comparison in Pharmacokinetic.** Computational Statistics and Data Analysis. 96:207-221.
- Termenon M, C Delon-Martin, A Jaillard, Achard S (2016). **Reliability of graph analysis of resting state fMRI using test-retest dataset from the human connectome project.** Neuroimage 142:172–187.

ATTENTIVE Development of a companion robot for the surveillance of fragile people

Coordinators

GIPSA-Lab:
Denis Pellerin,
Michèle Rombaut
LIG: Olivier Aycard,
Catherine Garbay

The surveillance of fragile persons by sensors placed on infrastructure (cameras, microphones) is generally poorly accepted because these sensors are too intrusive. Moreover, integration of these sensors into the infrastructure requires costly investments and their installation is often complex. To avoid such a situation, we have designed an experimental platform made up of a robot able: (i) to move, (ii) to perceive its environment, (iii) to focus its attention and (iv) to navigate in dynamic environments. The implemented algorithms concern data processing and fusion, target location and tracking, situation analysis and adaptation of the perception system.

Qbo robot with laser-sensor leg detection

Website: http://persyval-lab.org/en/content/attentive

Results

We have first proposed a system of classification of sound events in indoor environment [3], and an audiovisual fusion for the detection of successive speakers in a conversation [4]. Then we studied and developed a multimodal navigation system dedicated to the detection of humans [1]. This system is implemented on a Q.bo™ robot equipped with several sensors (laser, video camera, microphones). The robot chooses its route from its perception maps based on a belief modeling of the environment [2].

Some relevant publications

- Ratajczak R., Pellerin D., Labourey Q., Garbay C., A fast audiovisual attention model for human detection and localization on a companion robot, First Int. Conf. on Applications and Systems of Visual Paradigms (VISUAL 2016), Barcelona, Spain, November 2016.
- Labourey Q., Aycard O., Pellerin D., Rombaut R., Garbay C., An evidential filter for indoor navigation of a mobile robot in dynamic environment, Int. Conf. on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU'2016), Eindhoven, The Netherlands, June 2016.
- Labourey Q., Pellerin D., Rombaut M., Aycard O., Garbay C., Sound classification in indoor environment thanks to belief functions, European Signal Processing Conference (EUSIPCO'2015), Nice, France, August 2015.
- Labourey Q., Aycard O., Pellerin D., Rombaut M., Audiovisual data fusion for successive speaker tracking, Int. Conf. on Computer Vision Theory and Applications (VISAPP'2014), Lisbon, Portugal, January 2014.

GeoDialect Exploring geomatics tools for geolinguistic analysis

Coordinators

GIPSA-Lab:
Didier Demolin
LIG:
Paule-Annick Davoine

Dialectology addresses the study of the linguistic features of languages having a strong oral tradition such as local dialects. These linguistic features are various: phonetic, morphosyntactic, lexical, semantic or prosodic. To study local dialects, corpuses of phonetic data have been transcribed into linguistic atlases. We focus on the Linguistics Atlas of France (ALF), a major dialectological tool elaborated at the beginning of the 20th century. This cartographic heritage, unique in the world, produces first-rate data for dialectological researches. While theoretical approaches used for the construction of linguistic atlas are structured, the processing and the phonetic analysis of data, as well as the elaboration of interpretative maps, are still manually achieved, and software solutions are missing in geolinguistics.

Website: http://persyval-lab.org/en/exploratory-project/GeoDialect

Results

1900 ancient maps have been digitalized with a high-resolution and integrated into a webmapping tools, in order to promote the use of ALF [1]. A data model and a methodology have been proposed to integrate geolinguisitcs data into a Geographical Information System [2]. An algorithm to create automatically isoglosses (limits separating different lexical areas) and cartographical representations for geolinguistics analysis has been developed [3]. Thanks to the collaboration with L3i Laboratory, we have explored an algorithm to recognize phonetics symbols printed on the ALF maps, in order to propose a method to extract automatically the cartographical content and vectorization of old maps. GeoDialect has launched a first and decisive impulse for starting a long-term research project around the development of innovative methods for extracting and analyzing the linguistic features and the geographical data included in collection of old cartographic documents (PEPS en Réseau HuMain CartoDialect and ANR-15-CE38-0002 ECLATS) https://eclats.imag.fr/.

Some relevant publications

- http://cartodialect.imag.fr/
- Gally S., Chauvin C., Davoine P.-A., Demolin D., Contini C., GeoDialect: exploration des outils géomatiques pour le traitement et l'analyse des données géolinguistiques, Revue "Géolinguistique", vol. 14-2014, ELLUG, Grenoble,
- Davoine P-A, Chauvin C., Gally S., Garat Ph, Oton C., "New approach to explore and to study cartographic heritage in dialectology: application to the Linguistic Atlas of France", International Cartographic Conference, ICC 2015, Rio de Janeiro, Brasil August 23-28, 2015
- Quoc Bao Dang, Muhammad Muzzamil Luqman, Mickael Coustaty, Nibal Nayef, Cao De Tran, Jean-Marc Ogier - A multi-layer approach for camera-based complex map image retrieval and spotting system, IEEE IPTA 2014

Med_L&T_med Mining educational data to analyze learning and teaching methods, the case of medicine

The goal was to explore a general technical and pedagogical framework to support decisions in the context of technology enhanced learning (TEL) in the medical domain in which we can find several learning situations using emerging pedagogical approach (flipped classroom) with classical TEL (MCQ answers), like in PACES, or innovative pedagogical approach with new TEL systems (Serious games, simulators), like LOE or TELEOS.

Website: http://persyval-lab.org/en/exploratory-project/MedLTmed

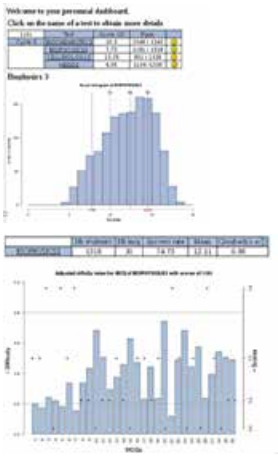
Results

We conducted several analyses based on PACES data. The most significant results are the development of suitable dashboard for learner, for teachers and for the administration through a qualitative and quantitative statistical analyses of answers on MCQs to tutorials and examination of students of the first year of health contest in Grenoble from 2006 to 2015. These results are a powerful synthesis for a student to evaluate his progression into his personal pathway of learning, for teachers to improve the quality of different MCQ series and detect the student dropout and for administration to help pedagogical decisions.

We also conducted several analyses based on a particular simulator for orthopedic surgery (TELEOS project http://teleos.imag.fr/) that need particulars algorithms and methods to understand the perception and gesture behavior during learning situations. This work is pursued now in the ANR project Hubble (http://hubblelearn.imag.fr/)

Coordinators

LIG: Vanda Luengo
TIMC-IMAG: Pierre Gillois



Some relevant publications

- Toussaint, B.-M., Luengo, V. and Jambon, F. and Tonetti, J. From Heterogeneous Multisource Traces to Perceptual-Gestural Sequences: the PeTra Treatment Approach. Proceedings of the 17th International Conference on Artificial Intelligence in Education (AIED 2015), Madrid, Spain. LNCS, vol. 9112, pp. 480-491. Springer, Heidelberg (2015).
- Toussaint, B.-M., Luengo, V. Mining surgery phase-related sequential rules from vertebroplasty simulations traces.Proceedings of the 15th International Conference on Artificial Intelligence in Medicine (AIME 2015), Pavia, Italy. LNCS, vol. 9105, pp. 32–41. Springer.
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PhonStat modeling and statistical analysis of experimental data in speech and cognition

Speech and Cognition department of GIPSA-lab studies the development of spoken communication in infants, the detection of dysfunction in voice and speech and how to prevent it. Experimental data are measured for several subjects and with repetitions in different conditions. The statistical analysis of these data requires to take into account the different sources of variability (mixed models) and to select the best model (variance-covariance matrix of the random effects, predictive covariates).

Website: http://phonestat2014.imag.fr/

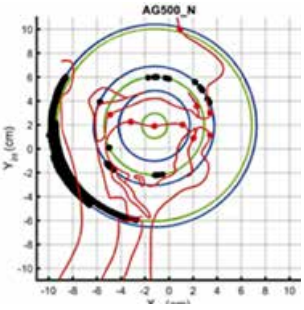
Results

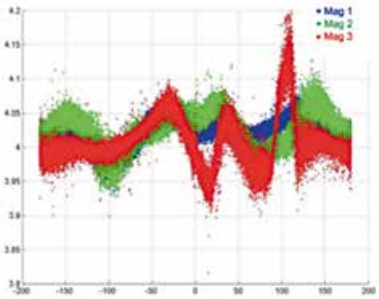
We have produced methodological papers explaining the advantage of mixed models for statistical analysis. We have just submitted one paper on frailty model, also called Cox models with random effects. These models are especially adapted to duration data, which are frequent in speech and language data.

We have also worked on penalization methods for mixed models. Penalized approaches have been developed for selecting covariates in linear mixed model, but few deal with covariance matrix selection because the penalized problem is non-convex. We are currently working on this extension. We have also developed a penalized approach for non-linear mixed models.

Coordinators

GIPSA-Lab: Maeva Garnier
LJK: Adeline Leclercq-Samson





Some relevant publications

- Bourne T, Garnier M, Samson A. Physiological and acoustic characteristics of the male music theatre voice. Journal of Acoustical Society of America, 140, 610, 2016.
- Ollier E, Samson A, Delavenne X, Viallon V. A SAEM Algorithm for Fused Lasso Penalized Non Linear Mixed Effect Models: Application to Group Comparison in Pharmacokinetic. Computational Statistics and Data Analysis, 96:207-221, 2016.
- Savariaux C, Badin P, Samson A, Gerber S. A comparative study of the precision of Carstens and NDI electromagnetic articulographs. Journal of Speech, Language, and Hearing Research, to appear.
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- Remacle A, Garnier M, Gerber S, David C, Petillon C. Identification of different vocal evolutions with a teaching day: Inter- and intra-subject variations. Journal of Voice (in revision).

CAFE&Test Causal feature selection for machine learning test of analog, mixed-signal and RF systems

Coordinators

IMSE-CNM, Seville, Spain: Gildas Léger
LIRIS, Lyon: Alexandre Aussem
TIMA: Manuel J. Barragán

The test of analog, mixed-signal and RF (AMS-RF) blocks embedded in complex systems has become a challenging, costly and time consuming task that has been identified as one of the main bottlenecks in the production of current and future integrated systems. This project brings together the expertise of microelectronic designers, test engineers and data mining mathematicians with the goal of exploring, identifying and developing systematic methodologies for reliable and accurate built-in Indirect Test strategies for AMS-RF complex systems.

Fig. 1 Machine learning based production test of integrated circuits.

Website: http://persyval-lab.org/en/exploratory-project/CAFETest

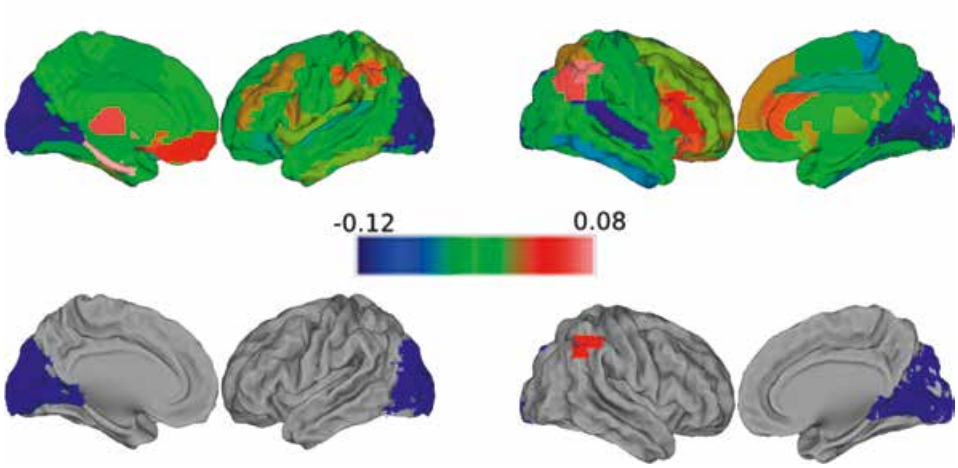
Results

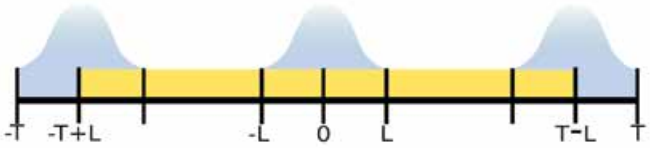
Indirect test reduces the complexity and cost of production tests by replacing conventional functional tests at the production line for a set of low-cost indirect observations, often called signatures (see Fig. 1). Test results are then inferred by post-processing these signatures by building non-linear multi-dimensional regression models. The underlying idea is that signatures are easier to measure than specifications and can be extracted using low-cost equipment, or even by simple on-chip built-in test instruments that can be integrated together with the Device Under Test.

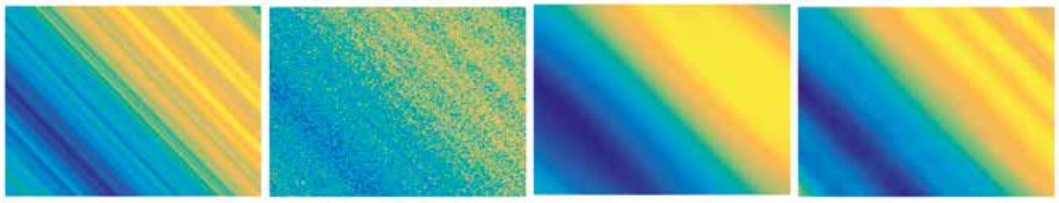
This project has already strengthened the international collaboration between TIMA (Grenoble, France) and IMSE-CNM (Seville, Spain). The work under development has been the key for a joint 3-year CNRS PICS project that has been recently accepted for funding.

Some relevant publications

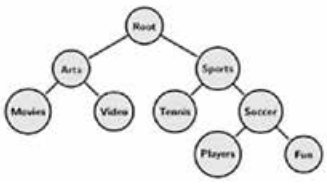
- G. Leger and M. J. Barragan, Questioning the reliability of Monte Carlo simulation for machine learning test validation, 21th IEEE European Test Symposium (ETS), Amsterdam, 2016, pp. 1-6.
- G. Leger and M. J. Barragan, Brownian distance correlation-directed search: Afast feature selection technique for alternate test, Integration, the VLSI Journal, vol. 55, September 2016, pp. 401-414.
- M. J. Barragan, G. Leger, A. Gines, E. Peralias, A. Rueda, On the limits of machine learning-based test: a calibrated mixed-signal system case study. Design Automation and Test in Europe 2017 (DATE'17), accepted for publication.

