RESEARCH CENTER
Rennes - Bretagne-Atlantique

FIELD

Activity Report 2019

Section Partnerships and Cooperations

Edition: 2020-03-21

CAIRN Project-Team

7. Partnerships and Cooperations

7.1. Regional Initiatives

7.1.1. Labex CominLabs - BBC (2016-2020)

Participants: Olivier Sentieys, Cédric Killian, Joel Ortiz Sosa.

The aim of the BBC (on-chip wireless Broadcast-Based parallel Computing) project is to evaluate the use of wireless links between cores inside chips and to define new paradigms. Using wireless communications enables broadcast capabilities for Wireless Networks on Chip (WiNoC) and new management techniques for memory hierarchy and parallelism. The key objectives concern improvement of power consumption, estimation of achievable data rates, flexibility and reconfigurability, size reduction and memory hierarchy management. In this project, CAIRN is addressing new low-power MAC (media access control) technique based on CDMA access as well as broadcast-based fast cooperation protocol designed for resource sharing (bandwidth, distributed memory, cache coherency) and parallel programming. For more details see https://bbc.cominlabs.u-bretagneloire.fr

7.2. National Initiatives

7.2.1. ANR AdequateDL

Participants: Olivier Sentieys, Silviu-Ioan Filip.

Program: ANR PRC

Project acronym: AdequateDL

Project title: Approximating Deep Learning Accelerators

Duration: Jan. 2019 - Dec. 2022

Coordinator: Cairn

Other partners: INL, CAIRN, LIRMM, CEA-LIST

The design and implementation of convolutional neural networks for deep learning is currently receiving a lot of attention from both industrials and academics. However, the computational workload involved with CNNs is often out of reach for low power embedded devices and is still very costly when run on datacenters. By relaxing the need for fully precise operations, approximate computing substantially improves performance and energy efficiency. Deep learning is very relevant in this context, since playing with the accuracy to reach adequate computations will significantly enhance performance, while keeping quality of results in a user-constrained range. AdequateDL will explore how approximations can improve performance and energy efficiency of hardware accelerators in deep-learning applications. Outcomes include a framework for accuracy exploration and the demonstration of order-of-magnitude gains in performance and energy efficiency of the proposed adequate accelerators with regards to conventional CPU/GPU computing platforms.

7.2.2. ANR RAKES

Participants: Olivier Sentieys, Cédric Killian, Joel Ortiz Sosa.

Program: ANR PRC

Project acronym: RAKES

Project title: Radio Killed an Electronic Star: speed-up parallel programming with broadcast communications based on hybrid wireless/wired network on chip

Duration: June 2019 - June 2023

Coordinator: TIMA

Other partners: TIMA, CAIRN, Lab-STICC

The efficient exploitation by software developers of multi/many-core architectures is tricky, especially when the specificities of the machine are visible to the application software. To limit the dependencies to the architecture, the generally accepted vision of the parallelism assumes a coherent shared memory and a few, either point to point or collective, synchronization primitives. However, because of the difference of speed between the processors and the main memory, fast and small dedicated hardware controlled memories containing copies of parts of the main memory (a.k.a caches) are used. Keeping these distributed copies up-to-date and synchronize the accesses to shared data, requires to distribute and share information between some may if not all the nodes. By nature, radio communications provide broadcast capabilities at negligible latency, they have thus the potential to disseminate information very quickly at the scale of a circuit and thus to be an opening for solving these issues. In the RAKES project, we intend to study how wireless communications can solve the scalability of the abovementioned problems, by using mixed wired/wireless Network on Chip. We plan to study several alternatives and to provide (a) a virtual platform for evaluation of the solutions and (b) an actual implementation of the solutions.

7.2.3. ANR Opticall^2

Participants: Olivier Sentieys, Cédric Killian, Daniel Chillet.

Program: ANR PRCE

Project acronym: Opticall^2

Project title: on-chip OPTIcal interconnect for ALL to ALL communications

Duration: Dec. 2018 - Nov. 2022

Coordinator: INL

Other partners: INL, CAIRN, C2N, CEA-LETI, Kalray

The aim of Opticall^2 is to design broadcast-enabled optical communication links in manycore architectures at wavelengths around 1.3μm. We aim to fabricate an optical broadcast link for which the optical power is equally shared by all the destinations using design techniques (different diode absorption lengths, trade-off depending on the current point in the circuit and the insertion losses). No optical switches will be used, which will allow the link latency to be minimized and will lead to deterministic communication times, which are both key features for efficient cache coherence protocols. The second main objective of Opticall^2 is to propose and design a new broadcast-aware cache coherence communication protocol allowing hundreds of computing clusters and memories to be interconnected, which is well adapted to the broadcast-enabled optical communication links. We expect better performance for the parallel execution of benchmark programs, and lower overall power consumption, specifically that due to invalidation or update messages.

7.2.4. ANR SHNOC

Participants: Cédric Killian, Daniel Chillet, Olivier Sentieys, Emmanuel Casseau.

Program: ANR JCJC (young researcher)

Project acronym: SHNOC

Project title: Scalable Hybrid Network-on-Chip

Duration: Feb. 2019 - Jan. 2022

P.I.: C. Killian, CAIRN

The goal of the SHNoC project is to tackle one of the manycore interconnect issues (scalability in terms of energy consumption and latency provided by the communication medium) by mixing emerging technologies. Technology evolution has allowed for the integration of silicon photonics and wireless on-chip communications, creating Optical and Wireless NoCs (ONoCs and WNoCs, respectively) paradigms. The recent publications highlight advantages and drawbacks for each technology: WNoCs are efficient for broadcast, ONoCs have low latency and high integrated density (throughput/cm^2) but are inefficient in multicast, while ENoCs are still the most efficient solution for small/average NoC size. The first contribution of this project is to study the compatibility of processes to associate the three aforementioned technologies and to define an hybrid

topology of the interconnection architecture. This exploration will determine the number of antennas for the WNoC, the amount of embedded lasers sources for the ONoC and the routers architecture for the ENoC. The second main contribution is to provide quality of service of communication by determining, at run-time, the best path among the three NoCs with respect to a target, e.g. minimizing the latency or energy. We expect to demonstrate that the three technologies are more efficient when jointly used and combined, with respect to traffic characteristics between cores and quality of service targeted.

7.2.5. IPL ZEP

Participants: Davide Pala, Olivier Sentieys.

Program: Inria Project Lab

Project acronym: ZEP

Project title: Zero-Power Computing Systems

Duration: Oct. 2017 - Nov. 2020

Coordinator: Inria Socrate

Other partners: Pacap, Cairn, Corse, CEA-LETI

The ZEP project addresses the issue of designing tiny, batteryless, computing objects harvesting energy in the environment. The main application target is Internet of Things (IoT) where small communicating objects will be composed of this computing part associated to a low-power wake-up radio system. The energy level harvested being very low, very frequent energy shortages are expected, which makes the systems following the paradigm of Intermittently-Powered Systems. In order for the system to maintain a consistent state, it will be based on a new architecture embedding non-volatile memory (NVRAM). The major outcomes of the project will be a prototype harvesting board including NVRAM and the design of a new non-volatile processor (NVP) associated with its optimizing compiler and operating system. Cairn is focusing on the microarchitecture of the NVP and on new strategies for backup and restore data and processor state. The ZEP project gathers four Inria teams that have a scientific background in architecture, compilation, operating system and low power together with the CEA Grenoble. Another important goal of the project is to structure the research and innovation that should occur within Inria to prepare the important technological shift brought by NVRAM technologies.

7.2.6. DGA RAPID - FLODAM (2017–2021)

Participants: Joseph Paturel, Simon Rokicki, Olivier Sentieys, Angeliki Kritikakou.

FLODAM is an industrial research project for methodologies and tools dedicated to the hardening of embedded multi-core processor architectures. The goal is to: 1) evaluate the impact of the natural or artificial environments on the resistance of the system components to faults based on models that reflect the reality of the system environment, 2) the exploration of architecture solutions to make the multi-core architectures fault tolerant to transient or permanent faults, and 3) test and evaluate the proposed fault tolerant architecture solutions and compare the results under different scenarios provided by the fault models. For more details see https://flodam.fr

7.3. European Initiatives

7.3.1. H2020 ARGO

Participants: Steven Derrien, Angeliki Kritikakou, Olivier Sentieys.