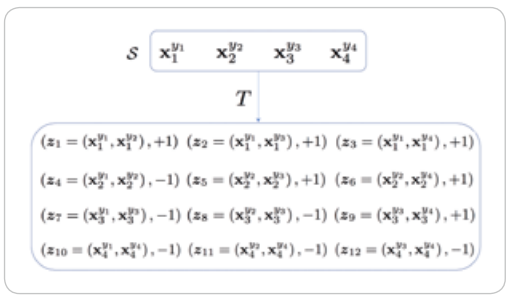


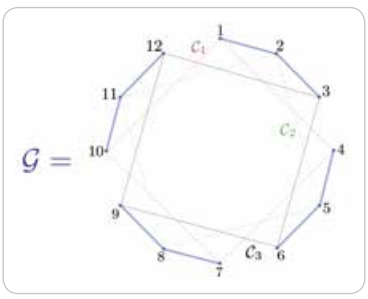


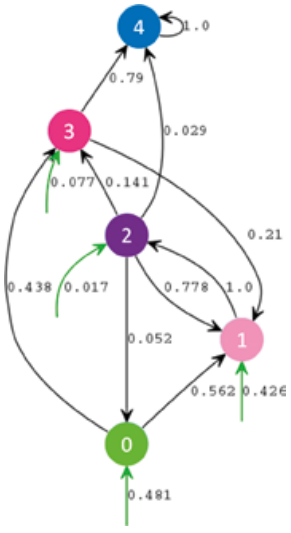


- $5 \times 10^{\nu}$ sites
- 10^6 categories
- 10^5 editors
- imbalanced nature of hierarchies
- Arbitrariness in taxonomy creation - personal biases









DIMENSIONALITY REDUCTION VIA SLICED INVERSE REGRESSION

A. Chiancone[1,2] S. Girard[1] J. Chanussot[2]
INRIA, Grenoble, Rhône-Alpes & LJK[1], GIPSA-Lab, Grenoble[2]

Problem outline :

In multidimensional data analysis, one has to deal with datasets made of n points in dimension p. When n and p are simultaneously large, classical statistical analysis methods and models fail. Our goal is to tackle this problem with a direct application on hyperspectral images. Here we focus on dimension reduction in the context of regression.

I. Sliced Inverse Regression (SIR)

Be X a p-dimensional explanatory variable, $\Sigma = Cov(X)$, Y the response variable we want to regress such that $Y = f(X, \epsilon)$, where ϵ is an unknown random error independent of X. Suppose that given the goal of predicting Y the information in X can be captured in a lower k-dimension projection representation, $k \ll p$:

$$Y = f(\beta_1^\intercal X, ..., \beta_k^\intercal X, \epsilon)$$

The information to regress Y lies in the k-dimensional projection subspace spanned by $\beta_1, ..., \beta_k$ which is called the effective dimension reduction (e.d.r.) space. How to estimate a basis of the e.d.r space ? If the following condition is satisfied :

$$(L)\ \mathbb{E}(b^\intercal X | \beta_1^\intercal X, ..., \beta_k^\intercal X) \text{ is linear in } \beta_1^\intercal X, ..., \beta_k^\intercal X, \forall b \in \mathbb{R}^p$$

then the k eigenvectors associated with the non null eigenvalues of the matrix $\Sigma^{-1}\Gamma$, where $\Gamma = Cov(\mathbb{E}(X|Y))$, are directions spanning the e.d.r. space. SIR procedure allows to estimate Γ slicing the range of Y and then to retrieve the e.d.r. directions diagonalizing the matrix $\Sigma^{-1}\Gamma$ and selecting the k first eigenvectors corresponding to the highest eigenvalues.

II. Our contribution : towards spatial-SIR

Our hypothesis is that the e.d.r. space is not unique all over the data. The different e.d.r. spaces can be investigated partitioning the data. Kuentz & Saracco (2009) proposed to clusterize X and run SIR independently in each cluster to better fit the (L) condition. Let us consider the single index model ($k = 1$) :

$$X = \bigcup_{i=1,...,c} X_i, \text{ such that (L) holds in each } X_i, \qquad Y_i = f_i(\gamma_i^\intercal X_i, \epsilon),\ \gamma_i \in \{\beta_1, ..., \beta_D\}$$

where $\beta_1, ..., \beta_D$, $D < c$ are the directions spanning the e.d.r. spaces. The number D of different e.d.r. spaces is unknown. Starting from the estimation $\hat{\gamma}_1, ..., \hat{\gamma}_c$ of the directions $\gamma_1, ..., \gamma_c$ we introduce a hierarchical merging techniques to identify the unknown directions $\beta_1, ..., \beta_D$.

III. Hierarchical merging technique

The most collinear vector to a set of vectors $A = \{\gamma_1, ..., \gamma_c\}$ given the proximity criterion $m(a, b) = \cos^2(a, b) = (a^\intercal b)^2$ is the solution of the following problem :

$$\lambda(A) = \max_{a \in \mathbb{R}^p} \sum_{\gamma_i \in A} w_i m(\gamma_i, a) \quad s.t. \quad \|a\| = 1$$
$$= \text{largest eigenvalue of } \sum_{\gamma_i \in A} w_i \gamma_i \gamma_i^\intercal$$

where w_i are weights and sum to one. To build the hierarchy we consider the following iterative algorithm initialized with the set A=$\{\{\hat{\gamma}_1\}, ..., \{\hat{\gamma}_c\}\}$:

while $card(A) \neq 1$
  Let $a, b \in A$ **such that** $\lambda(a \bigcup b) > \lambda(c \bigcup d)\ \forall c, d \in A$
  $A = (A \setminus \{a, b\}) \bigcup \{a \bigcup b\}$
end

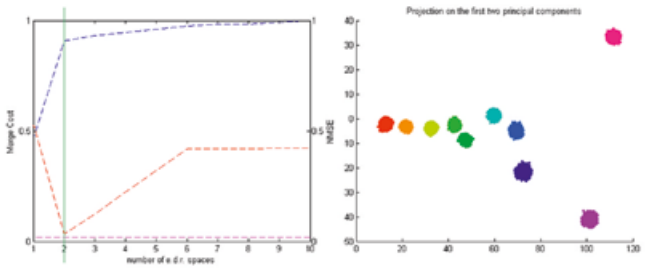
at each step the cardinality of the set A decreases merging the most collinear sets of directions. Therefore it is possible to infer the number D of underlying e.d.r. spaces analyzing the values of λ in the hierarchy.

IV. Validation on simulated data

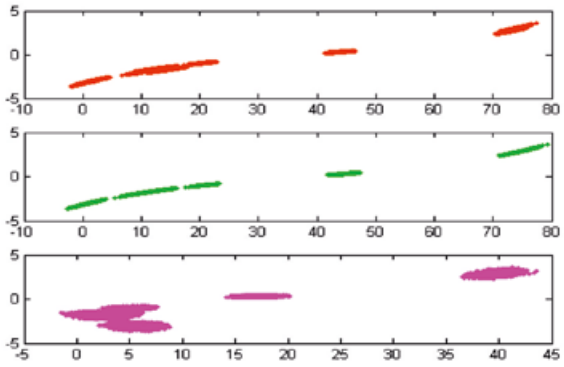
We simulated a dataset X with 100000 observations in dimension $p = 100$ from a multivariate Gaussian mixture model with 10 mixtures with uniform mixing proportions.
We studied the case of two e.d.r. spaces β_1, β_2 s.t. $\beta_1 \perp \beta_2$ projecting each mixture in one of the two directions. The response variable is then simulated :

$$Y_i = sinh(\beta_{g(i)}^\intercal X_i) + \epsilon,\ g : \{1, ..., 10\} \to \{1, 2\}$$

using the real partition we estimated $\{\hat{\gamma}_1, ..., \hat{\gamma}_1\}$ and regressed the function. We show the Normalized Mean Squared Error (NMSE) of our approach (red) and the theoretical lower bound given the regression techniques (magenta). The merge cost (blue) below shows a discontinuity according to the number of e.d.r. spaces. Thus our approach selects the real number D of e.d.r. spaces which also corresponds to the minimum in the error (green line).



We show below the result of our approach (red) the true data (green) and the estimation of SIR (magenta). On the y-axis the true Y values are plotted. Respectively the x-axis are the estimated projection with our approach, the real projection and the SIR estimated projection. Unsurprisingly SIR fails when dealing with multiple e.d.r. spaces while our approach gives small errors.



V. Conclusion and future work

We generalized SIR for multiple e.d.r. spaces and we show the capability of our approach on simulated data. Coming soon :
– Insert spatial information using a segmentation as a partition of the data thus leading to spatial-SIR.
– Retrieve physical parameters on hyperspectral images on Mars.

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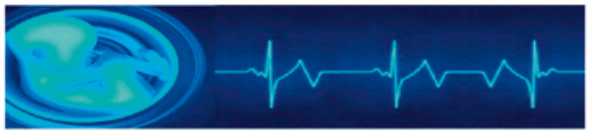
Li, K.C. (1991). Sliced inverse regression for dimension reduction (with discussion). Journal of the American Statistical Association, 86, 316-342.

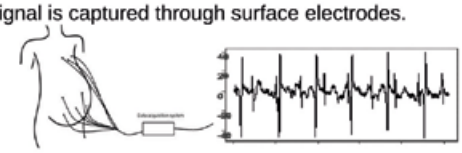
Kuentz, V., & Saracco, J. (2010). Cluster-based sliced inverse regression. Journal of the Korean Statistical Society, 39(2), 251-267.

Saman Noorzadeh, Bertrand Rivet[1] Pierre-Yves Guméry[2]
GIPSA lab, VIBS Team[1] TIMC lab, PRETA team[2]

Context



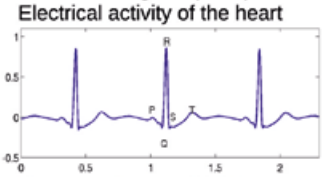
Monitoring the Fetal cardiac activities would let the early detection of cardiac diseases.
The signal is captured through surface electrodes.



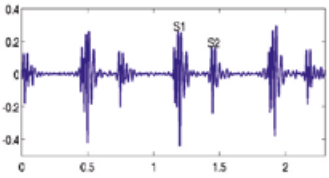
Problem: Fetal signals have very low SNR, mostly because of maternal cardiac signals.
Aim: Maternal and Fetal cardiac signal separation based on multi-modality, using minimum data channel.

Multi-modality

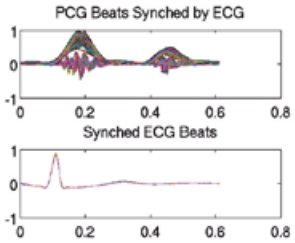
Electrocardiogram (ECG):
Electrical activity of the heart



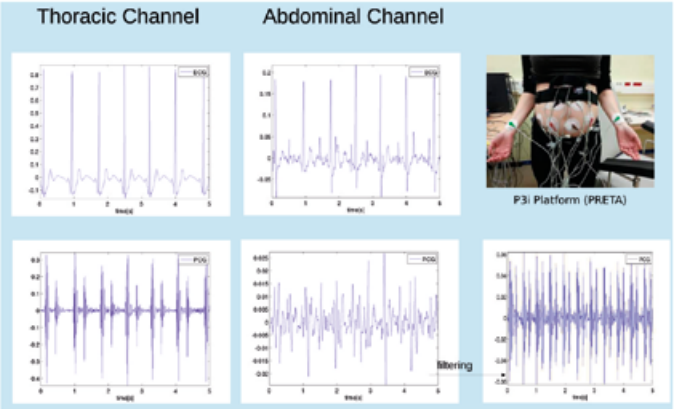
Phonocardiogram (PCG):
Mechanical activity of the heart



The signals exhibit non-stationary physiological delays, so the detection of ECG waves is not possible directly from PCG



Data Acquisition



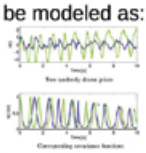
Non-Parametric Model

A periodic signal can be described as a Gaussian Process:

$$\mathcal{GP}(m(t), k(t_1, t_2))$$

Fetal and maternal ECGs as a quasi-periodic signal can be modeled as:

$$s_m(t) \sim \mathcal{GP}(0, k_m(t_1, t_2))$$
$$s_f(t) \sim \mathcal{GP}(0, k_f(t_1, t_2))$$



With mean and Covariance functions:

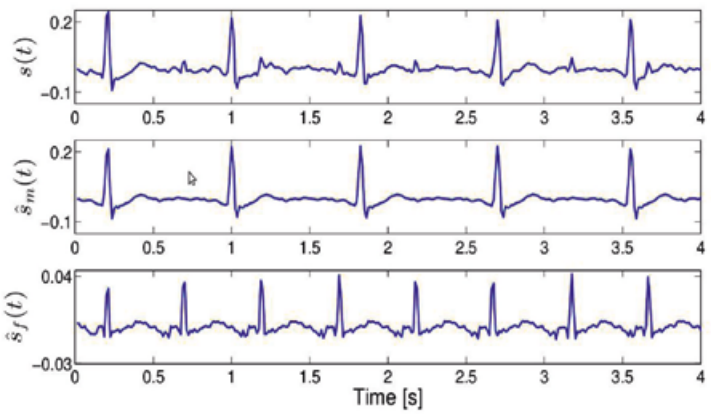
$$m(t) = 0$$
$$k(t_1, t_2) = \sigma^2 \exp\left(-\frac{(t_1 - t_2)^2}{2l^2}\right) \times \exp\left(-\frac{\sin(\theta(t_1) - \theta(t_2))^2}{2\lambda^2}\right)$$

fECG and mECG estimated from noisy channel, x:

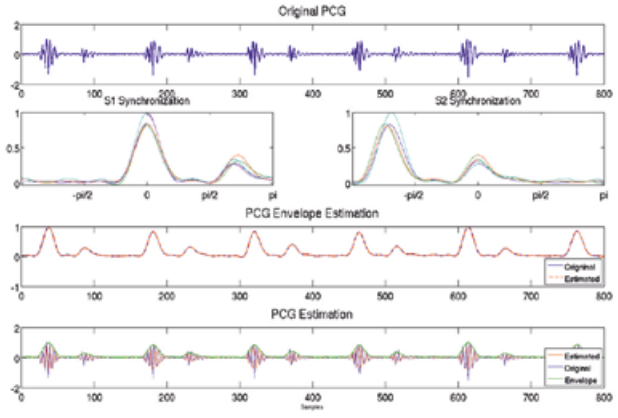
$$x(t) = s_m(t) + s_f(t) + n(t)$$
$$\hat{s}_m(t_*) = \mathbf{k}_m(t_*)^T K^{-1}\mathbf{x}$$
$$\hat{s}_f(t_*) = \mathbf{k}_f(t_*)^T K^{-1}\mathbf{x}$$

RESULTS

Fetal ECG Extraction



PCG Modeling



ANR

PERSYVAL-Lab

Kevin Caye[1], Olivier Michel[2], Olivier François[1]
TIMC-IMAG[1], GIPSA-lab[2]

Introduction

Geography and landscape are important determinants of genetic variation in natural populations, and several ancestry estimation methods have been proposed to investigate population structure using genetic and geographic data simultaneously. Those approaches are often based on computer-intensive stochastic simulations, and do not scale with the dimensions of the data sets generated by high-throughput sequencing technologies. There is a growing demand for faster algorithms able to analyze genome-wide patterns of population genetic variation in their geographic context.