Program: H2020-ICT-04-2015

Project acronym: ARGO

Project title: WCET-Aware Parallelization of Model-Based Applications for Heterogeneous Parallel Systems

Duration: Feb. 2016 - Feb. 2019

Coordinator: KIT

Other partners: KIT (Germany), UR1/Inria/CAIRN, Recore Systems (Netherlands), TEI-WG (Greece), Scilab Ent. (France), Absint (Ger.), DLR (Ger.), Fraunhofer (Ger.)

Increasing performance and reducing cost, while maintaining safety levels and programmability are the key demands for embedded and cyber-physical systems, e.g. aerospace, automation, and automotive. For many applications, the necessary performance with low energy consumption can only be provided by customized computing platforms based on heterogeneous many-core architectures. However, their parallel programming with time-critical embedded applications suffers from a complex toolchain and programming process. ARGO will address this challenge with a holistic approach for programming heterogeneous multi- and many-core architectures using automatic parallelization of model-based real-time applications. ARGO will enhance WCET-aware automatic parallelization by a cross-layer programming approach combining automatic tool-based and user-guided parallelization to reduce the need for expertise in programming parallel heterogeneous architectures. The ARGO approach will be assessed and demonstrated by prototyping comprehensive time-critical applications from both aerospace and industrial automation domains on customized heterogeneous many-core platforms.

7.3.2. ANR International ARTEFaCT

Participants: Olivier Sentieys, Van-Phu Ha, Tomofumi Yuki.

Program: ANR International France-Switzerland

Project acronym: ARTEFaCT

Project title: AppRoximaTivE Flexible Circuits and Computing for IoT

Duration: Feb. 2016 - Dec. 2019

Coordinator: CEA

Other partners: CEA-LETI, CAIRN, EPFL

The ARTEFaCT project aims to build on the preliminary results on inexact and exact near-threshold and sub-threshold circuit design to achieve major energy consumption reductions by enabling adaptive accuracy control of applications. ARTEFaCT proposes to address, in a consistent fashion, the entire design stack, from physical hardware design, up to software application analysis, compiler optimizations, and dynamic energy management. We do believe that combining sub-near-threshold with inexact circuits on the hardware side and, in addition, extending this with intelligent and adaptive power management on the software side will produce outstanding results in terms of energy reduction, i.e., at least one order of magnitude, in IoT applications. The project will contribute along three research directions: (1) approximate, ultra low-power circuit design, (2) modeling and analysis of variable levels of computation precision in applications, and (3) accuracy-energy trade- offs in software.

7.4. International Initiatives

7.4.1. Inria International Labs

EPFL-Inria

Associate Team involved in the International Lab:

7.4.1.1. IoTA

Title: Ultra-Low Power Computing Platform for IoT leveraging Controlled Approximation

International Partner (Institution - Laboratory - Researcher):

Ecole Polytechnique Fédérale de Lausanne (Switzerland) - Prof. Christian Enz

Start year: 2017

See also: https://team.inria.fr/cairn/IOTA

Energy issues are central to the evolution of the Internet of Things (IoT), and more generally to the ICT industry. Current low-power design techniques cannot support the estimated growth in number of IoT objects and at the same time keep the energy consumption within sustainable bounds, both on the IoT node side and on cloud/edge-cloud side. This project aims to build on the preliminary results on inexact and exact sub/near-threshold circuit design to achieve major energy consumption reductions by enabling adaptive accuracy control of applications. Advanced ultra low-power hardware design methods utilize very low supply voltage, such as in near-threshold and sub-threshold designs. These emerging technologies are very promising avenues to decrease active and stand-by-power in electronic devices. To move another step forward, recently, approximate computing has become a major field of research in the past few years. IoTA proposes to address, in a consistent fashion, the entire design stack, from hardware design, up to software application analysis, compiler optimizations, and dynamic energy management. We do believe that combining sub-near-threshold with inexact circuits on the hardware side and, in addition, extending this with intelligent and adaptive power management on the software side will produce outstanding results in terms of energy reduction, i.e., at least one order of magnitude, in IoT. The main scientific challenge is twofold: (1) to add adaptive accuracy to hardware blocks built in near/sub threshold technology and (2) to provide the tools and methods to program and make efficient use of these hardware blocks for applications in the IoT domain. This entails developing approximate computing units, on one side, and methods and tools, on the other side, to rigorously explore trade-offs between accuracy and energy consumption in IoT systems. The expertise of the members of the two teams is complementary and covers all required technical knowledge necessary to reach our objectives, i.e., ultra low power hardware design (EPFL), approximate operators and functions (Inria, EPFL), formal analysis of precision in algorithms (Inria), and static and dynamic energy management (Inria, EPFL). Finally, the proof of concept will consist of results on (1) an adaptive, inexact or exact, ultra-low power microprocessor in 28 nm process and (2) a real prototype implemented in an FPGA platform combining processors and hardware accelerators. Several software use-cases relevant for the IoT domain will be considered, e.g., embedded vision, IoT sensors data fusion, to practically demonstrate the benefits of our approach.

7.4.2. Inria Associate Teams Not Involved in an Inria International Labs

7.4.2.1. IntelliVIS

Title: Design Automation for Intelligent Vision Hardware in Cyber Physical Systems

International Partner (Institution - Laboratory - Researcher):

IIT Goa (India) - Prof. Sharad Sinha

Start year: 2019

The proposed collaborative research work is focused on the design and development of artificial intelligence based embedded vision architectures for cyber physical systems (CPS). Embedded vision architectures for cyber physical systems (CPS), sometimes referred to as “Visual IoT”, are challenging to design because of primary constraints of compute resources, energy and power management. Embedded vision nodes in CPS, when designed with the application of Artificial Intelligence principles and algorithms, will turn into intelligent nodes (self-learning devices) capable of performing computation and inference at the node resulting in node-level cognition. This would allow only necessary and relevant post processed data to be sent to a human or a computer-based analyst for further processing and refinement in results. However, design and development of such nodes is non-trivial. Many existing computer vision algorithms, typically ported to embedded platforms, are compute and memory intensive thus limiting the operational time when ported to battery powered devices. In addition, transmission of captured visual data, with minimal processing at the node to extract actionable insights poses increased demands on computational, communication and energy requirements. Visual saliency i.e. extraction of key features or regions of interest in images or videos captured by an embedded vision node and related post processing for inference using AI techniques is an interesting and challenging research direction. The primary reason being

that such an approach is expected to cover a wider range of application specific scenarios than statically determined approaches specific to each scenario involving remote off-loading of compute or scenario specific data on servers. Apart from a general approach to visual saliency in nodes using AI based methods (machine and deep learning methods), another principal goal of the proposed project is also to examine and propose methods that allow rapid deployment of AI techniques in these nodes. Many AI techniques are data driven and for a node to adapt from one environment or application specific scenario to another, rapid deployment of AI techniques over the air (OTA) would be an interesting and challenging research direction.

7.4.3. Inria International Partners

7.4.3.1. DARE

Title: Design space exploration Approaches for Reliable Embedded systems

International Partner (Institution - Laboratory - Researcher):

IMEC (Belgium) - Francky Catthoor, IMEC fellow

Duration: 2017 - 2021

Start year: 2017

This collaborative research focuses on methodologies to design low cost and efficient techniques for safety-critical embedded systems, which require high performance and safety implying both fault tolerance and hard real-time constraints. More precisely, the objective is to develop Design Space Exploration (DSE) methodology applicable to any platform domain to drive the design of adaptive predictable low cost and efficient error detection techniques. Run-time dynamic control mechanisms are proposed to actively optimize system fault tolerance by exploring the trade-offs between predictability, reliability, performance and energy consumption using the information received from the environment and the platform during execution. In contrast to design-time static approaches the dynamism can then be exploited to improve energy consumption and performance.

7.4.3.2. LRS

Title: Loop unRolling Stones: compiling in the polyhedral model

International Partner (Institution - Laboratory - Researcher):

Colorado State University (United States) - Department of Computer Science - Prof. Sanjay Rajopadhye

7.4.3.3. HARAMCOP

Title: Hardware accelerators modeling using constraint-based programming

International Partner (Institution - Laboratory - Researcher):

Lund University (Sweden) - Department of Computer Science - Prof. Krzysztof Kuchcinski

7.4.3.4. DeLeES

Title: Energy-efficient Deep Learning Systems for Low-cost Embedded Systems

International Partner (Institution - Laboratory - Researcher):

University of British Columbia (Vancouver, Canada) - Electrical and Computer Engineering - Prof. Guy Lemieux

Start year: 2018

This collaboration is centered around creation of deep-learning inference systems which are energy efficient and low cost. There are two design approaches: (i) an all-digital low-precision system, and (ii) mixed analog/digital low-precision system.

7.4.3.5. Informal International Partners

Dept. of Electrical and Computer Engineering, Concordia University (Canada), Optical network-on-chip, manycore architectures.

LSSI laboratory, Québec University in Trois-Rivières (Canada), Design of architectures for digital filters and mobile communications.

Department of Electrical and Computer Engineering, University of Patras (Greece), Wireless Sensor Networks, Worst-Case Execution Time, Priority Scheduling.

Karlsruhe Institute of Technology - KIT (Germany), Loop parallelization and compilation techniques for embedded multicores.

PARC Lab., the University of Auckland (New-Zealand), Fault-tolerant task scheduling onto multi-core.

Ruhr - University of Bochum - RUB (Germany), Reconfigurable architectures.

University of Science and Technology of Hanoi (Vietnam), Participation of several CAIRN's members in the Master ICT / Embedded Systems.

7.5. International Research Visitors

7.5.1. Visits of International Scientists

- Bernard Goossens, Univ. Perpignan, July 2019.
- Sharad Sinha, IIT Goa, India, July 2019.

7.5.2. Visits to International Teams

7.5.2.1. Sabbatical programme

Steven Derrien visited Colorado State University for a 6 month sabbatical from January to July 2019, where he collaborated with Sanjay Rajopadhye. This collaboration has led to two joint PhD between Université de Rennes 1 and Colorado State University which both started in late 2019.

7.5.2.2. Research Stays Abroad

- Olivier Sentieys visited Colorado State University, Computer Science Department and gave a seminar on Approximate Computing in November 2019.
- P. Dobias (PhD student) spent 5 months in the Parallel and Reconfigurable Lab. of the Electrical and Computer Engineering department, the University of Auckland, New Zealand, from November 2018 until March 2019.

CELTIQUE Project-Team

5. Partnerships and Cooperations

5.1. National Initiatives

5.1.1. The ANR Scrypt project

Participants: Frédéric Besson, Sandrine Blazy, Thomas Jensen, David Pichardie, Alexandre Dang, Remi Hutin.

Security, Secure compilation

The Scrypt project (ANR-18-CE25-0014) aims at providing secure implementations of crypto-graphic primitives using formal methods and secure compilation techniques. One specific goal is to design secure compilers which preserve the security of the source code against side-channel attacks.

This is a joint project with the Inria team MARELLE, École Polytechnique and AMOSSYS.

5.1.2. The ANR MALTHY project

Participant: David Cachera.

The MALTHY project, funded by ANR in the program INS 2013, aims at advancing the state-of-the-art in real-time and hybrid model checking by applying advanced methods and tools from linear algebra and algebraic geometry. MALTHY is coordinated by VERIMAG, involving CEA-LIST, Inria Rennes (Tamis and Celtique), Inria Saclay (MAXPLUS) and VISEO/Object Direct.

5.1.3. The ANR AJACS project

Participants: Thomas Jensen, Alan Schmitt.

The goal of the AJACS project is to provide strong security and privacy guarantees on the client side for web application scripts. To this end, we propose to define a mechanized semantics of the full JavaScript language, the most widely used language for the Web. We then propose to develop and prove correct analyses for JavaScript programs, in particular information flow analyses that guarantee no secret information is leaked to malicious parties. The definition of sub-languages of JavaScript, with certified compilation techniques targeting them, will allow us to derive more precise analyses. Finally, we propose to design and certify security and privacy enforcement mechanisms for web applications, including the APIs used to program real-world applications.

The project partners include the following Inria teams: Celtique, Indes, Prosecco, and Toccata; it also involves researchers from Imperial College as external collaborators. The project runs from December 2014 to March 2019.

5.1.4. The ANR DISCOVER project

Participants: Sandrine Blazy, David Cachera, Delphine Demange, Thomas Jensen, David Pichardie, Yon Fernandez de Retana, Thomas Rubiano, Yannick Zakowski.

The DISCOVER project project (2014–09/2019) aims at leveraging recent foundational work on formal verification and proof assistants to design, implement and verify compilation techniques used for high-level concurrent and managed programming languages. The ultimate goal of DISCOVER is to devise new formalisms and proof techniques able to scale to the mechanized correctness proof of a compiler involving a rich class of optimizations, leading to efficient and scalable applications, written in higher-level languages than those currently handled by cutting-edge verified compilers.

In the light of recent work in optimizations techniques used in production compilers of high-level languages, control-flow-graph based intermediate representations seems too rigid. Indeed, the analyses and optimizations in these compilers work on more abstract representations, where programs are represented with data and control dependencies. The most representative representation is the sea-of-nodes form, used in the Java Hotspot Server Compiler, and which is the rationale behind the highly relaxed definition of the Java memory model. DISCOVER proposes to tackle the problem of verified compilation for shared-memory concurrency with a resolute language-based approach, and to investigate the formalization of adequate program intermediate representations and associated correctness proof techniques.

The project started in October 2014 and ended on September 2019.

5.1.5. The ANR CISC project

Participants: Frédéric Besson, Thomas Jensen, Alan Schmitt.

The goal of the CISC project is to investigate multitier languages and compilers to build secure IoT applications with private communication. In particular, we aim at extending multitier platforms by a new orchestration language that we call Hiphop.js to synchronize internal and external activities of IoT applications as a whole. Our goal is to define language, semantics, attacker models, and policies for the IoT and investigate automatic implementation of privacy and security policies by multitier compilation of IoT applications. To guarantee such applications are correct, and in particular that the required security and privacy properties are achieved, we propose to certify them using the Coq proof assistant. We plan to implement the CISC results as extensions of the multitier language Hop.js (developed at Inria), based on the JavaScript language to maximize its impact. Using the new platform, we will carry out experimental studies on IoT security.

The project partners include the following Inria teams: Celtique, Collège de France, Indes, and Privatics. The project runs from April 2018 to March 2022.

5.2. European Initiatives

5.2.1. FP7 & H2020 Projects

5.2.1.1. The ERC VESTA project

Participants: David Pichardie, Sandrine Blazy, Nicolas Barré, Stefania Dumbrava, Jean-Christophe Léchenet, Rémi Hutin, Aurèle Barrière, Solène Mirliaz.

The VESTA project aims at proposing guidance and tool-support to the designers of static analysis, in order to build advanced but reliable static analysis tools. We focus on analyzing low-level softwares written in C, leveraging on the CompCert verified compiler. Verasco is a verified static analyser that analyses C programs and follows many of the advanced abstract interpretation techniques developped for Astrée. The outcome of the VESTA project will be a platform that help designing other verified advanced abstract interpreters like Verasco, without starting from a white page. We will apply this technique to develop security analyses for C programs. The platform will be open-source and will help the adoption of abstract interpretation techniques.

This a consolidator ERC awarded to David Pichardie for 5 years. The project started in September 2018.

5.2.1.2. The SPARTA cybersecurity competence network

Participants: Thomas Jensen, Frédéric Besson.

SPARTA is a novel Cybersecurity Competence Network, supported by the EU's H2020 program, with the objective to develop and implement top-tier research and innovation collaborative actions. Guided by concrete challenges forming an ambitious Cybersecurity Research & Innovation Roadmap, SPARTA will set up unique collaboration means, leading the way in building transformative capabilities and forming a world-leading Cybersecurity Competence Network across the EU. The SPARTA consortium assembles 44 actors from 14 EU Member States at the intersection of scientific excellence, technological innovation, and societal sciences in cybersecurity.