Input Data

Genotypic data:
DNA Sequencing Technologies :

- SNPs array (*Arabidopsis thaliana* RegMap lines [4] : 200k loci of 1 307 individuals)
- next generation sequencing (1000 Genome project [2] : whole genome of 2504 individuals)

	chr: 1 pos: 657	chr: 1 pos: 3102
02B6	1	1
09A3	1	0
12A1	1	1

Spatial data:
Individual spatial coordinates of *Arabidopsis thaliana* RegMap Lines dataset.

References

[1] Deng Cai et al. Graph regularized nonnegative matrix factorization for data representation. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 33(8):1548–1560, 2011.

[2] 1000 Genomes Project Consortium et al. A global reference for human genetic variation. *Nature*, 526(7571):68–74, 2015.

[3] Eric Frichot et al. Fast and efficient estimation of individual ancestry coefficients. *Genetics*, 196(4):973–983, 2014.

[4] Matthew W Horton et al. Genome-wide patterns of genetic variation in worldwide arabidopsis thaliana accessions from the regmap panel. *Nature genetics*, 44(2):212–216, 2012.

Model

Ancestry coefficients and ancestral population definitions:
We write G the genomic matrix.

$$P(G_{i,\ell}=j) = \sum_{k=1}^{K} Q_{i,k} f_{k,\ell}(j),$$

$$P = QF^T,$$

where Q is the ancestry coefficient matrix and F the ancestral genotype frequency matrix.
Optimisation Problem:
Optimisation problem to estimate Q and F of sNMF method [3]:

$$\min_{Q,F} \quad \|X - QF^T\|^2$$

$$\text{such as} \quad Q \succeq 0,\ F \succeq 0$$

$$\sum_{k=1}^{K} Q_{i,k} = 1,\ \forall i \in \{1,...,n\}$$

$$\sum_{j=0}^{d} f_{k,\ell}(j) = 1,\ \forall \ell \in \{1,...,L\},$$

where X is a binary matrix which encode absence or the presence of each genotype at each locus.
Graphe based regularization:
We construct a weighted graph using spatial data:

$$W_{i,j} = e^{-\frac{\|z_i - z_j\|^2}{\sigma}},$$

where z are geographic positions.
The loss function introduce in GNMF method [1] is:

$$\|X - QF^T\|^2 + \lambda \sum_{i,j}^{n} W_{i,j} \|Q_{i,} - Q_{j,}\|^2$$

$$\|X - QF^T\|^2 + \lambda \text{trace}(Q^T L Q),$$

where L is the graph laplacian matrix.

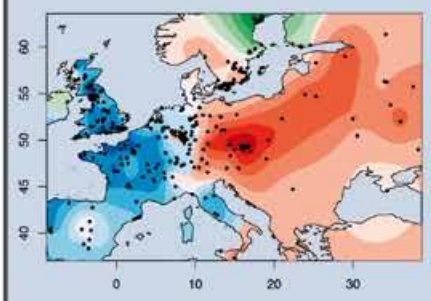
Algorithm

- The TESS3 optimisation problem is not convex.
- It is convex with respect to one of the variables Q or F when the other one is fixed.
- We can use a block-coordinate descent scheme

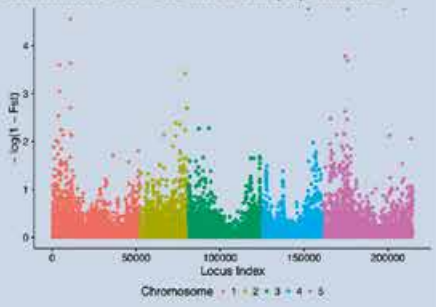
for $it \in \{1,...,itMax\}$ **do**
  Least squares problems
  for $j \in \{1,...,(D+1)L\}$ **do**
    $F^T_{j,} \leftarrow \arg\min \|Vec(X^j) - Qf\|^2$
  end for
  Projection onto F polygon of constraints
  $F \leftarrow \mathcal{P}_F(F)$
  ℓ_2-regularized least squares problems
  for $i \in \{1,...,n\}$ **do**
    $Q^T_{Ri,} \leftarrow \arg\min \|X^T_{R,i} - Fq\|^2 + \lambda\mu_i \|q\|^2$
  end for
  Projection onto Q polygon of constraints
  $Q \leftarrow \mathcal{P}_Q(R^T Q_R)$
end for

Results

We computed population structure of the *Arabidopsis thaliana* RegMap Lines dataset with $K = 3$ ancestral populations.
Individual ancestry coefficients: Ancestry coefficients can be projected on a map.



Ancestral populations: A F_{st} statistic is calculated to represent the genotype distribution differentiation between ancestral populations.



ANR PERSYVAL-Lab

Valentin Reis, advisors Jérôme Lelong(LJK) & Denis Trystram(LIG)

Abstract

EASY-Backfilling is a popular scheduling heuristic for allocating jobs in large scale High Performance Computing platforms. While its aggressive reservation mechanism is fast and prevents job starvation, it does not try to optimize any scheduling objective *per se*. Our work poses the question of how to improve this default heuristic. We show that the average waiting time can be reduced consistently (between 11% to 42% for the logs used) compared to EASY, with almost no increase in maximum waiting times. This work departs from previous learning-based approaches and shows that scheduling heuristics for HPC can be learned directly in a policy space.

Introduction

We consider in this work the problem of tuning EASY using queue reordering policies. More precisely, we propose to tune the reordering using a simulation-based methodology. For a given system, we choose the policy in order to minimize the average waiting time. This methodology departs from the First-Come, First-Serve rule and introduces a risk on the maximum values of the waiting time, which we control using a queue thresholding mechanism. This new approach is evaluated through a comprehensive experimental campaign on five production logs. In particular, we show that the behavior of the systems under study is stable enough to learn a heuristic that generalizes in a *train/test* fashion.

System Description

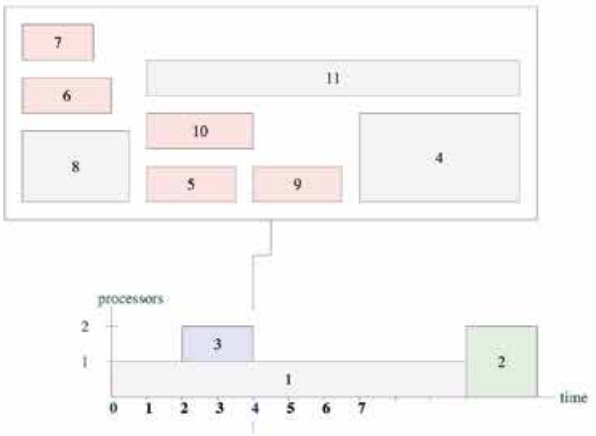
Parallel jobs are submitted over time and must be scheduled on the machine. Each job j has attributes:

- Submission date r_j
- Resource requirement q_j
- Actual running time p_j
- Requested running time $\tilde{p}_j$

The computational hardness, parameter uncertainty and real-time aspect of this problem force us to consider simple families of heuristics.

EASY-Backfilling

The EASY-Backfilling heuristic starts jobs on the system as soon as there is free space, by picking from a *primary* (originally First-Come, First-Serve) queue. A "backfilling" thechnique is then applied on a *backfilling* queue (originally FCFS) to leverage the available upper bounds of the running times. Either queue can diverge from the FCFS order. See below for a simplified example.



Scheduling Objective

- Improve the Average Waiting Time of the N jobs from the trace:

$$\frac{1}{N}\sum_j (start_j - r_j) \quad (1)$$

where $start_j$ is the starting time of job j.

- Control the Maximum Waiting Time of the N jobs from the trace:

$$\max_j (start_j - r_j) \quad (2)$$

Queue Reordering

We simulate the system for 49 reasonable policies that reorder the primary and backfilling queues. These policies are generated by using 7 classical queue reordering policies:

- FCFS: First-Come First-Serve, which is the widely used default policy.
- LCFS: Last-Come First-Serve.
- LPF: Longest estimated Processing time $\tilde{p}_j$ First.
- SPF: Smallest estimated Processing time $\tilde{p}_j$ First.
- LQF: Largest resource requirement q_j First.
- SQF: Smallest resource requirement q_j First.
- EXP: Largest Expansion Factor First, where the expansion factor is defined as:

$$\frac{start_j - r_j + \tilde{p}_j}{\tilde{p}_j} \quad (3)$$

Figure 1 reports the average and maximum waiting times of these 49 policies on the first half of the traces (the *training* phase). While it is possible to greatly reduce the average waiting time, this comes at a high cost in maximum waiting time.

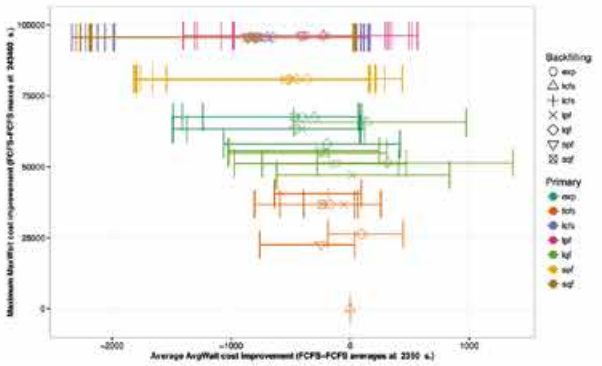


Figure 1: Bi-objective view of the 49 policies.

Thresholding

We introduce a thresholding mechanism in order to control the values of the maximum waiting time. If a single job's "waiting time so far" exceeds a threshold T, we push it at the head of the queue. Figure 2 shows that allows to improve the average waiting time while keeping the maximum waiting times low. Moreover, it shows that the performance of the best in-hindsight policy on the *training* trace generalizes well to the *testing* trace.

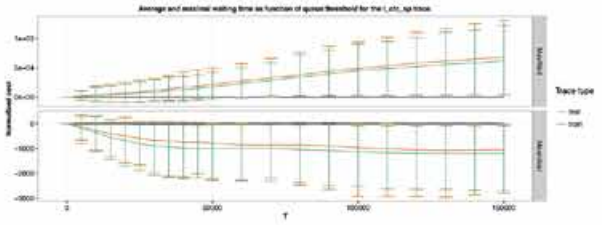


Figure 2: Train/Test Evolution of the Average and Maximum job waiting time with threshold T.

Stability

Figure 3 shows the stability of the performance of the 49 heuristics between the training and testing traces for two workload traces.

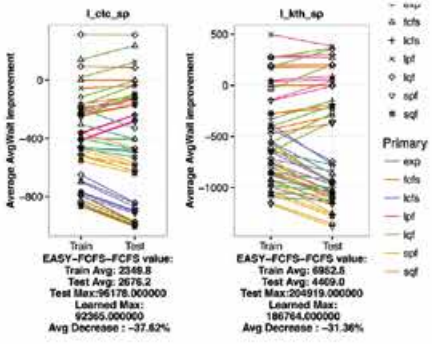


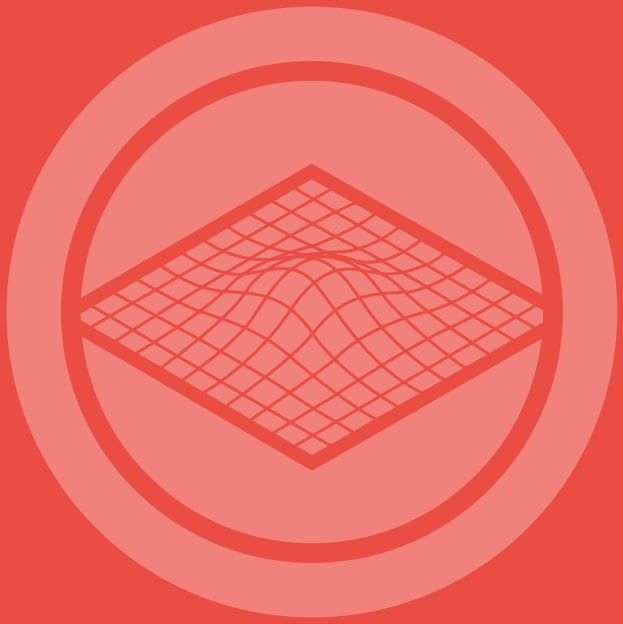
Figure 3: Train/test parallel plot of the performance of the 49 policies on the CTC-SP2 and KTH-SP2 workloads.

Conclusions

- Thresholded policies allow to optimize the cumulative cost while keeping the maximum cost in check.
- The search space of basic queue reorderings is stable in terms of performance.

Forthcoming Research

- Eliminating the dependence on the simulator: bandit selection of heuristics.
- Chosing policies in a contextual manner: learning a classifier-based heuristic.



MODELING AND SIMULATING THE PHYSICAL WORLD

Coordinators

LJK: Christophe Picard
TIMC-IMAG: Laurent Desbat

Scientific committee

GIPSA-lab: Isabelle Sivignon
Institut Fourier: Eric Dumas
LIG: Jean-Louis Roch
LJK: Eric Blayo, Christophe Picard, Adeline Samson Leclercq
TIMC-IMAG: Laurent Desbat

The ever increasing complexity of observed phenomena in natural and social sciences requires the development of conceptual tools to comprehend their significance and react in accordance. With the mathematical models build accordingly, we can refine hypotheses, discover new phenomena or act on them. The complexity of mathematical models describing the physical world call for new numerical approaches using efficient computing methods. The complexity may be inherent to the physical world such as interactions on different time and space scales between various physical phenomena, but can also results from model uncertainties.
Joint efforts from computer scientists to physicists and mathematicians are needed to address this complexity in order to propose innovative solutions. The goal of the SIM research track is to pursue new numerical and mathematical ideas for understanding and simulating complex systems, in particular in the framework of:

- Multi-scale, multi-physics modelling
- Uncertainties in modeling
- Numerical methods and high-performance computing
- Optimization and inverse problems.