Celtique is coordinating the Inria participation in the SPARTA network. The team contributes to the programme on intelligent infrastructures with techniques for building security-enhanced systems code that respects strong information flow constraints. The team is also leading the elaboration of the SPARTA scientific roadmap, in collaboration with TU Munich.

5.2.2. Collaborations in European Programs, Except FP7 & H2020

Program:CA COST Action CA15123

Project acronym: EUTYPES

Project title: European research network on types for programming and verification

Duration: 03/2016 to 03/2020

Coordinator: Herman Geuvers (Radboud University Nijmegen, The Netherlands)

Other partners: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Macedonia, Germany, Hungary, Israel, Italy, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, United Kingdom

Abstract: Types are pervasive in programming and information technology. A type defines a formal interface between software components, allowing the automatic verification of their connections, and greatly enhancing the robustness and reliability of computations and communications. In rich dependent type theories, the full functional specification of a program can be expressed as a type. Type systems have rapidly evolved over the past years, becoming more sophisticated, capturing new aspects of the behaviour of programs and the dynamics of their execution.

This COST Action will give a strong impetus to research on type theory and its many applications in computer science, by promoting (1) the synergy between theoretical computer scientists, logicians and mathematicians to develop new foundations for type theory, for example as based on the recent development of "homotopy type theory", (2) the joint development of type theoretic tools as proof assistants and integrated programming environments, (3) the study of dependent types for programming and its deployment in software development, (4) the study of dependent types for verification and its deployment in software analysis and verification. The action will also tie together these different areas and promote cross-fertilisation.

Sandrine Blazy is Substitute Member of the Managment Committee for France.

5.3. International Initiatives

5.3.1. WEBCERT

Title: Verified Trustworthy web Applications

International Partner (Institution - Laboratory - Researcher):

Imperial College London - Department of Computing - Philippa Gardner

Duration: 2015 - 2019

Start year: 2015

See also: JSCert web page

The WebCert partnership focuses on applying formal methods to the JavaScript language: mechanized specification, development of an executable formal specification, design of a program logic, development of verification tools, and study of secure sub-languages.

CIDRE Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

- **Labex COMINLABS contract (2016-2019): "BigClin" - https://bigclin.cominlabs.u-bretagneloire.fr/fr**

  Health Big Data (HBD) is more than just a very large amount of data or a large number of data sources. The data collected or produced during the clinical care process can be exploited at different levels and across different domains, especially concerning questions related to clinical and translational research. To leverage these big, heterogeneous, sensitive and multi-domain clinical data, new infrastructures are arising in most of the academic hospitals, which are intended to integrate, reuse and share data for research.

  Yet, a well-known challenge for secondary use of HBD is that much of detailed patient information is embedded in narrative text, mostly stored as unstructured data. The lack of efficient Natural Language Processing (NLP) resources dedicated to clinical narratives, especially for French, leads to the development of ad-hoc NLP tools with limited targeted purposes. Moreover, the scalability and real-time issues are rarely taken into account for these possibly costly NLP tools, which make them inappropriate in real-world scenarios. Some other today's challenges when reusing Health data are still not resolved: data quality assessment for research purposes, scalability issues when integrating heterogeneous HBD or patient data privacy and data protection. These barriers are completely interwoven with unstructured data reuse and thus constitute an overall issue which must be addressed globally.

  In this project, we plan to develop distributed methods to ensure both the scalability and the online processing of these NLP/IR and data mining techniques; In a second step, we will evaluate the added value of these methods in several real clinical data and on real use-cases, including epidemilology and pharmaco-vigilance, clinical practice assessment and health care quality research, clinical trials.

8.2. National Initiatives

- **ANR Project: PAMELA (2016-2020) - https://project.inria.fr/pamela/**

  PAMELA is a collaborative ANR project involving Rennes 1 university (ASAP and CIDRE teams in Rennes), Inria Lille (MAGNET team), LIP6 (MLIA team) and two start-ups, Mediego and Snips. It aims at developing machine learning theories and algorithms in order to learn local and personalized models from data distributed over networked infrastructures. The project seeks to provide first answers to modern information systems built by interconnecting many personal devices holding private user data in the search of personalized suggestions and recommendations. More precisely, we will focus on learning in a collaborative way with the help of neighbors in a network. We aim to lay the first blocks of a scientific foundation for these new types of systems, in effect moving from graphs of data to graphs of data and learned models. CIDRE's contribution in this project involves the design of adversary models and privacy metrics suitable to the privacy-related issues of this distributed learning paradigm.

8.3. International Research Visitors

8.3.1. Research Stays Abroad

Emmanuelle Anceaume has been invited by the University of La Sapienza (Italy) from the 1st to the 30th of September 2019. During this stay, she collaborated with Profs Leonardo Querzony and Giuseppe A. Di Luna. Their collaboration gave rise to an implementation of the Replicated State Machine, which is resilient to Byzantine behaviors in asynchronous environments [18] (will appear at IPDPS in 2020).

8.4. European Initiatives

8.4.1. H2020 Projects

- **SPARTA (2019-2022) - https://www.sparta.eu/**

  SPARTA is a Cybersecurity Competence Network supported by the EU's H2020 program (Grant agreement ID: 830892) and led by CEA. This 3 years project started in February 2019. It aims to coordinate and develop the implementation of high-level research and innovation in digital security, in order to strengthen the strategic autonomy of the European Union.The CIDRE team is involved both in the workpackage 2 (SPARTA Roadmap) that aims to develop an ambitious Cybersecurity Research and Innovation Roadmap and the workpackage 6 (SPARTA Program HAII-T) that will develop a foundation for secure-by-design Intelligent infrastructures. More precisely, in the context of a task dedicated to resilience-by-design, we design an intrusion detection mechanism that combines both signature-based and anomaly-based approaches.

GALLINETTE Project-Team

7. Partnerships and Cooperations

7.1. Regional Initiatives

Vercoma (Atlanstic 2020/Attractivity grant)

Goal: Verified computer mathematics.

Coordinator: A. Mahboubi.

Duration: 08/2018 - 08/2021.

7.2. National Initiatives

7.2.1. ANR

FastRelax (ANR-14-CE25-0018).

Goal: Develop computer-aided proofs of numerical values, with certified and reasonably tight error bounds, without sacrificing efficiency.

Coordinator: Bruno Salvy (Inria, ENS Lyon).

Participant: A. Mahboubi.

Duration: 2014-2019.

Website: http://fastrelax.gforge.inria.fr/.

Note: This project started when A. Mahboubi was still in the Specfun project at the Saclay Île-de-France CRI. The budget is still managed there, within the Toccata project, but remains available to A. Mahboubi.

7.3. European Initiatives

7.3.1. FP7 & H2020 Projects

7.3.1.1. CoqHoTT

Title: Coq for Homotopy Type Theory

Programm: H2020

Type: ERC

Duration: June 2015 - May 2020

Coordinator: Inria

Inria contact: Nicolas TABAREAU

Every year, software bugs cost hundreds of millions of euros to companies and administrations. Hence, software quality is a prevalent notion and interactive theorem provers based on type theory have shown their efficiency to prove correctness of important pieces of software like the C compiler of the CompCert project. One main interest of such theorem provers is the ability to extract directly the code from the proof. Unfortunately, their democratization suffers from a major drawback, the mismatch between equality in mathematics and in type theory. Thus, significant Coq developments have only been done by virtuosos playing with advanced concepts of computer science and mathematics. Recently, an extension of type theory with homotopical concepts such as univalence is gaining traction because it allows for the first time to marry together expected principles of equality. But the univalence principle has been treated so far as a new axiom which breaks one fundamental property of mechanized proofs: the ability to compute with programs that make use

of this axiom. The main goal of the CoqHoTT project is to provide a new generation of proof assistants with a computational version of univalence and use them as a base to implement effective logical model transformation so that the power of the internal logic of the proof assistant needed to prove the correctness of a program can be decided and changed at compile time—according to a trade-off between efficiency and logical expressivity. Our approach is based on a radically new compilation phase technique into a core type theory to modularize the difficulty of finding a decidable type checking algorithm for homotopy type theory. The impact of the CoqHoTT project will be very strong. Even if Coq is already a success, this project will promote it as a major proof assistant, for both computer scientists and mathematicians. CoqHoTT will become an essential tool for program certification and formalization of mathematics.