Ongoing projects concern: Geometry and Spectral Optimization; Duality in Image Reconstruction from Integrals over Lines and Circles; Efficient Spatial Simulation of Biochemical Reactions; Cancer and population dynamics; non-stationarity of extremes; Decantation in dense fluids; Advanced Modelling for Reliability and maintenance Evaluation; Complex network of simultaneous discrete evolution; Efficient algorithms for stochastic semidefinite programming; control approaches for estimation purposes, etc.

SIM MODELING AND SIMULATING THE PHYSICAL WORLD

GALOIS

Geometric Algorithms in Combinatorics, Combinatorial Algorithms in Geometry

SIM

This project-team is concerned with geometrical and topological aspects of discrete mathematics.

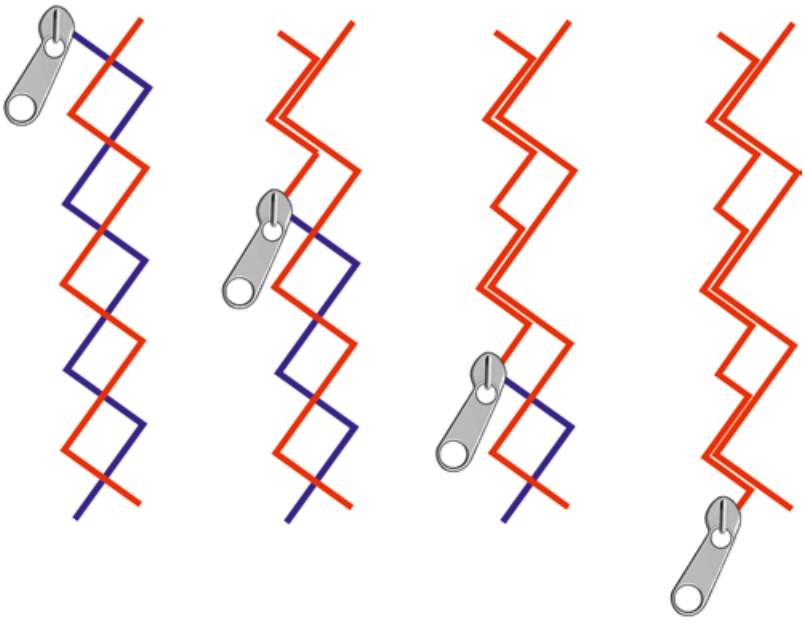
On the one hand we are mostly interested with graphs embedded in surfaces, and how cycles in the graph (curves in the surface) intersect. These questions have numerous applications in Computer Assisted Design (CAD) and routing. On the other hand we study some of the most emblematic problems lying at the intersection of Graphs and Geometry, such as the Travelling Salesman Problem, the Geometric Spanner Problem, the Boxicity of graphs, or the Lonely Runner Conjecture.

Website: https://persyval-lab.org/en/sites/galois

Main Scientific Results and Ongoing Work

Topology and Algorithms on Combinatorial Maps - PhD of Vincent Despré.

We have obtained several important results concerning graphs on surfaces. This includes a counterexample to a conjecture by Mohar and Thomassen concerning splitting cycles in triangulations [2] and a quasi-linear time algorithm to detect curves homotopic to a single curve, a problem first raised by Poincaré more than a century ago. The algorithm is based on an unzip procedure depicted in Figure 1. Other subjects related to surfaces are in progress, for instance on packing homotopic paths in collaboration with CWI and Maastricht University.

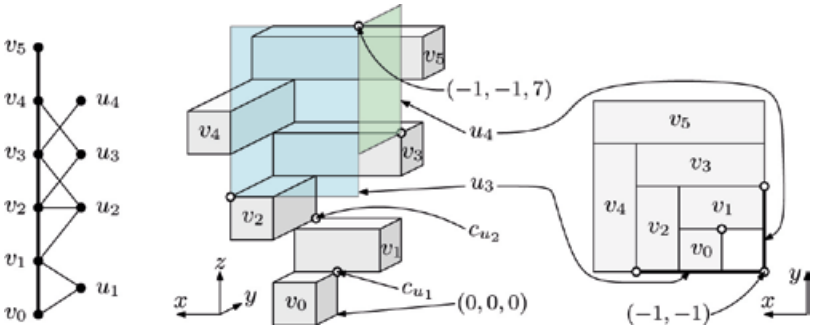


Coordinators

GIPSA-lab:
Francis Lazarus
G-SCOP: András Sebő

Graph Boxicity

The boxicity of a graph is the smallest dimension d in which we can represent a given graph as the intersection of d-dimensional boxes, as illustrated in Figure 2.



This parameter has important applications in the study of ecological and sociological networks. The behaviour of this parameter is surprisingly similar to the behaviour of the Colin de Verdière number, introduced by Yves Colin de Verdière in the 90s, which has a purely algebraic definition. It was conjectured that the boxicity is always at most the Colin de Verdière number. Yves Colin de Verdière gave several presentations to explain us his work on his parameter, and then we were able to prove that certain random graphs are counterexamples to the conjecture. This lead to the study of the boxicity of graphs embeddable on a fixed surface and several important results were obtained on this topic [3].

Progress is the Travelling Salesman problem.

This problem is related to a range of fundamental problems of network design. GALOIS enabled the clarification of structural properties, relations to deep results of matroid or matching theory, in collaboration with German and American partners. These have been used for breakthrough approximation results for a range of problems. Part of the results have been already published, and provide the currently best known approximation ratios for three versions of first plan: the general metric path TSP [4], for the graph TSP, and for the minimum cardinality 2-edge-connected subgraph problem.

Valorization

ANR project GATO (Graphes Algorithmes et TOpologie): This ANR project (2016–2020) involves the GALOIS participants of G-SCOP and GIPSA-Lab as well as other members of LIRMM (Montpellier) and LIX (Palaiseau).

Some relevant publications

- R. Bacher, **Counting invertible Schrödinger operators over finite fields for trees, cycles and complete graphs,** Electronic Journal of Combinatorics, (2015) 22(4), P4.40.
- V. Despré and F. Lazarus, **Some Triangulated Surfaces without Balanced Splitting,** Graphs and Combinatorics (2016) 32(6), 2339–2353.
- L. Esperet, **Box representations of embedded graphs,** Discrete & Computational Geometry, 2016.
- A. Sebo, A. van Zuylen, **The Salesman's Improved Paths: A 3/2+1/34 Approximation,** Foundations of Computer Science (FOCS 16).
- T. Kaiser, M. Stehlík, **Colouring quadrangulations of projective spaces,** J. Combin. Theory Ser. B 113 (2015), 1–17.

GeoSpec

Geometry and Spectral Optimization

SIM

The mathematical theory of complexity is that of classifying objects or problems based on how difficult they are to apprehend or to solve.

It is a well-known subject of research in applied mathematics for example in Numerical Analysis or Combinatorics where estimating the number of steps needed to compute a quantity is crucial in the perspective of a computer implementation. In more fundamental mathematics, for example in Geometry or Dynamical Systems, the exact geometry of an object is rarely known with sufficient accuracy: for instance, it may be altered with time, as is the case of many mechanical parts, or simply because it is a priori unknown, such as the structure of the Universe. For these reasons, the features of an object are often appraised in terms of associated algebraic or analytic quantities (for instance, the decay rate of the solution of a Partial Differential Equation, etc.), which pave the way to a measure of their complexity. The purpose of the GeoSpec project-team is to develop a synergy between fundamental and applied mathematicians in order to study important problems related to the complexity of two-dimensional objects (such as surfaces) and initiate investigations in higher dimension where the situation is, for most problems, widely unknown. We aim at studying the complexity of the geometry of a mathematical object (e.g. a manifold) through three different aspects: its metric (that is, the way distances are measured on the object), its dynamics (i.e. the trajectories followed by particles moving on it) and its spectrum (i.e. its resonance frequencies). More specifically, we intend to study extremal manifolds for invariants describing this complexity in each of the above items.

Website: https://ljk.imag.fr/GeoSpec/

Main Scientific Results and Ongoing Work

Parametrization of irregular surfaces:
The study of isometric embeddings is strongly related to the regularity of relevant objects. As suggested by Nash and Kuiper theorem, every admissible embedding is expected to have an irregular behavior like, for instance Cantor sets. Our first contribution is related to the parametrization, with as few parameters as possible, of such irregular surfaces. We illustrate in Figure 1 a recursive process which is able to generate irregular objects only with a few thousands of parameters. The bottleneck of this approach was to mix both tools from computational geometry and technics of sparse representation. This step forward is a promising and crucial progress to analyze spectral properties of embedded surfaces.

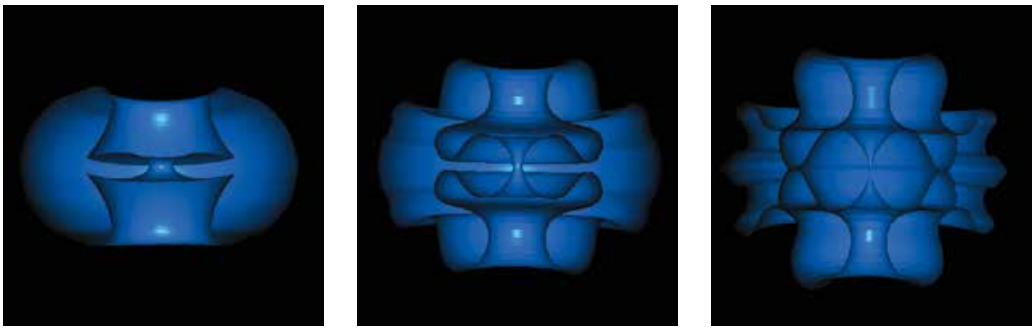
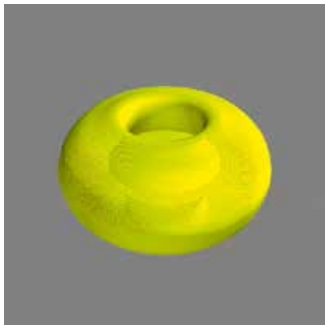
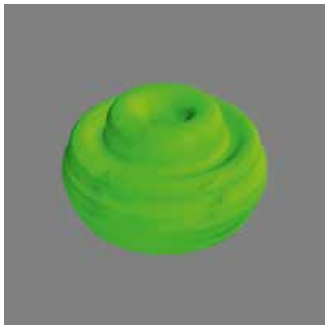
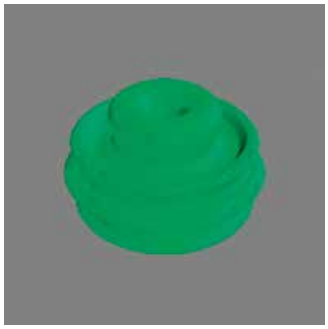


Figure 1

Coordinators

Institut Fourier:
Gérard Besson
LJK: Edouard Oudet

Vector fields, complexity and diffusion process:
In a starting Phd work, we are investigating existence results associated to non-variational spectral shape optimization problems. After this preliminary study, a better understanding of the diffusion process should make it possible to link our drift model with complex geometrical open problems in Riemannian Geometry.

Valorization

- Organization of a CIRM meeting at Luminy in February 2017.
- Organization of a summer school at Grenoble in 2018.

Some relevant publications

- M. Bonafini, G. Orlandi and E. Oudet, **Variational approximation of functionals defined on 1-dimensional connected sets: the planar case,** submitted.
- F. Hamel, E. Russ, **Comparison results for semilinear elliptic equations using a new symmetrization, method,** to appear in Math. Ann.
- E. Lanneau, D.-M. Nguyen and A. Wright, **Finiteness of Teichmuller curves in non-arithmetic rank 1 orbit closures,** to appear in Amer. J. Math. (2016).
- E. Lanneau, F. Valdez, **Computing the Teichmueller polynomial,** to appear in J. Eur. Math. Soc. (2016).

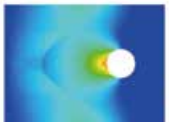
MASSIF MAcroScopic SImulation of Fibrous materials

Coordinators

Inria/LIG: Bruno Raffin
Inria/LJK: Florence Bertails-Descoubes
LJK: Pierre Saramito

Unlike fluids for which a number of numerical models have been proposed, complex divided materials such as fibrous media remain less studied from a macroscopic point of view: there is currently no well-accepted numerical model for capturing the dynamics of entangled materials in a predictive way. The industrial demand has however been strongly increasing these latest years, encompassing the fields of cosmetology (fine prediction of hair mechanical behavior), virtual entertainment (simulation of hair and fur for special effects), or virtual prototyping in mechanical engineering (cables entanglement, composite materials).

Website: http://persyval-lab.org/en/exploratory-project/MASSIF



Results

The exploratory project MASSIF has launched a first and decisive impulse for starting this long-term research project around the macroscopic modelling of fibrous materials. In particular, this project gave us the unique opportunity to hire Gilles Daviet as a PhD student (funded by Persyval from 2013 to 2016) to pursue our first studies on the topic. Gilles Daviet's PhD thesis started with an exhaustive state-of-the-art on existing models for fiber assemblies; then we have focused on a simplified but still longstanding challenge: that of designing a numerical model for macroscopic granular flows, able to capture nonsmooth stick-slip transitions occurring between grains. The corresponding constitutive law, known as the Drucker-Prager law, was usually regularized by previous approaches, then losing some key emerging effects in the dynamics of the flow, such as stable stacking. Gilles Daviet's PhD work showed that it was not only possible to preserve nonsmoothness of the law numerically, but also to solve the resulting one-step problem in an efficient manner by adapting existing solvers from discrete frictional contact problems. This pluridisciplinary work led to 2 journal publications [1,2], as well as several communications and posters at various conferences ranging from mechanics and physics to computer graphics. All the corresponding source code was delivered freely under the GNU GPL License.
More information is available here: http://bipop.inrialpes.fr/people/gdaviet/

Some relevant publications

- G. Daviet, F. Bertails-Descoubes, A Semi-Implicit Material Point Method for the Continuum Simulation of Granular Materials, ACM SIGGRAPH 2016.
- G. Daviet, F. Bertails-Descoubes, Nonsmosoth simulation of dense granular flows with pressure-dependent yield stress, JNNFM 2016.