Program: COST

Project acronym: EUTYPES

Project title: The European research network on types for programming and verification

Duration: 21/03/2016 - 20/03/2020.

Coordinator: Herman Geuvers (Radboud Univerity, Nijmegen, The Netherlands)

Abstract: Types are pervasive in programming and information technology. A type defines a formal interface between software components, allowing the automatic verification of their connections, and greatly enhancing the robustness and reliability of computations and communications. In rich dependent type theories, the full functional specification of a program can be expressed as a type. Type systems have rapidly evolved over the past years, becoming more sophisticated, capturing new aspects of the behaviour of programs and the dynamics of their execution.

This COST Action will give a strong impetus to research on type theory and its many applications in computer science, by promoting (1) the synergy between theoretical computer scientists, logicians and mathematicians to develop new foundations for type theory, for example as based on the recent development of "homotopy type theory", (2) the joint development of type theoretic tools as proof assistants and integrated programming environments, (3) the study of dependent types for programming and its deployment in software development, (4) the study of dependent types for verification and its deployment in software analysis and verification. The action will also tie together these different areas and promote cross-fertilisation.

Europe has a strong type theory community, ranging from foundational research to applications in programming languages, verification and theorem proving, which is in urgent need of better networking. A COST Action that crosses the borders will support the collaboration between groups and complementary expertise, and mobilise a critical mass of existing type theory research.

7.4. International Initiatives

7.4.1. Inria International Labs

Inria Chile

Associate Team involved in the International Lab:

7.4.1.1. GECO

Title: Gradual verification and robust proof Engineering for COq

International Partner (Institution - Laboratory - Researcher):

Universidad de Chile (Chile) - Centrum Wiskunde & Informatica - Éric Tanter

Start year: 2018

See also: http://geco.gforge.inria.fr

The development of tools to construct software systems that respect a given specification is a major challenge of current and future research in computer science. Interactive theorem provers based on type theory, such as Coq, have shown their effectiveness to prove correctness of important pieces of software like the C compiler of the CompCert project. Certified programming with dependent types is attracting a lot of attention recently, and Coq is the de facto standard for such endeavors, with an increasing amount of users, pedagogical material, and large-scale projects. Nevertheless, significant work remains to be done to make Coq more usable from a software engineering point of view.

This collaboration project gathers the expertise of researchers from Chile (Inria Chile, Universidad de Chile, Universidad Católica de Valparaíso) and France (Inria Nantes, Inria Paris), in different areas that are crucial to develop the vision of certified software engineering. The focus of this project is both theoretical and practical, covering novel foundations and methods, design of concrete languages and tools, and validation through specific case studies.

The end result will be a number of enhancements to the Coq proof assistant (frameworks, tactic language) together with guidelines and demonstrations of their applicability in realistic scenarios.

7.4.2. Inria International Partners

7.4.2.1. Informal International Partners

- A. Mahboubi holds a part-time endowed professor position in the Department of Mathematics at the Vrije Universiteit Amsterdam (the Netherlands).

7.5. International Research Visitors

7.5.1. Visits of International Scientists

- Matias Toro (U. Chile) visited 1 week in January to work with G. Munch-Maccagnoni.

7.5.2. Visits to International Teams

7.5.2.1. Research Stays Abroad

+ G. Munch-Maccagnoni visited E. Tanter and M. Toro (U. Chile) in March.

HYCOMES Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

Participants: Benoît Caillaud, Aurélien Lamercerie.

The Hycomes has been participating to the SUNSET project (2016–2019) of the CominLabs excellence laboratory [0]. This project focuses on the computation of surgical procedural knowledge models from recordings of individual procedures, and their execution [28]. The objective is to develop an enabling technology for procedural knowledge based computer assistance of surgery. In this project, we demonstrate its potential added value in nurse and surgeon training. The main contribution of the Hycomes team to this project has been the development of Demodocos, a process model synthesis tool, capable of generating models of a surgical procedure, from a few recordings of actual procedures. Demodocos has been interfaced to the `#SEVEN` virtual reality scenario modeling language and engine, developed in the Hybrid team at Inria Rennes. In 2019, the team has contributed to two publications presenting experimental results of the SUNSET project [9][6].

8.2. National Initiatives

8.2.1. Inria Project Lab (IPL): ModeliScale, Languages and Compilation for Cyber-Physical System Design

The project gathers researchers from three Inria teams, and from three other research labs in Grenoble and Paris area.

Name	*Team*	*Inria Center or Laboratory*
Vincent Acary Bernard Brogliato Alexandre Rocca	Tripop	Inria Grenoble Rhône Alpes
Albert Benveniste Benoît Caillaud Khalil Ghorbal Christelle Kozaily Mathias Malandain Benoît Vernay	Hycomes	Inria Rennes Bretagne Atlantique
Marc Pouzet Tim Bourke Imsail Lakhim-Bennani	Parkas	ENS & Inria Paris
Goran Frehse	SSH	ENSTA Paris-Tech.
Antoine Girard		L2S-CNRS, Saclay
Eric Goubault Sylvie Putot	Cosynus	LIX, École Polytechnique, Saclay

The main objective of ModeliScale is to advance modeling technologies (languages, compile-time analyses, simulation techniques) for CPS combining physical interactions, communication layers and software components. We believe that mastering CPS comprising thousands to millions of components requires radical changes of paradigms. For instance, modeling techniques must be revised, especially when physics is involved. Modeling languages must be enhanced to cope with larger models. This can only be done by combining new compilation techniques (to master the structural complexity of models) with new mathematical tools (new numerical methods, in particular).

[0] http://www.s3pm.cominlabs.ueb.eu/

MiodeliScale gathers a broad scope of experts in programming language design and compilation (reactive synchronous programming), numerical solvers (nonsmooth dynamical systems) and hybrid systems modeling and analysis (guaranteed simulation, verification). The research program is carried out in close cooperation with the Modelica community as well as industrial partners, namely, Dassault Systèmes as a Modelica/FMI tool vendor, and EDF and Engie as end users.

In 2019, three general meetings have been organized, with presentations of the partners on new results related to hybrid systems modeling and verification.

Two PhDs are funded by the ModeliScale IPL. Both started in October 2018:

- Christelle Kozaily has started a PhD, under the supervision of Vincent Acary (TRIPOP team at Inria Grenoble), Benoît Caillaud, Khalil Ghorbal on the structural and numerical analysis of non-smooth DAE systems. She is located in the Hycomes team at Inria Rennes.
- Ismail Lahkim-Bennani has started a PhD under the supervision of Goran Frehse (ENSTA Paris-Tech.) and Marc Pouzet (PARKAS team, Inria/ENS Paris). His PhD topic is on random testing of hybrid systems, using techniques inspired by QuickCheck [36].

8.2.2. FUI ModeliScale: Scalable Modeling and Simulation of Large Cyber-Physical Systems

Participants: Albert Benveniste, Benoît Caillaud, Khalil Ghorbal, Mathias Malandain.

FUI ModeliScale is a French national collaborative project coordinated by Dassault Systèmes. The partners of this project are: EDF and Engie as main industrial users; DPS, Eurobios and PhiMeca are SME providing mathematical modeling expertise; CEA INES (Chambéry) and Inria are the academic partners. The project started January 2018, for a maximal duration of 42 months. Three Inria teams are contributing to the project : Hycomes, Parkas (Inria Paris / ENS) and Tripop (Inria Grenoble / LJK).