TONNETZ Musical modeling for real-time interaction

Coordinators

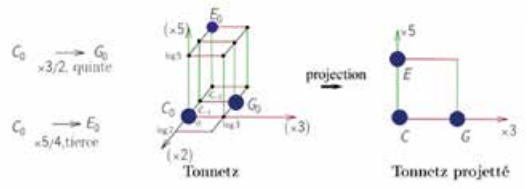
Malik Mezzadri,
Alexandre Ratchov
GIPSA-lab: Laurent Girin
Institut Fourier: Frédéric Faure

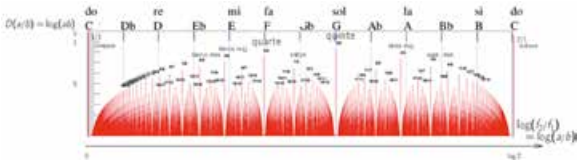
Why some musical notes played together sound harmoniously with so varied colors? What are the frequencies of these notes that resonate? Are there any missing notes in the equal-tempered scale (used in western music since XIX^{e})? These notes could have an interesting role in a musical creation? How to play with them? In this project we have addressed these questions.

Website: http://www-fourier.ujf-grenoble.fr/faure/Modelisation_musicale/index.html

Results

The sound of a sung voice or of a musical instrument is a periodic signal and is a superposition of pure notes called harmonics, located at multiple frequencies of the note that one hears. All this notes contribute to the timbre of the voice or the instrument. We are very sensitive to this structure in particular to the first ratio of frequencies that are rational numbers a/b and correspond to musical intervals. Using prime numbers P, a musical interval log(a/b) can be represented as a displacement on the Z-lattice generated by log(P). This lattice is called Tonnetz. A musical chord is like a compact "molecule" on this lattice and its musical color and resonance is determined by its shape. We introduced "adaptative temperament" that gives a natural way to select musical notes and harmonies on this lattice. We can use this geometric representation of music for live performances and/or music writing (as shown at a concert with Magic Malik orchestra, Hexagone de Meylan 2015 February 27th).





Selected publication

- F.Faure M. Mezzadri, A. Ratchov, Analyse et jeu musical en tempérament juste adaptatif preprint hal-01119499.

Inverse Problems and Applications

Inverse problems have been a very active field of mathematical and numerical research over the last decades, driven by many applications of important economic and societal impact. They are intrinsically difficult to solve, due to their very mathematical structure and to the fact that generally only partial data is available. In the last decade, new and exciting directions of research have emerged from neighboring topics such as control theory, shape optimization or geometry, and, for data reconstruction, new imaging methodologies have been invented. Our project focuses on multiwave and plasmonic inverse problems, which are promising and exciting new directions, where our team is at the forefront of international research.

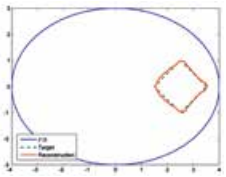
Website: http://www-ljk.imag.fr/membres/Faouzi.Triki/projetPbsInverses/index.html

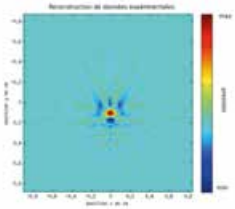
Results

Regarding plasmonics, which aims at constructing high-contrast composites with nearly singular geometries so as to localize and enhance electromagnetic fields in regions of tens of nanometers, we investigated the spectrum of the Neumann-Poincaré operator associated to a single inclusion, two close-to-touching inclusions as well as a periodic distribution of small inclusions. We derived a first mathematical complete model for the photoacoustic effect generated by the electromagnetic heating of nanoparticles. We obtained the first uniqueness and stability results for the multi-frequency electrical impedance tomography problem. Regarding multiwave imaging, a class of inverse problems where several waves of different types are cleverly combined to transform an ill-posed problem into a stable one, we showed how the reconstruction of the targeted physical parameters is sensitive to errors in mathematical models and measurements. The project strengthened the inverse problem topic in Grenoble, helped to create new collaborations, and to set up the LUG FUI project with MicrodB company.

Coordinators

GIPSA-lab: Didier Georges
Institut Fourier: Yves-Collin de Verdière
LJK: Faouzi Triki
TIMC/IMAG: Laurent Desbat





Some relevant publications

- Rolf Clackdoyle, Laurent Desbat. Data consistency conditions for truncated fanbeam and parallel projections. Medical Physics, 2015, 42 (2), pp.831-845.
- H. Ammari and F. Triki. Identification of an inclusion in Multifrequency Electric Impedance Tomography, Communications in Partial Differential Equations, Volume 42, 2017.
- M. Choulli, F. Triki, New stability for the inverse medium problem with internal data, SIAM J. Math. Anal. 47 (2015), no. 3, 1778-1799.
- G. Bao, J. Lin, P. Li, and F. Triki, Inverse scattering problems with multi-frequencies, Inverse Problems, 31 (9) (2015).
- H. Ammari, E. Bonnetier, F. Triki and M. Vogelius, Elliptic estimates in composite media with smooth inclusions: an integral equation approach, Ann. Sci. Éc. Norm. Sup. 48(2), 2015.

OCA Using coprocessors to solve Combinatorial Optimization problems faster

This project is at the interface between Operations Research and Distributed algorithms. The objective is to study the contribution of coprocessors, more specifically GPU and MICS/Xeon Phi for key issues in Operation research with a focus on difficult combinatorial optimization problems. One cannot just adapt the more efficient sequential algorithms for those problems because of the technological constraints of coprocessors. The challenge is to develop new algorithms dedicated to parallel computing for those problems. For instance, one could mix divide and conquer methods with dynamic programming for hybrid parallel systems. The evaluation of the interest of using one or several coprocessors for solving those problems could help pushing back the limits: reasonable times, size of the problems...
GPU architectures, even although offering a great calculation power turn out to be difficult to program. Indeed, the programming model is close to the hardware characteristics in order not to loose power in the high-level “abstraction” realization. Intel offers the Xeon Phi (2013- KNC version): a coprocessor, which execution model and programming are close to multicore architectures (core and hyper thread notions, cache levels and memory hierarchy).

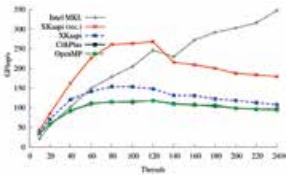
Website: http://persyval-lab.org/fr/research/exploratory-project/oca

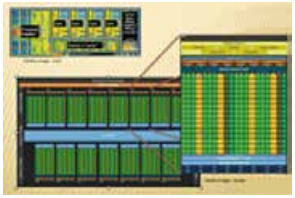
Results

We developed technics at two levels: at low level, the objective is to make the best use of the hardware capacities by overlapping communications by GPU or CPU computations [Gautier et al. 2013]; at a higher level, we studied and developed other technics for scheduling tasks by taking into account affinity without considering a cost model [Bleuse et al. 2014]. This work also allowed improving theoretical lower and upper bounds for difficult combinatorial problems like bin stretching [Gabay et al. 2014, Brauner et al. 2014, Gabay et al. 2014].

Coordinators

G-SCOP: Nadia Brauner
Inria: Thierry Gautier





Some relevant publications

- R. Bleuse, T. Gautier, J.V.F. Lima, G. Mounié, D. Trystram. Scheduling data flow program in XKaapi: A new affinity based Algorithm for Heterogeneous Architectures. Euro-Par'14, Porto, Portugal, aug 2014.
- N. Brauner, M. Gabay and V. Kotov. Online Bin Stretching with Bunch technics. Theoretical Computer Science, 602:103-113, 2015.
- M. Gabay, N. Brauner, V. Kotov. Computing Lower Bounds for Semi-Online Optimization Problems: Application to the Bin Stretching 4'OR. (available online 2017).
- T. Gautier, J.V.F. Lima, N. Maillard, B. Raffin. XKaapi: A Runtime System for Data-Flow Task Programming on Heterogeneous Architectures. IPDPS'2013, Boston, USA.
- J.V.F. Lima, F. Broquedis, T. Gautier, B. Raffin. Preliminary Experiments with XKaapi on Intel Xeon Phi Coprocessor. SBAC-PAD, Porto de Galinhas, Brésil, 2013.

Set Theory and Algorithms for Dynamical Systems

Coordinators

GIPSA-lab:
Mirko Fiacchini
VERIMAG: Thao Dang

In this project, we propose to use set-theoretic approaches to develop methods and algorithms for modelling and analysis of complex physical systems, in particular for tackling uncertainty.

Website: http://sites.google.com/site/settheoryandalgorithms/home

Results

Regarding *stabilizability of switched systems,* we found new conditions for discrete-time switched linear systems. We have used SMT (Satisfiability Modulo Theories) and the tool Z3 to address the problem of inclusion test of union of ellipsoids. Regarding *nonlinear discrete-time systems* we have investigated a systematic method for computing approximations of the domain of attraction and convex Lyapunov functions for some classes of nonlinear discrete-time systems. This has been applied to dynamical models of cancer under chemotherapy.
Another result of the project is the *development of efficient algorithms for set operations arising in verification and synthesis procedures.* A new algorithm has been designed for the reachability operators for polynomial discrete-time systems required by a safe parameter synthesis technique, proposed in our previous work. This algorithm has been successfully applied for population models in macro-biology. Based on Signal Temporal Logic, we designed an algorithm for synthesizing parameters of a polynomial system so that it satisfies a given STL property. We developed a new method for reachability analysis to check the robustness of given controllers, designed from nominal models, against both nonlinearities and uncertainties of real systems. We have also proposed a set-membership approach to design reliable static stabilizing controllers for non-linear dynamical systems.
The project led to the ANR COMPACS project on Computation Aware Implementation of Control Systems.

Some relevant publications

- Nacim Meslem, Nacim Ramdani. Reliable stabilizing controller based on set-value parameter synthesis. IMA Journal of Mathematical Control and Information, Oxford University Press (OUP), 2015, pp.1-20.
- Nassim Loukkas, Nacim Meslem, John Jairo Martinez Molina. Set-Membership Tests to Evaluate the Performance of Nominal Feedback Control Laws. IEEE Conference on Control Applications (CCA 2016).
- Rachid Riah, Mirko Fiacchini, Mazen Alamir. Domain of attraction estimation of cancer chemotherapy model affected by state proportional uncertainty. European Control Conference (ECC 2016).
- Mirko Fiacchini, Antoine Girard, and Marc Jungers. On the stabilizability of discrete-time switched linear systems: novel conditions and comparisons. IEEE Transactions on Automatic Control 61.5 (2016): 1181-1193.
- Tommaso Dreossi, Thao Dang, Carla Piazza. Reachability Computation for Polynomial Dynamical Systems. Formal Methods in System Design, 2017.

CanDyPop Cancer and populations dynamics

Coordinator

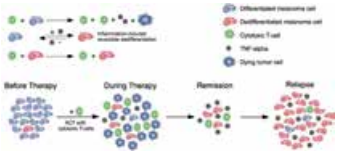
Institut Fourier:
Loren Coquille

The project aims at using probabilistic and statistical methods to study the dynamics of complex populations, in particular the development of certain cancer types.

Website: http://www-fourier.ujf-grenoblefr/~coquilll/CanDyPop.php

Results

We have recently proposed a *stochastic model of immunotherapy against melanoma* [1], comprising a logistic growth part and a predator-prey part between tumor cells, and immune cells. In the setting of a master internship [2] that will be pursued by a PhD, we have validated this model on real data from the University Clinic of Bonn. From a probabilistic point of view, we want to study a diffusion approximation of the original stochastic model, which will capture stochastic phenomena absent from the deterministic model.
In the setting of collaboration with doctors of the CHU and the Albert Bonniot Institute of Grenoble, in partnership with the University Hospital of Seoul, based on imaging data of pulmonary artery, we are constructing *a probabilistic model of tumor growth based on the biological development of cancer,* including the possible mutations of cancer cells. We have a list of data computed from CT images showing the temporal evolution of this cancer on more than 60 Korean patients. The aim is to obtain a model capable of reproducing the scanner observations, and to predict the tumor growth of future patients.
We are also working on *the Mendelian diploid model* which describes the time evolution of the three genotypes (aa; aA;AA) under the action of heredity (reproduction according to Mendelian rules) and selection (natural death and competition for ressources). We have obtained a quantitative result of genetic coexistence, showing mathematically that diploid populations have a selective advantage with respect to haploid ones [3].
Finally, we are studying *metastability in a model of population dynamics with competition.* The large population limit of the model, which is deterministic, has already been studied and a collaboration with Charline Smadi (IRSTEA) focuses on tackling the probabilistic part.



Some relevant publications

- M. Baar, L. Coquille, H. Mayer, M. Hölzel, M. Rogava, T. Tüting, and A. Bovier, A stochastic model for immunotherapy of cancer, Scientific Reports, 6 (2016), p. 24169, 1505.00452.
- Modibo Diabate. Parameter estimation in a stochastic model of immunotherapy against melanoma. Master thesis, 2017.
- A. Bovier, L.Coquille and R. Neukirch. Recovery of a recessive allele in a Mendelian diploid model. Preprint.

MeStaMaQ Statistical Mechanics of Quantum Walks

Quantum Walks (QWs) provide approximations of the quantum dynamics of complex physical systems in certain regimes and they also appear as tools in the elaboration and assessment of quantum algorithms for computer science. Moreover, the probabilistic interpretation of quantum mechanics confers on QWs the status of non-commutative generalisations of the notion of classical random walk. A quantum walker may be viewed as a quantum particle with spin moving on an infinite graph described by a vector in a Hilbert space related to the underlying graph. Its paradigmatic one time step unitary dynamics consists of a local action on its spin, followed by the action of a shift translating the particle onto one of the nearest neighbours of the site it occupies, depending on the state of its spin. This point of view has led to numerous works devoted to the study of spectral and transport properties of QWs in the last decade. The project MeStaMaQ goes one step further and considers quantum walkers in contact with an environment characterised by macroscopic properties in the sense of thermodynamics, and studies the effect of this environment on their dynamical properties.