The focus of the project is on the scalable analysis, compilation and simulation of large Modelica models. One of the main contributions expected from Inria are:

- A novel structural analysis algorithms for multimode DAE systems, capable of handling large systems of guarded equations, that do not depend on the enumeration of a possibly exponential number of modes.
- The partitioning and high-performance distributed co-simulation of large Modelica models, based on the results of the structural analysis.

In 2019, the effort has been put on the first objective, and two important milestones have been reached:

- The design of a novel algorithm for the structural analysis of multimode DAE systems. This algorithm is a generalization of the Pryce structural analysis method to the multimode case. The key feature of our method is that it works on implicit representations of the set of modes, and of the varying structure of the multimode DAE. In other words, it does not imply the enumeration of the system's modes. Performing the structural analysis at compile-time brings two decisive advantages: 1/ it allows to deliver to the user precise diagnostics about the model, and can be compared type-checking in programming languages; 2/ it is instrumental for the generation of efficient simulation code. Our algorithm is the first method enabling the compile-time analysis of systems with extremely large combinatorics of modes.
- Our multimode DAE structural analysis algorithm has been implemented in IsamDAE, a software comprizing an algorithmic library, to be used in modeling language compilers (Modelica tools) and a standalone tool, to be used independently of a complex Modelica toolset. IsamDAE has allowed to benchmark the method against several families of models, inspired by case-studies developed by industrial partners of the FUI ModeliScale project. Despite the tool is still under development, we have already been able to deal with models with up to 10^{23} modes.

On top of these two main results, the Hycomes team has started investigating the use of Quantized Space Systems (QSS), for the simulation of large DAE systems. QSSs simulation (QSS) was introduced in the early 2000's by F. Cellier and E. Kofman as an alternative to time-based simulation, which is the dominant approach to ODE/DAE systems simulation. Rather than linking QSS to Discrete Event Simulation, we propose to relate it to Synchronous Programming and its continuous time extension Zelus. In the deliverable [20], we expose our understanding of QSS and its variants, then we propose ideas toward a QSS-based cosimulation, by building on top of our knowledge on distributed executions of synchronous programs.

The plan for 2020 is to extend our structural analysis to cover impulsive mode changes and the consistent initialization problem, in the multimode case. A coupling of IsamDAE with Dymola (Dassault Système's commercial implementation of the Modelica language) is under development.

Another future development is to turn our structural analysis method to a compositional method, where large models could be considered by parts. This is a key problem in the Modelica language, as the compilation of a Modelica model is not modular.

Work on QSS methods will continue, and we envision to prototype a QSS-based distributed simulation method for hybrid ODE systems, based on the Zélus language.

8.3. International Initiatives

8.3.1. Inria International Partners

8.3.1.1. Informal International Partners

We have a long standing informal collaboration with Martin Otter (DLR, Munich, Germany) and Hilding Helmqvist (Mogram AB, Lund, Sweden). In 2019, this fruitful collaboration has resulted in one publication [7]. The publication draws links between two radically different, but equivalent approaches to the same problem: the impulsive behavior of some multimode DAE, when it is switching from one mode to another. The first approach relies on a transformation of the multimode DAE system to a special index one form, for which state-jumps are proved to be solution of a system of algebraic equations relating right limits to left limits. The second approach builds on the use of nonstandard analysis, combined with the heritage of synchronous programming languages, particularly on the concept of constructive semantics. This gives a formulation of the state-jumps, as a system of difference equations, with an infinitesimal time-step. The latter approach is more general than the former, in the sense that impulsive behavior can be characterized for a larger class of multimode DAE systems. Yet, both approaches coincide on a restricted class of multimode DAEs.

PACAP Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

The Brittany Region is partially funding the PhD fellowship for Niloofar Charmchi on the topic "Hardware prefetching and related issues" and Nicolas Bellec on the topic "Security in real-time embedded systems".

9.2. National Initiatives

9.2.1. Zero Power Computing Systems (ZEP): Inria Project Lab (2017–2020)

Participants: Erven Rohou, Bahram Yarahmadi.

This proposal addresses the issue of designing tiny wireless, batteryless, computing objects, harvesting energy in the environment. The energy level harvested being very low, very frequent energy shortages are expected. In order for the new system to maintain a consistent state, it will be based on a new architecture embedding non-volatile RAM (NVRAM). In order to benefit from the hardware innovations related to energy harvesting and NVRAM, software mechanisms will be designed. On the one hand, a compilation pass will compute a worst-case energy consumption. On the other hand, dedicated runtime mechanisms will allow:

1. to manage efficiently and correctly the NVRAM-based hardware architecture;
2. to use energy intelligently, by computing the worst-case energy consumption.

The ZEP project gathers four Inria teams that have a scientific background in architecture, compilation, operating systems together with the CEA Lialp and Lisan laboratories of CEA LETI & LIST [39]. The main application target is Internet of Things (IoT).

9.2.2. NOPE

Participants: Piéric Giraud, Erven Rohou, Bahram Yarahmadi.

NOPE is a one-year exploratory action funded by the Labex Cominlabs. This project aimed at being a first step, and served to elaborate more ambitious future works. Through this project, the consortium was able to grow its knowledge on a topical research theme and lay the foundations of an innovative hardware-software approach. The short term goals were:

- building and sharing across the consortium a strong expertise in state-of-the art results and tools on transient computing, and identifying challenges that should be focused on;
- initiating collaborations between the participants in order to identify opportunities at the hardware-software interface;
- building the foundations of a shared experimental platform for transient computing.

An intern, Piéric Giraud, was hired thanks to NOPE. He ported our WCET infrastructure Heptane to the MSP430 instruction set.

The NOPE project gathers teams PACAP, IETR Syscom and LS2N STR.

9.2.3. Hybrid SIMD architectures (2018–2019)

Participants: Caroline Collange, Alexandre Kouyoumdjian, Erven Rohou.

The project objective is to define new parallel computer architectures that offer high parallel performance on high-regularity workloads while keeping the flexibility to run more irregular parallel workloads. inspired by both GPU and SIMD or vector architectures.

This project is funded by the French Ministry of Armed Forces (*Ministère des Armées*).

9.2.4. DGA/PEC ARMOUR (2018–2021)

Participants: Kévin Le Bon, Erven Rohou.

ARMOUR (dynAmic binaRy optiMizatiOn cyber-secURity) aims at improving the security of computing systems at the software level. Our contribution will be twofold: (1) identify vulnerabilities in existing software, and (2) develop adaptive countermeasure mechanisms against attacks. We will rely on dynamic binary rewriting (DBR) which consists in observing a program and modifying its binary representation in memory while it runs. DBR does not require the source code of the programs it manipulates, making it convenient for commercial and legacy applications. We will study the feasibility of an adaptive security agent that monitors target applications and deploys (or removes) countermeasures based on dynamic conditions. Lightweight monitoring is appropriate when the threat condition is low, heavy countermeasures will be dynamically woven into the code when an attack is detected. Vulnerability analysis will be based on advanced fuzzing. DBR makes it possible to monitor and modify deeply embedded variables, inaccessible to traditional monitoring systems, and also to detect unexpected/suspicious values taken by variables and act before the application crashes.

ARMOUR is funded by DGA (*Direction Générale de l'Armement*) and PEC (*Pôle d'Excellence Cyber*).

9.2.5. ANR DYVE (31/03/2020 – 30/09/2023)

Participants: Arthur Blanleuil, Caroline Collange, Pierre-Yves Peneau.

Most of today's computer systems have CPU cores and GPU cores on the same chip. Though both are general-purpose, CPUs and GPUs still have fundamentally different software stacks and programming models, starting from the instruction set architecture. Indeed, GPUs rely on static vectorization of parallel applications, which demands vector instruction sets instead of CPU scalar instruction sets. In the DYVE project, we advocate a disruptive change in both CPU and GPU architecture by introducing Dynamic Vectorization at the hardware level.

Dynamic Vectorization will combine the efficiency of GPUs with the programmability and compatibility of CPUs by bringing them together into heterogeneous general-purpose multicores. It will enable processor architectures of the next decades to provide (1) high performance on sequential program sections thanks to latency-optimized cores, (2) energy-efficiency on parallel sections thanks to throughput-optimized cores, (3) programmability, binary compatibility and portability.

DYVE is funded by the ANR through the JCJC funding instrument.

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

9.3.1.1. ARGO

Participants: Damien Hardy, Isabelle Puaut, Stefanos Skalistis.

Title: Argo: WCET-Aware Parallelization of Model-Based Applications for Heterogeneous Parallel Systems

Program: H2020

Type: RIA

Duration: Jan 2016 – Mar 2019

Coordinator: Karlsruhe Institut für Technologie (Germany)

Université de Rennes 1 contact: Steven Derrien

Partners:

Karlsruher Institut für Technologie (Germany)

SCILAB enterprises SAS (France)

Université de Rennes 1 (France)

Technologiko Ekpaideftiko Idryma (TEI) Dytikis Elladas (Greece)

Absint GmbH (Germany)

Deutsches Zentrum für Luft- und Raumfahrt EV (Germany)

Fraunhofer (Germany)

Increasing performance and reducing costs, while maintaining safety levels and programmability are the key demands for embedded and cyber-physical systems in European domains, e.g. aerospace, automation, and automotive. For many applications, the necessary performance with low energy consumption can only be provided by customized computing platforms based on heterogeneous many-core architectures. However, their parallel programming with time-critical embedded applications suffers from a complex toolchain and programming process. Argo (WCET-Aware PaRallelization of Model-Based Applications for HeteroGeneOus Parallel Systems) will address this challenge with a holistic approach for programming heterogeneous multi- and many-core architectures using automatic parallelization of model-based real-time applications. Argo will enhance WCET-aware automatic parallelization by a crosslayer programming approach combining automatic tool-based and user-guided parallelization to reduce the need for expertise in programming parallel heterogeneous architectures. The Argo approach will be assessed and demonstrated by prototyping comprehensive time-critical applications from both aerospace and industrial automation domains on customized heterogeneous many-core platforms.

Argo also involves Steven Derrien and Angeliki Kritikakou from the CAIRN team.

9.3.1.2. HiPEAC4 NoE

Participants: Pierre Michaud, Erven Rohou, André Seznec, Isabelle Puaut.

P. Michaud, A. Seznec and E. Rohou are members of the European Network of Excellence HiPEAC4.

HiPEAC4 addresses the design and implementation of high-performance commodity computing devices in the 10+ year horizon, covering both the processor design, the optimizing compiler infrastructure, and the evaluation of upcoming applications made possible by the increased computing power of future devices.

9.3.1.3. Eurolab-4-HPC

Participant: Erven Rohou.

Title: EuroLab-4-HPC: Foundations of a European Research Center of Excellence in High Performance Computing Systems

Program: H2020

Duration: September 2018 – September 2020

Coordinator: Chalmers Tekniska Hoegskola AB (Sweden)

Partners:

Barcelona Supercomputing Center - Centro Nacional de Supercomputacion (Spain)

Chalmers Tekniska Hoegskola (Sweden)

Foundation for Research and Technology Hellas (Greece)

Universität Stuttgart (Germany)

The University of Manchester (United Kingdom)

Inria (France)

Universität Augsburg (Germany)

ETH Zürich (Switzerland)

École Polytechnique Federale de Lausanne (Switzerland)

Technion - Israel Institute of Technology (Israel)

The University of Edinburgh (United Kingdom)

Rheinisch-Westfaelische Technische Hochschule Aachen (Germany)

Universiteit Gent (Belgium)

Inria contact: Albert Cohen (Inria Paris)

Europe has built momentum in becoming a leader in large parts of the HPC ecosystem. It has brought together technical and business stakeholders from application developers via system software to exascale systems. Despite such gains, excellence in high performance computing systems is often fragmented and opportunities for synergy missed. To compete internationally, Europe must bring together the best research groups to tackle the long-term challenges for HPC. These typically cut across layers, e.g., performance, energy efficiency and dependability, so excellence in research must target all the layers in the system stack. The EuroLab-4-HPC project's bold overall goal is to build connected and sustainable leadership in high-performance computing systems by bringing together the different and leading performance oriented communities in Europe, working across all layers of the system stack and, at the same time, fueling new industries in HPC.

9.4. International Initiatives

9.4.1. ANR CHIST-ERA SECODE 2016–2019

Participants: Damien Hardy, Erven Rohou.

Title: SECODE – Secure Codes to Thwart Cyber-Physical Attacks

CHIST-ERA - RTCPS

Duration: January 2016 – December 2019 (one year extension)

Coordinator: Télécom Paris Tech (France)

Partners:

Télécom Paris Tech (France)

Inria (France)

Université Paris 8 (France)

Sabancı Üniversitesi (Turkey)

Université Catholique de Louvain (Belgium)

Inria contact: Erven Rohou

In this project, we specify and design error correction codes suitable for an efficient protection of sensitive information in the context of Internet of Things (IoT) and connected objects. Such codes mitigate passive attacks, like memory disclosure, and active attacks, like stack smashing. The innovation of this project is to leverage these codes for protecting against both cyber and physical attacks. The main advantage is a full coverage of attacks of the connected embedded systems, which is considered as a smart connected device and also a physical device. The outcome of the project is first a method to generate and execute cyber-resilient software, and second to protect data and its manipulation from physical threats like side-channel attacks.

9.4.2. Informal International Partners

Caroline Collange has collaborated with Marcos Yukio Siraichi, Vinicius Fernandes dos Santos and Fernando Magno Quintão Pereira from UFMG, Brazil [31].

Isabelle Puaut has collaborated with Renato Mancuso (University of Boston, USA) and Heechul Yun (University of Kansas, USA) on predictable memory hierarchies [26]. She has collaborated with Martin Schoeberl (Technical University of Denmark) on predictable branch predictors [29].

Erven Rohou has been collaborating with Prof. Ahmed El-Mahdy (Egypt-Japan University of Science and Technology, Alexandria, Egypt) and his group [21], [22].

Erven Rohou and Loïc Besnard have been collaborating with Prof. João Cardoso (University of Porto, Porto, Portugal) and his group [16].

SUMO Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Rennes Métropole: Allocation d'Installation Scientifique (AIS)

- Individual grant, led by Nicolas Markey

The objective of this project is to explore two research directions in the continuity of recent works: a truly quantitative theory of formal verification on the one hand, and the development of strategy-synthesis algorithms for modular systems on the other hand. It ended in June 2019.

9.2. National Initiatives

9.2.1. ANR TickTac: Efficient Techniques for Verification and Synthesis of Real-Time Systems (2019-2023)

- Link to website
- Led by Ocan Sankur (SUMO);
- SUMO participants: Emily Clément, Léo Henry, Thierry Jéron, Nicolas Markey, Victor Roussanaly, Ocan Sankur
- Partners: LSV (Cachan), ISIR (Paris), LaBRI (Bordeaux), LRDE (Paris), LIF (Marseille)

The aim of TickTac is to develop novel algorithms for the verification and synthesis of real-time systems using the timed automata formalism. One of the project's objectives is to develop an open-source and configurable model checker which will allow the community to compare algorithms. The algorithms and the tool will be used on a motion planning case study for robotics.

9.2.2. ANR HeadWork: Human-Centric Data-oriented WORKflows (2016-2020)

- Link to website
- Led by David Gross-Amblard (Université Rennes 1);
- Participants : Éric Badouel, Loïc Hélouët, Adrian Puerto Aubel, Rituraj Singh;
- Partners: Inria Project-Teams Valda (Paris), DRUID (Rennes), SUMO (Rennes), Links (Lille), MNHN, Foule Factory.

The objective of this project is to develop techniques to facilite development, deployment, and monitoring of crowd-based participative applications. This requires handling complex workflows with multiple participants, incertainty in data collections, incentives, skills of contributors, ... To overcome these challenges, Headwork will define rich workflows with multiple participants, data and knowledge models to capture various kind of crowd applications with complex data acquisition tasks and human specificities. We will also address methods for deploying, verifying, optimizing, but also monitoring and adapting crowd-based workflow executions at run time.