Website: http://www-fourier.ujf-grenoble.fr/~joye/mestamaq.html

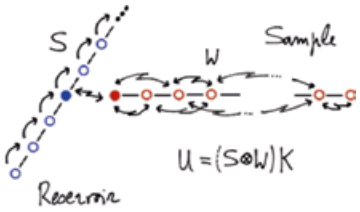
Results

Within the framework of many-body quantum statistical mechanics, we consider non-interacting fermionic quantum walkers on a finite **sample** put in contact with an infinite **reservoir** of similar fermionic quantum walkers characterised by their density. The discrete free unitary dynamics **W** on the sample is arbitrary whereas that on the reservoir is given by a shift **S**. The unitary coupling **K** exchanges quantum walkers between the sample and the reservoir so that **U=(S⊗W)K** yields the coupled one time step unitary dynamics on the relevant tensor product of fermionic Fock spaces. Under natural mixing assumptions on the dynamics, we prove that the one-body and two-body reduced density matrices on the sample converge for large times to density matrices fully characterised by the particle density of the reservoir. Moreover, the asymptotic density profile of quantum walkers on the sample is completely flat, independently of the dynamics **W** in the sample, displaying a strong manifestation of thermalisation.

This project has been done in collaboration with O. Bourget (PUC, Santiago Chile), E. Hamza (Cairo U. Egypt), M. Merkli (MUN St.John's Canada).

Coordinator

Institut Fourier: Alain Joye



Selected publication

• E.Hamza, A.Joye. Thermalization of Fermionic Quantum Walkers, J. Stat. Phys., 166, pp.1365-1392 (2017).

STAREX Dealing with non stationarity of extremes

Extreme value theory provides an efficient tool to solve relevant problems in various disciplines, including risk management, meteorology and many other fields. The objective of this project is to go beyond the stationary framework. We propose the development of new probabilistic and statistical tools to deal with non stationary data. Although we focus on theoretical challenges, upstream of the societal challenges, our work is driven by climatological and hydrological applications, or more generally by environmental applications.

Website: http://persyval-lab.org/en/exploratory-project/starex

Results

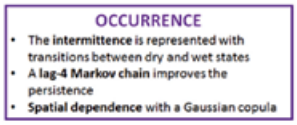
Our first subject concerns *statistical modeling of precipitation amount,* a topic currently very active as the distribution of precipitation (rainfall) is a heavy-tailed one. At the moment, there is no general method for modeling the entire range of data with high performance. Recently, in order to propose a method that jointly models the small, moderate, and large precipitation values, a new class of distribution called Extended Generalized Pareto Distribution (EGPD) was introduced. We have generalized this class of models, for which we have developed nonparametric or semi-parametric tools. We are also developping a multi-site model targeting the reproduction of extreme events at different temporal and spatial scales. This precipitation model, named G-Wex, relies on the structure proposed by Wilks (1998), for which the process representing the precipitation occurrences at the different stations is independent to the process generating the amounts of the precipitation events. Different G-Wex model variations are applied to a dense network of gauges of the Aare-Rhine hydrological system in Switzerland. Performances are then evaluated at different temporal (e.g. 1-day and 3-day annual maxima) and spatial scales (e.g. at the stations and for different catchment subdivisions).

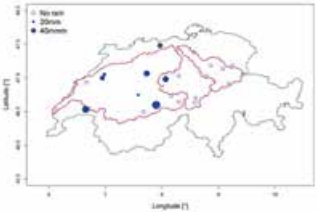
A second subject concerns *modeling and testing extreme events.* To define extreme events is a question by itself, and we are still working on that point. The aim is to develop statistical procedures to detect changes in extremes for streamflow data. The approach that we are investigating consists in nonparametric change point tests based on the notion of copulas, to model the dependence structure. We aim at reconsidering the stationarity assumption in the dependence structure of multivariate extremes, both from data-oriented and model based perspectives.

This project has boosted several cross-disciplinary collaborations, with a climatology laboratory (Philippe Naveau) and with Laboratoire d'étude des Transferts en Hydrologie et Environnement (Anne-Catherine Favre), which will be pursued through the Idex Cross-Disciplinary Project Trajectories.

Coordinator

LJK: Clémentine Prieur



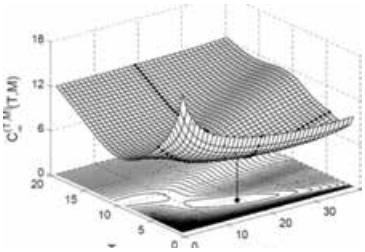


AMORE Advanced MOdelling for Reliability and maintenance Evaluation

Coordinators

GIPSA-lab:
Christophe Bérenguer
LJK: Laurent Doyen

For complex systems, maintenance costs represent very often a high proportion of the overall ownership and operating cost. Maintenance optimization requires to develop mathematical models which allow to assess the maintained system performance in terms of reliability and availability and to find the best trade-off between preventive and corrective maintenance costs. The environmental conditions and other influencing factors should also be taken into account when seeking for optimal maintenance policies. The envisioned breakthroughs within this project towards improved reliability/availability performance and optimal maintenance policies are made possible thanks to advanced probabilistic modeling and statistical treatment of available data to build complementary kinds of models (deterioration, maintenance effect and maintenance policies models) necessary to make optimal maintenance decisions.



Website: http://amore2016.imag.fr/

Results

The project contributes to the development of the software VAM (Virtual Age Models), an R package for modelling and assessment of maintenance effects and wear-out. In particular, AMORE will contribute to the integration of heterogeneity effects in VAM. We have developed advanced deterioration modelling for mechanical actuators: an hybrid physics-based & stochastic approach; online observer-based deterioration evaluation for RUL estimation. For maintenance effect modeling, we have proposed generic models taking into account observed and non-observed heterogeneity in imperfect maintenance models. We also contributed to online implementation and optimization of dynamic maintenance,online adaptation of the condition monitoring quality [2], and synthesis and assessment of diagnosis and prognosis condition indices for condition-based and predictive maintenance decision making [1].
This project has allowed to boost collaborations and joint submissions of several research projects.

Some relevant publications

- K.T. Huynh, A. Grall, C. Bérenguer. Assessment of diagnostic and prognostic condition indices for efficient and robust maintenance decision-making of systems subject to stress corrosion cracking. Reliability Engineering and System Safety, Elsevier, 2017, 159.
- P.K.N. Thi, K.T. Huynh, P.D. Van, C. Bérenguer, A. Grall. Adjusting condition monitoring quality for condition-based maintenance optimization of deteriorating systems. 9th International Conference on Modelling in Industrial Maintenance and Reliability, MIMAR 2016, Jul 2016, Londres, United Kingdom.

SWITCHED HYPERBOLIC SYSTEMS: MODELLING, SIMULATION AND STABILIZATION

P.-O. Lamare[a], A. Girard[a], C. Prieur[b]
Laboratoire Jean Kuntzmann[a] CNRS-GIPSA-lab[b]

Motivation

Modelling of physical networks

- Open channels for hydrosystems
- Road traffic
- Power distribution
- Pipeline transport
- ...

Switching for describing

- logical decisions
- different regimes
- saturation phenomena
- ...

Equations

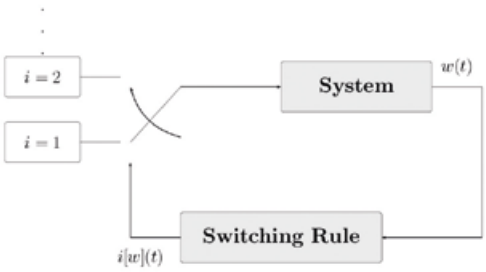
Hyperbolic partial differential equations:

$$\partial_t y^+(t,x) + \Lambda^+_{\sigma(t)}(t,x)\partial_x y^+(t,x) = f^+_{\sigma(t)}(t,x,y),$$
$$\partial_t y^-(t,x) - \Lambda^-_{\sigma(t)}(t,x)\partial_x y^-(t,x) = f^-_{\sigma(t)}(t,x,y),$$

Boundary Conditions: $\begin{pmatrix} y^+(t,0) \\ y^-(t,1) \end{pmatrix} = G_{\sigma(t)} \begin{pmatrix} y^+(t,1) \\ y^-(t,0) \end{pmatrix},$

Initial Condition: $y(x,0) = y^0(x).$

$\sigma : [0,+\infty) \to \mathcal{I}$ is the **switching signal**. It is a piecewise constant signal. The set $\mathcal{I}$ can be discrete or a continuum.



Main Results

Switching stabilization

Analysis by the powerful **Lyapunov theory** for the case without reaction term, and linear boundary conditions.

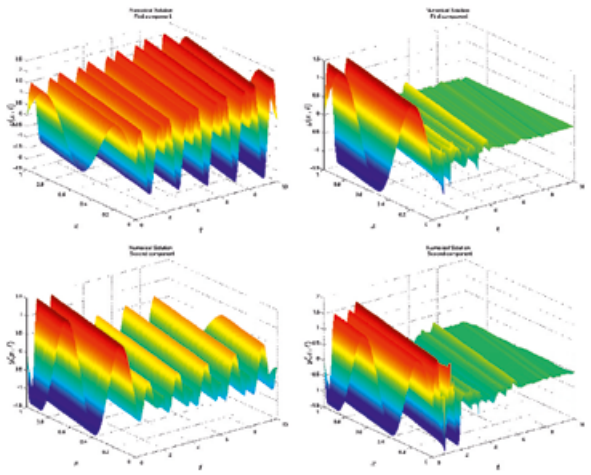
A candidate Lyapunov function:

$$V(t) = \int_0^1 y(t,x)^\top Q y(t,x) e^{-\mu x} dx, \quad Q \in \mathbb{R}^{n\times n}.$$

3 switching strategies follows from the Lyapunov analysis

- **Argmin**
- **Argmin with Hysteresis**
- **Argmin, Hysteresis with Low-Pass Filter**

Example



Unswitched case. With $i = 1$. With the Argmin rule.

And also...

The previous switching rules have been tested with an application on the Saint-Venant equations for a multibief network.

Giving some numerical conditions for the existence of a quadratic Lyapunov function

Considering more general Lyapunov function, such as the ones depending in the space variable asks to consider an infinite number of Linear Matrix Inequalities (LMI). We aim to find some sufficient conditions to reduce the size of the problem.

Perspectives

- Add a switched source term. Develop some switching strategies with it.
- Consider the switching as a perturbation.
- Consider a gain in the boundary conditions.
- Add some nonlinearity in the velocities expressions.

Conclusion

- Switching strategies developed for the switched infinite-dimensional case.
- Proof of existence and uniqueness of solution for two of them.
- Effectiveness of the previous for a real application.

Reference

An article in the proceeding of an international conference:

[1] Pierre-Olivier Lamare, Antoine Girard, and Christophe Prieur. Lyapunov techniques for stabilization of switched linear systems of conservation laws. In *Proceedings of the 52nd IEEE Conference on Decision and Control*, pages 448–453, Florence, Italie, December 2013. http://cdc2013.units.it/ This work has been partially supported by the LabEx PERSYVAL-Lab ANR-11-LABX-0025 and by PHC TOURNESOL FR 2013.

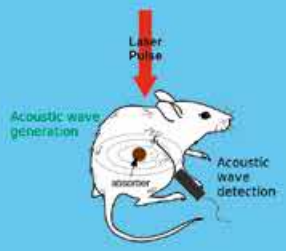
INVERSE PROBLEMS IN PHOTOACOUSTIC IMAGING

Margaux Vauthrin
Laboratoire Jean Kuntzmann, Université Joseph Fourier, Grenoble

Photoacoustic imaging

Photoacoustic generation

- Laser pulse
- Heating of absorbers
- Dilatation and generation of an acoustic wave
- Propagation in the domain
- Detection of the acoustic wave on the boundary

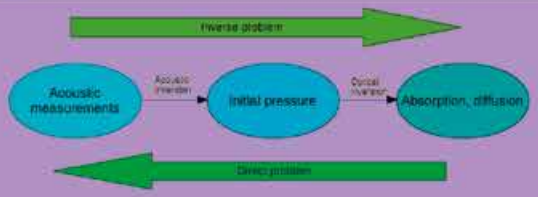


Generated pressure

$$p_0 = \Gamma \mu_a u$$

with p_0 the generated pressure, Γ the Grüneisen parameter, u the fluence of the laser and μ_a the absorption coefficient.

Inverse problem



- Inversion of the acoustic wave propagation [1] :

$$\begin{cases} \frac{1}{c_s^2}\frac{\partial^2 p}{\partial t^2} - \Delta p = 0 \\ p(x,0) = p_0(x) \\ \frac{\partial p}{\partial t}(x,0) = 0 \end{cases}$$

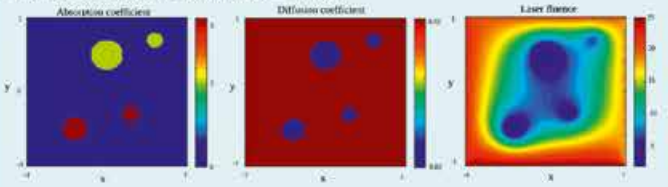
- Inversion of the optical wave diffusion [2] :

$$-\nabla \cdot D(x)\nabla u(x) + \mu_a(x)u(x) = 0$$

Simulations

Diffusion simulation :

- Domain Ω is the $[-1,1] \times [-1,1]$ square
- D, μ_a and laser illumination on $\partial\Omega$ are given
- Finite difference simulation of the diffusion equation
- Gives the acoustic source $p_0 = \Gamma \mu_a u$.

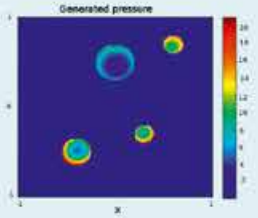


Acoustic simulation

- Acoustic detectors are on $\partial\Omega$
- Finite difference simulation of the wave equation

$$p(x,0) = p_0(x)$$

- Pressure profiles measured by each detector during a time T



Acoustic speed correction

The medium is considered to be a mixture of blood and water. The absorption and speed of sound both depend on the volume fraction of blood f_{blood}.

$$c_s = \sqrt{\frac{K_w K_{bl}}{(f_{blood}K_w + (1 - f_{blood})K_{bl})\rho_{sol}}}$$

$$\mu_a(\lambda) = 5.3 \cdot 10^{-2} f_{blood} + 10^{-5}$$

We then have a relation between speed of sound and absorption :

$$c_s = \sqrt{\frac{K_w K_{bl}}{(\frac{\mu_a(\lambda)-10^{-5}}{5.3\cdot10^{-2}}K_w + (1 - \frac{\mu_a(\lambda)-10^{-5}}{5.3\cdot10^{-2}})K_{bl})(\rho_w + \frac{\mu_a(\lambda)-10^{-5}}{5.3\cdot10^{-2}}(\rho_{bl} - \rho_w))}}$$

Absorption reconstruction and speed of sound correction

Step 1 :

- Acoustic inversion of simulated p_0 with constant speed of sound c_s
- Γ is known, and D supposed to be a constant
- μ_a^1 is found by solving the following equation :

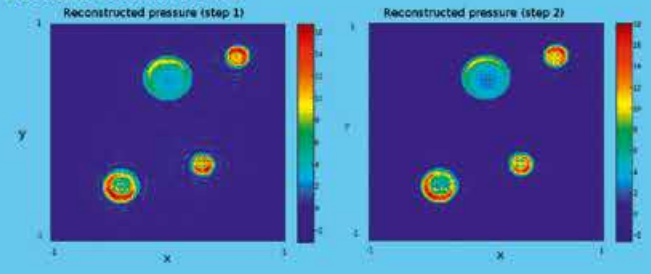
$$\text{div}(D\nabla.u_1) = \mu_a u_1 = \frac{p_0}{\Gamma}$$

Step 2 :

- $\mu_a^1 \rightarrow$ correction of c_s
- Acoustic inversion with new c_s
- Calculation of μ_a^2

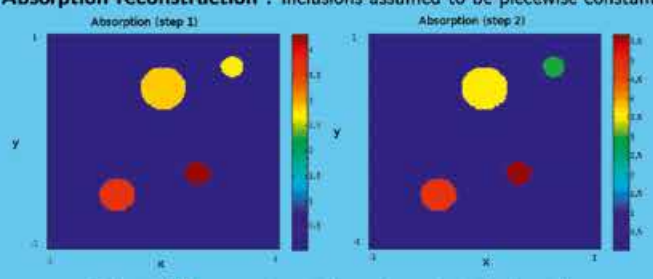
Results

Acoustic reconstruction



Relative L^2 errors : 0.1339 (step 1) and 0.1043 (step 2)

Absorption reconstruction : inclusions assumed to be piecewise constants



Relative L^2 errors : 0.1198 (step 1) and 0.0909 (step 2)

Conclusion and outlook

The aim of this work was to find a correction of the acoustic speed that improves the reconstruction of the optical properties. This model has now to be used to reconstruct the diffusion coefficient in order to solve the optical inverse problem completely.

Références

[1] Xu, Wang, Rev. Sci. Instruments 77, 041101 (2006)
[2] Bal, Uhlmann, Inv. Problems, 26(8), 085010 (2010)

NONSMOOTH CONTINUUM SIMULATION OF GRANULAR FLOWS

Gilles Daviet and Florence Bertails-Descoubes
Inria Rhône-Alpes - Laboratoire Jean Kuntzmann (Université Grenoble Alpes, CNRS)

Motivation

We focus on the **continuum simulation** of granular flows, from which we observe two peculiar features:

- Due to the Coulombic nature of the friction between particles, granular materials exhibit a yield-stress which depends on the local pressure;
- While hardly compressible, granulars may dilate.

Many continuum-based simulation methods enforce a divergence-free velocity field when simulating granular flows. This can lead to negative pressure values in the wake of obstacles, and therefore difficulties in the definition of the yield-stress (Chauchat and Médale, 2014). Furthermore, Seguin et al. (2016) observed from physical experiments that the **pressure and stress fields behind an intruder** moving in a 2d granular medium **should vanish**.

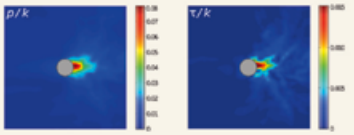


Figure: Capture of the pressure (left) and stress (right) fields induced by an intruder moving from the left to the right inside a 2d granular media. Reproduced from Seguin et al. (2016).

In this work **we do not preclude the expansion of the material**, and propose a numerical algorithm to compute the resulting flow over a finite element discretization. Thanks to a direct treatment of nonsmoothness without regularization, we are able to capture dead-zones and the transition between fluid and solid regimes in an accurate way.

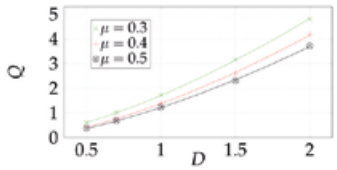


Figure: Dimensionless discharge rate Q of a 2d silo as a function of the dimensionless outlet size D for $\mathrm{Re} = 100$.

Results with dense rheology

- **Flow around obstacles.** Our method yields as expected a vanishing pressure field in the wake of the obstacles.
- **Beverloo scaling.** We retrieve the empirical power-$\frac{3}{2}$ law w.r.t. the outlet size for the discharge of a 2D silo.

1. Dense flow rheology

We first assume that the material is dense everywhere. We use a viscoplastic **Drucker–Prager rheology** with a Newtonian viscosity η and a pressure-dependent yield-stress $\kappa(p) = \sigma_0 + \mu p$. The total stress tensor is $\sigma_{tot} := 2\eta\dot{\boldsymbol{\varepsilon}} + \boldsymbol{\tau} - p\mathbb{I}$, with $\dot{\boldsymbol{\varepsilon}}$ the strain rate and

$$\begin{cases} \boldsymbol{\tau} = \kappa(p)\dfrac{\mathrm{Dev}\,\dot{\boldsymbol{\varepsilon}}}{|\mathrm{Dev}\,\dot{\boldsymbol{\varepsilon}}|} & \text{if } \mathrm{Dev}\,\dot{\boldsymbol{\varepsilon}} \neq 0 \\ |\boldsymbol{\tau}| \leq \kappa(p) & \text{if } \mathrm{Dev}\,\dot{\boldsymbol{\varepsilon}} = 0, \end{cases} \tag{1}$$

The pressure p enforces the non-compressiblity constraint $\nabla \cdot \mathbf{u} \geq 0$, *i.e.*

$$0 \leq \nabla \cdot \mathbf{u} \perp p \geq 0. \tag{2}$$

Reformulation. We show that (1) and (2) can be written equivalently $f_{DS}(\tilde{\boldsymbol{\varepsilon}}, \boldsymbol{\lambda}) = 0$ with $\tilde{\boldsymbol{\varepsilon}} := \dot{\boldsymbol{\varepsilon}} + \mu|\mathrm{Dev}\,\dot{\boldsymbol{\varepsilon}}|\sqrt{\frac{2}{d}}\mathbb{I}$, $\boldsymbol{\lambda} := p\mathbb{I} - \boldsymbol{\tau}$ and for $\xi > 0$,

$$f_{DS}(\tilde{\boldsymbol{\varepsilon}}, \boldsymbol{\lambda}) := \Pi_{T_\kappa}(\boldsymbol{\lambda} - \xi\tilde{\boldsymbol{\varepsilon}}) - \boldsymbol{\lambda},$$

$$T_\kappa := \left\{\boldsymbol{\tau}, |\mathrm{Dev}\,\boldsymbol{\tau}| \leq \kappa\left(\tfrac{1}{d}\mathrm{Tr}\,\boldsymbol{\tau}\right)\right\}.$$

2. Finite-element discretization

In the creeping flow limit, the dimensionless conservation of momentum equation over a domain Ω leads to the weak formulation

$$\begin{aligned} \frac{1}{\mathrm{Re}}\int_\Omega \mathrm{D}(\mathbf{u}) : \mathrm{D}(\mathbf{v}) &= \int_\Omega \mathbf{f}.\mathbf{v} - \int_\Omega \mathbf{v}.\nabla\cdot\boldsymbol{\lambda} \quad \forall \mathbf{v} \in H^1_0(\Omega) \\ \int_\Omega \boldsymbol{\gamma} : \boldsymbol{\tau} &= \int_\Omega \mathrm{D}(\mathbf{u}) : \boldsymbol{\tau} \quad \forall \boldsymbol{\tau} \in L_2(\Omega) \\ f_{DS}(\boldsymbol{\gamma}, \boldsymbol{\lambda}) &= 0. \end{aligned}$$

Discretizing over a basis of Lagrange polynomials and writing the rheology constraint at the Gauss quadrature points $(\mathbf{q}_i)$ yields the system

$$\begin{cases} A\mathbf{u} = \mathbf{f} + B^\top\boldsymbol{\lambda} \\ \boldsymbol{\gamma} = B\mathbf{u} + \mathbf{k} \\ f_{DS}(\bar{\boldsymbol{\gamma}}_i, \boldsymbol{\lambda}_i) = 0 \quad \forall i. \end{cases} \tag{3}$$

Problem (3) has a structure similar to that of **Coulomb friction problems** in discrete contact mechanics, except that the matrix A has a dense inverse (Daviet and Bertails-Descoubes, 2016b).

3. Solving the DCFP (3)

Following (Acary et al., 2011), we compute the solution of Problem (3) as a **sequence of Second-Order Cone Quadratic problems**,

$$\min_{\boldsymbol{\lambda} \in T_\kappa} \frac{1}{2}\boldsymbol{\lambda}^\top W\boldsymbol{\lambda} + \boldsymbol{\lambda}^\top\left(\mathbf{b} + s^k\mathbb{I}\right) \tag{S}$$

with $W := HA^{-1}H^\top$ and $\mathbf{b} := \mathbf{k} + BA^{-1}\mathbf{f}$. We can then use two classes of methods:

1. **Interior-points solvers.** Their main advantages are a super-linear convergence rate and the availability of efficient solvers. (S) can be reformulated as a Second Order Cone Program,

$$\begin{aligned} &\min_{t\in\mathbb{R},\boldsymbol{\lambda}} t + \boldsymbol{\lambda}^\top(\mathbf{b} + s\mathbb{I}) \\ &L\boldsymbol{\gamma} = H^\top\boldsymbol{\lambda}, \qquad \boldsymbol{\lambda} \in T^n_\kappa, \quad 2t \leq \boldsymbol{\gamma}^\top\boldsymbol{\gamma} \end{aligned}$$

with L a square-root of A.

2. **First-order proximal methods** have slower convergence, but are easier to warm-start, which is very interesting for our fixed-point loop.

Figure: Pressure (left) and normal velocity (right) fields in a left-to-right granular flow around obstacles

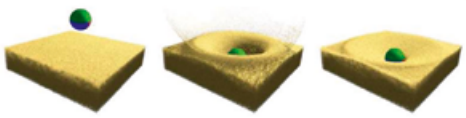


Figure: A ball impacting a granular bed.

4. Varying density of grains

Rheology. Let $\phi(\mathbf{x}, t)$ denote the **volume fraction of grains** field, modeled as a continuous function or a set of Lagrangian particles (Daviet and Bertails-Descoubes, 2016a). Let ϕ_{max} be the critical volume fraction above which compression is forbidden. Linearizing $\phi(\mathbf{x}, t + \Delta_t) \leq \phi_{max}$ over a timestep Δ_t yield

$$0 \leq \phi(t)\nabla\cdot\dot{\boldsymbol{\varepsilon}} + \frac{\phi_{max} - \phi(t)}{\Delta_t} \perp p \geq 0. \tag{4}$$

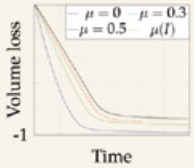
The Drucker–Prager rheology then satisfies $f_{DS}(\bar{\boldsymbol{\gamma}}, \boldsymbol{\lambda}) = 0$ with $\bar{\boldsymbol{\gamma}} := \phi(t)\dot{\boldsymbol{\varepsilon}} + \frac{\phi_{max} - \phi(t)}{\Delta_t}\sqrt{\frac{2}{d}}\mathbb{I}$. The finite-element discretization yields a system which has exactly the same problem structure as Problem (3).

Time integration is done in a semi-implicit manner. At each timestep t^k:

1. Construct and solve Problem (3) with $\phi(t^k)$ to get the new velocity $\mathbf{u}(t^{k+1})$.
2. Advect the volume fraction field with the velocity $\mathbf{u}(t^{k+1})$ to get $\phi(t^{k+1})$.

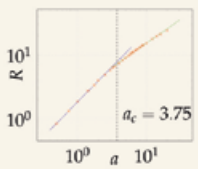
Results with 2D fraction field

Silo discharge



We retrieve the constant flow rate distinguishing granular materials from Newtonian fluids.

Column collapse



We retrieve a critical aspect-ratio a_c in the run-out length versus aspect-ratio curve.

Figure: Collapse of a granular column of aspect-ratio $a = 1.42$ with $\mu = 0.32$.

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IDENTIFICATION BY ELECTRO-LOCALIZATION
Stability Results of Disks & Multifrequency Measurement

E. Bonnetier, F. Triki, C-H. Tsou

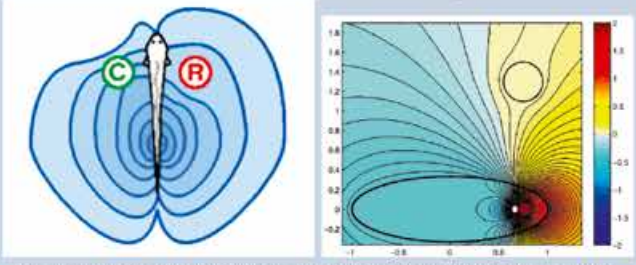
Introduction

Electro-localization is the ability that special fish species use to recognize their environment. By generating a weak, height frequency electric current, electric fishes detect the voltage potential's perturbation created by a nearby target of which the conductivity is different to water. The aim of the thesis is to derive fast and efficient algorithms for real time identification by electric fish like aquatic robots. Mathematically the identification by electro-localization is an inverse conductivity problem with a finite number of multifrequency boundary Cauchy pairs.

Electric fish

- Electric organ: generate a stable, high-frequency, weak electric field.
- Electroreceptors: measure the transdermal potential modulations caused by a nearby target.
- Nervous system: perceive target's shape.

The electric fish, and its electric organs



The generated electric field by the fish, its interaction with a target.

Mathematical model

Let $\Omega \subset \mathbb{R}^2$ be a bounded domain, $D \subset \Omega$ is an inclusion and $k > 0, k \neq 1$. We consider the conductivity equation:

$$\begin{cases} \operatorname{div}((1+(k-1)\chi_D)\nabla u) = 0, & \text{in } \Omega \\ \dfrac{\partial u}{\partial \nu} = g \quad \text{on } \partial\Omega, \\ \int_{\partial\Omega} u ds = 0, \end{cases} \tag{1}$$

where χ_D is the characteristic function and $g \in H_0^{-1/2}(\partial\Omega)$.
Our objective is to recover D by the following two approaches.

A) Assuming D is a disk and using a single boundary Cauchy pair.

B) Using multifrequency boundary Cauchy pairs.

Denoting by u_i the solution to (1) corresponding to D is a disk centred at z_i with radius R_i,

Theorem 1. *Let $\varepsilon \in (0,1)$ and assume that*

$$||u_1|_{\partial\Omega} - u_2|_{\partial\Omega}||_{L^\infty(\partial\Omega)} = \varepsilon. \tag{2}$$

Then, there exist constants $0 < \alpha, \beta < 1$ and $C > 0$, such that

$$|z_1 - z_2| \leq C\varepsilon^\alpha, \qquad |R_1 - R_2| \leq C\varepsilon^\beta. \tag{3}$$

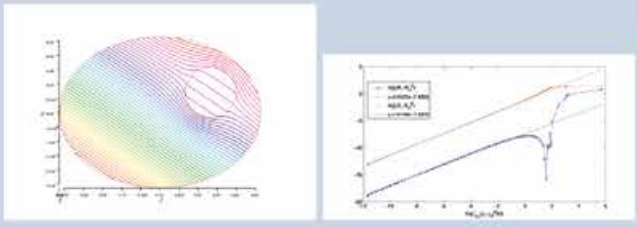
Numerical Result

A) Our scheme is essentially based on the minimizing of the functional

$$J(u) = \frac{1}{2}\int_{\partial\Omega} |u - u_{meas}|^2 d\sigma,$$

where u is the simulated solution of (1) and u_{meas} is the measurements. The setting of all numerical tests is as follows:

- We use FreeFem++ for our numerical experiments.
- We use P2 finite elements for the numerical resolution of the PDEs.
- At each iteration, we remesh the domain to adapt to the new predicted position of the disk.



We find in this case that $\alpha = 0.95$ for radius estimate and $\beta = 1.01$ for location estimate.

B)

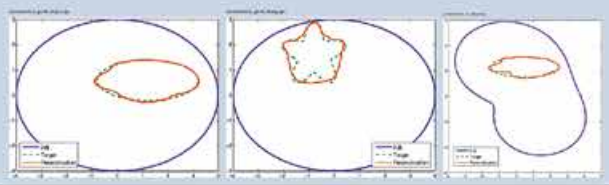
Theorem 2. *Let D and $\tilde{D}$ be two inclusions in Ω. Denoting by u (resp. $\tilde{u}$) the solution of (1) with the inclusion D (resp. $\tilde{D}$). Let*

$$\varepsilon = \sup_{x\in\partial\Omega, \omega\in[\underline{\omega},\overline{\omega}]} |u - \tilde{u}|.$$

Then, there exist constants $C > 0$ and $0 < \tau < 1$ such that,

$$|D \triangle \tilde{D}| \leq C\left(\frac{1}{\ln(\varepsilon^{-1})}\right)^\tau. \tag{4}$$

Here, $\triangle$ denotes the symmetric difference and the constants C, τ depend only on Ω and g.



Forthcoming Research

Extend the research to recover a target in unbounded domains (Ω is the exterior of a bounded domain).

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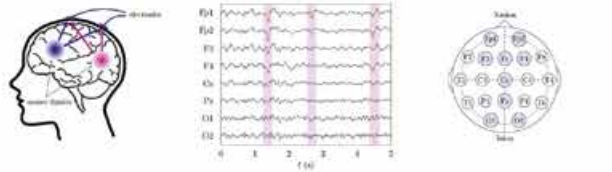
1. Electroencephalography (EEG)

- Recording of the electrical activity on the scalp generated by underlying source dipoles in the brain.
- Applications: diagnosis, neurofeedback, brain computer interface (BCI).
- Good temporal resolution **but** *bad spatial one*: the source signals are *mixed*.
- **Goal**: improve the spatial resolution by retrieving the true source signals.



Left: schematic illustration of the mixing process of the source dipoles on the electrodes. The electrical signals of the source dipoles are mixed when getting through the brain, the skull and the scalp.
Middle: signals of the colored electrodes on the right of an EEG recording acquired on an epileptic patient with 19 electrodes (see on the right). The colored areas correspond to pseudo-slow wave complexes, often seen in epileptic patients. One can see that these peaks appear on several electrodes (mainly the frontal ones). This illustrates the mixing process since they are induced by one source dipole in the brain.
Right: locations of the electrodes on the scalp of the recording in the middle. They are placed according to the 10-20 international system.

2. Blind source separation (BSS) for EEG

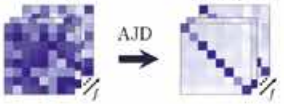
- *Hypothesis 1*: EEG recordings follow the instantaneous linear mixing model [1]:

$$\boldsymbol{x}(t) = \boldsymbol{A}\boldsymbol{s}(t), \tag{1}$$

where t is a time index, $\boldsymbol{x}(t)$ and $\boldsymbol{s}(t)$ in $\mathbb{R}^n$ correspond to the electrodes and source signals respectively, and $\boldsymbol{A}$ in $\mathbb{R}^{n\times n}$ is an invertible mixing matrix.
- *Hypothesis 2*: the true source signals are statistically independent [2].
- EEG signals are characterized by their spectra in the frequency domain, thus we can exploit this diversity by using the *Fourier cospectra* $\boldsymbol{C}_f$ for frequencies of interest f [1]:
  - ▶ element i, j: covariance between signals of electrodes i and j at frequency f.
  - ▶ in $\mathcal{S}_n^{++}$, the set of $n \times n$ *symmetric positive definite* (SPD) matrices.
- To retrieve the source process, we have to find an invertible matrix $\boldsymbol{B}$ in $\mathbb{R}^{n\times n}$ such that matrices $\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T$ are diagonal.
  - ▶ $\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T$ are the cospectra of $\widetilde{\boldsymbol{s}}(t) = \boldsymbol{B}\boldsymbol{x}(t)$.
  - ▶ Diagonal cospectra means statistical independence of the components of $\widetilde{\boldsymbol{s}}(t)$. Thus, $\widetilde{\boldsymbol{s}}(t)$ corresponds to the source signals.

3. Approximate joint diagonalization (AJD)

- Given a set $\{\boldsymbol{C}_f\}$ of SPD matrices, the goal is to find a basis $\boldsymbol{B}$ in $\mathbb{R}^{n\times n}$ such that $\{\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T\}$ contains matrices as much diagonal as possible.



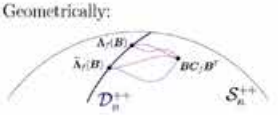
- It is done by minimizing a diagonality measure $f(\boldsymbol{B})$ of the set $\{\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T\}$ [3]:

$$\underset{\boldsymbol{B}}{\operatorname{argmin}}\ f(\boldsymbol{B}) = \sum_f w_f\, d(\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T, \boldsymbol{\Lambda}_f(\boldsymbol{B})), \tag{2}$$

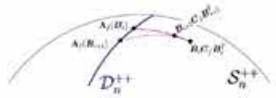
  - ▶ w_f are positive weights,
  - ▶ $d(\cdot,\cdot)$ is a *divergence* (possibly squared distance) on $\mathcal{S}_n^{++}$,
  - ▶ $\boldsymbol{\Lambda}_f(B)$ are target matrices in $\mathcal{D}_n^{++}$, the set of diagonal matrices with strictly positive elements.
- A *natural choice* for $\boldsymbol{\Lambda}_f(\boldsymbol{B})$ is to take the closest diagonal matrix to $\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T$ according to the divergence $d(\cdot,\cdot)$ [3]:

$$\underset{\boldsymbol{\Lambda}_f(\boldsymbol{B})}{\operatorname{argmin}}\ d(\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T, \boldsymbol{\Lambda}_f(\boldsymbol{B})). \tag{3}$$

- There is no closed form solution to this problem, thus we must use an *iterative optimization process* [2]. To avoid degenerate solutions, *e.g.* the trivial solution $\boldsymbol{B} = \boldsymbol{0}$, a constraint on the determinant or the norm of the lines of $\boldsymbol{B}$ is needed.
- Geometrically:



Schematic illustration of the influence of the divergence and target diagonal matrices on the AJD criterion. The target diagonal matrix ($\boldsymbol{\Lambda}_f(B)$ or $\widetilde{\boldsymbol{\Lambda}}_f(\boldsymbol{B})$ here) determines where on $\mathcal{D}_n^{++}$ one wants to go. The divergence, which corresponds to a path on $\mathcal{S}_n^{++}$ (blue and purple curves joining $\boldsymbol{B}\boldsymbol{C}_f\boldsymbol{B}^T$ and $\boldsymbol{\Lambda}_f(\boldsymbol{B})$ or $\widetilde{\boldsymbol{\Lambda}}_f(\boldsymbol{B})$ here), determines how to get closer to the target diagonal matrix.



Schematic illustration of the iterative optimization process. Given the iterate $\boldsymbol{B}_i$, the next iterate $\boldsymbol{B}_{i+1}$ is obtained such that $\boldsymbol{B}_{i+1}\boldsymbol{C}_f\boldsymbol{B}_{i+1}^T$ gets closer to $\mathcal{D}_n^{++}$ according to the divergence $d(\cdot,\cdot)$ and the diagonal matrix $\boldsymbol{\Lambda}_f(\boldsymbol{B}_i)$. Note that the target diagonal matrix moves on $\mathcal{D}_n^{++}$ as the iterate $\boldsymbol{B}_i$ is updated.

4. Divergences

- **Frobenius**: most studied AJD criterion, arises from the reasoning that one needs to minimize the off-diagonal elements of matrices to diagonalize [4].

$$\delta_{\mathrm{F}}^2(\boldsymbol{C},\boldsymbol{\Lambda}) = \|\boldsymbol{C}-\boldsymbol{\Lambda}\|_F^2, \qquad \boldsymbol{\Lambda} = \mathrm{ddiag}(\boldsymbol{C}). \tag{4}$$

- **Kullback-Leibler**: links with the *likelihood* and *mutual information* [5]. It yields several diagonality measures and we consider the left and right ones here.

$$\begin{aligned} d_{\mathrm{KL}}(\boldsymbol{P},\boldsymbol{S}) &= \mathrm{tr}(\boldsymbol{P}^{-1}\boldsymbol{S}-\boldsymbol{I}_n) - \log\det(\boldsymbol{P}^{-1}\boldsymbol{S}),\\ d_{\mathrm{lKL}}(\boldsymbol{C},\boldsymbol{\Lambda}) &= d_{\mathrm{KL}}(\boldsymbol{\Lambda},\boldsymbol{C}), \qquad \boldsymbol{\Lambda} = \mathrm{ddiag}(\boldsymbol{C}),\\ d_{\mathrm{rKL}}(\boldsymbol{C},\boldsymbol{\Lambda}) &= d_{\mathrm{KL}}(\boldsymbol{C},\boldsymbol{\Lambda}), \qquad \boldsymbol{\Lambda} = \mathrm{ddiag}(\boldsymbol{C}^{-1})^{-1}. \end{aligned} \tag{5}$$

- **Natural Riemannian**: major interest both from *differential geometry* [6] and *information geometric* [7] point of views.

$$\delta_{\mathrm{R}}^2(\boldsymbol{C},\boldsymbol{\Lambda}) = \left\|\log\left(\boldsymbol{\Lambda}^{-1/2}\boldsymbol{C}\boldsymbol{\Lambda}^{-1/2}\right)\right\|_F^2, \qquad \mathrm{ddiag}(\boldsymbol{C}^{-1}\boldsymbol{\Lambda}) = 0. \tag{6}$$

- **Bhattacharyya**: closely related to the natural Riemannian distance while numerically cheaper [8].

$$\delta_{\mathrm{B}}^2(\boldsymbol{C},\boldsymbol{\Lambda}) = 4\log\frac{\det\left((\boldsymbol{C}+\boldsymbol{\Lambda})/2\right)}{\det(\boldsymbol{C})^{1/2}\det(\boldsymbol{\Lambda})^{1/2}}, \qquad 2\,\mathrm{ddiag}\left((\boldsymbol{C}+\boldsymbol{\Lambda})^{-1}\right) = \boldsymbol{\Lambda}^{-1}. \tag{7}$$

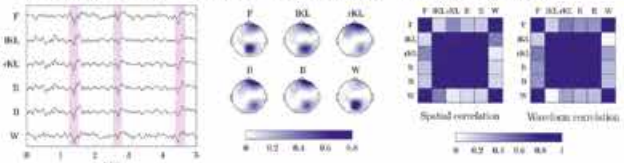
- **Wasserstein**: important for optimal transport [9] and covariance matrices [10].

$$\delta_{\mathrm{W}}^2(\boldsymbol{C},\boldsymbol{\Lambda}) = \mathrm{tr}\left(\frac{1}{2}(\boldsymbol{C}+\boldsymbol{\Lambda}) - (\boldsymbol{\Lambda}^{1/2}\boldsymbol{C}\boldsymbol{\Lambda}^{1/2})^{1/2}\right), \qquad \mathrm{ddiag}\left((\boldsymbol{\Lambda}^{1/2}\boldsymbol{C}\boldsymbol{\Lambda}^{1/2})^{1/2}\right) = \boldsymbol{\Lambda}. \tag{8}$$

$\boldsymbol{I}_n$ denotes the identity matrix, $\mathrm{ddiag}(\cdot)$ cancels the off-diagonal elements of its argument, $\mathrm{tr}(\cdot)$ and $\det(\cdot)$ are the trace and determinant operators.

5. Numerical experiment

- We perform the BSS of the EEG recording shown in section 1 with all divergences of section 4. We focus on the recovery of the peak-slow wave complexes.



Left: waveforms of the estimated source corresponding to the peak-slow wave complexes for all divergences considered.
Middle: spatial distributions of the estimated source on the scalp for all divergences considered.
Right: spatial and waveform correlations of the sources recovered with the different divergences.

- Two groups of similar sources can be distinguished when comparing the waveforms and spatial distributions:
  - ▶ Frobenius and Wasserstein (mainly parietal).
  - ▶ right/left Kullback-Leibler, Bhattacharyya and Riemannian (mainly frontal).
- Peak-slow wave complexes source dipole: negative and positive poles propagate to the parietal and frontal electrodes, respectively.

6. Conclusions and perspectives

- The different criteria give different information that can be *complementary*. Thus, we should find a way to *combine* them to obtain more robust and accurate results.
- The different criteria possess *different theoretical properties* [11]. Their study might bring *new insights* on the AJD problem.
- We associated the divergences with their closest diagonal matrices. Other combinations might be interesting and lead to a *better understanding* of their influence.
- There are links between AJD and *center of mass* [11]. We need to further investigate these links and develop methods that simultaneously seek both of them.

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NOTES

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