9.2.3. IPL HAC-SPECIS: High-performance Application and Computers, Studying PErformance and Correctness In Simulation (2016-2020)

- Link to website
- Led by Arnaud Legrand (Inria Grenoble Rhône-Alpes)
- Participants: Thierry Jéron, The Anh Pham.
- Partners: Inria project-teams Avalon (Lyon), POLARIS (Grenoble), HiePACS, STORM (Bordeaux), MExICo (Saclay), MYRIADS, SUMO (Rennes), VeriDis (Nancy).

The Inria Project Lab HAC-SPECIS (High-performance Application and Computers, Studying PErformance and Correctness In Simulation, is a transversal project internal to Inria. The goal of the HAC SPECIS project is to answer the methodological needs raised by the recent evolution of HPC architectures by allowing application and runtime developers to study such systems both from the correctness and performance point of view. Inside this project, we collaborate with Martin Quinson (Myriads team) on the dynamic formal verification of high performance runtimes and applications. The PhD of The Anh Pham is granted by this project.

This year we have been mainly interested in the extension of the SimGrid programming model of MPI with synchronization primitives, the formalisation in ATL, of this model, and its adaptation to dynamic partial-order-reduction methods (DPOR) that allow to reduce the explored state space. A prototype implementation of an existing method that combines DPOR with true-concurrency models has been experimented on toy examples. The Anh Pham completed his PhD in december 2019.

9.2.4. National informal collaborations

The team collaborates with the following researchers:

- Béatrice Bérard (LIP6, Paris 6) on problems of opacity and diagnosis, and on problems related to logics and partial orders for security;
- Patricia Bouyer (LSV, ENS Paris-Saclay) on the analysis of probabilistic timed systems and quantitative aspects of verification;
- Thomas Chatain and Stefan Haar (Inria team MExICo, LSV, ENS Paris-Saclay) on topics related to concurrency and time, and to modeling and verification of metro networks, multimodal systems and passenger flows;
- Gwenaël Delaval and Éric Rutten (Inria team Ctrl-A, LIG, Université Grenoble-Alpes) on the control of reconfigurable systems and the link between Reax and Heptagon/BZR (http://bzr.inria.fr/);
- Serge Haddad (Inria team MExICo, LSV, ENS Paris-Saclay) on opacity and diagnosis;
- Loïg Jézéquel (LS2N, Université de Nantes) on stochastic and timed nets, and on distributed optimal planning;
- Didier Lime and Olivier H. Roux (LS2N, Université de Nantes) on stochastic and timed Petri nets;
- François Laroussinie (IRIF, UP7-Diderot) on logics for multi-agent systems,

9.3. International Initiatives

9.3.1. Inria International Labs

LIRIMA: International Laboratory for Research in Computer Science and Applied Mathematics

9.3.1.1. FUCHSIA

Associate Team involved in the international lab LIRIMA.

Title: Flexible user-centric higher-order systems for collective intelligence in agencies

International Partner

U. Yaoundé (Cameroon) Georges-Edouard Kouamou

Start year: 2019

See also: https://project.inria.fr/fuchsia/

Develop methods and tools, based on guarded attribute grammars, to design flexible and adaptive systems for information gathering and deliberation in order to collaboratively build expertise in health emergency situations.

9.3.2. Inria Associate Teams Not Involved in an Inria International Labs

9.3.2.1. EQUAVE

Title: Efficient Quantitative Verification

International Partner

Indian Institute of Technology Bombay (India) - Dpt of Computer Science and Engineering - S. Akshay

Start year: 2018

See also: http://www.irisa.fr/sumo/EQUAVE

Formal verification has been addressed for a long time. A lot of effort has been devoted to Boolean verification, i.e., formal analyis of systems that check whether a given property is true or false.

In many settings, a Boolean verdict is not sufficient. The notions of interest are for instance the amount of confidential information leaked by a system, the proportion of some protein after a duration in some experiment in a biological system, whether a distributed protocol satisfies some property only for a bounded number of participants... This calls for quantitative verification, in which algorithms compute a value such as the probability for a property to hold, the mean cost of runs satisfying it, the time needed to achieve a complex workflow...

A second limitation of formal verification is the efficiency of algorithms. Even for simple questions, verification is rapidly PSPACE-complete. However, some classes of models allow polynomial time verification. The key techniques to master complexity are to use concurrency, approximation, etc

The objective of this project is to study efficient techniques for quantitative verification, and develop efficient algorithms for models such as stochastic games, timed and concurrent systems.

9.3.3. Inria International Partners

9.3.3.1. Informal International Partners

The team collaborates with the following researchers:

- S. Akshay (IIT Bombay, India) on timed concurrent models;
- Andrea D'Ariano (University Roma Tre, Italy), on train regulation.
- Christel Baier (Technical University of Dresden, Germany) on verification and control of stochastic systems;
- Thomas Brihaye (Université de Mons, Belgium) on the verification of stochastic timed systems;
- Gilles Geeraerts and Jean-François Raskin, (Université Libre de Bruxelles, Belgium) on multiplayer game theory and synthesis;
- Alessandro Giua and Michele Pinna (University Cagliari, Italy) on diagnosis and unfolding techniques for concurrent systems.

- Igor Konnov (Interchain, Austria), Marijana Laźic (Technical University Munich, Germany) and Josef Widder (Interchain, Austria) on the automated verification of randomized distributed algorithms.
- Stéfane Lafortune (University of Michigan, USA) on the control of cyber-physical systems;
- Kim G. Larsen (University Aalborg, Denmark) on quantitative timed games, and on topics related to urban train systems modeling;
- John Mullins (Polytechnique Montréal, Canada) on security and opacity;
- Mickael Randour (Université de Mons, Belgium) on quantitative games for synthesis.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- S. Akshay (IIT Bombay, India) visited the team for one week.
- Christel Baier and Jakob Piribauer (TU Dresden, Germany) visited the SUMO team for one week in september.
- Khushraj Nanik Madnani (IIT Bombay, India) visited our team during two months.
- Laurie Ricker (Mount Allison University, Canada) visited the team during 2 months.
- Graeme Zinck (Mount Allison University, Canada) visited our team during four months. He obtained a 5000$ grant provided by Mitacs through a collaboration between Mount Allison University (L. Ricker) and Inria (Loïc Hélouët and Hervé Marchand). Two papers are in preparation (one regarding the enforcement of opacity for modular systems (submitted to Ifac World congress) and the other about the enforcement of concurrent secrets for multiple systems.

9.4.1.1. Internships

- Pierre Boudart, ENS Ulm, June-July 2019, Éric Fabre.
- Kritin Garg and Sharvik Mital, IIT Bombay, May-July 2019, Éric Fabre, Blaise Genest and Loïc Hélouët.
- Mathieu Poirier, ENS Rennes, May-July 2019, Éric Badouel and Adrian Puerto Aubel.
- Bastien Thomas, ENS Rennes, Feb-July 2019, Nathalie Bertrand.

TAMIS Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

- ANR MALTHY, Méthodes ALgébriques pour la vérification de modèles Temporisés et HYbrides, Thao Dang, 4 years, Inria and VISEO and CEA and VERIMAG
- ANR COGITO, Runtime Code Generation to Secure Devices, 3 years, Inria and CEA and ENSMSE and XLIM.
- ANR AHMA, Automated Hardware Malware Analysis, 3,5 years, JCJC.

8.1.2. DGA

- PhD grant for Nisrine Jafri (2016–2019),
- PhD grant for Lamine Noureddine (2017-2020)
- PhD grant for Christophe Genevey Metat (2018-2021)
- PhD grant for Cassius De Oliveira Puodzius (2019-2022)

8.2. European Initiatives

8.2.1. ENABLE-S3 (352)

Title: ENABLE-S3: European Initiative to Enable Validation for Highly Automated Safe and Secure Systems

Program: H2020

Duration: 05/2016 - 04/2019

Coordinator: Avl List Gmbh (Austria)

Partners:

Aalborg Universitet (Denmark); Airbus Defence And Space Gmbh (Germany); Ait Austrian Institute Of Technology Gmbh (Austria); Avl Deutschland Gmbh (Germany); Avl Software And Functions Gmbh (Germany); Btc Embedded Systems Ag (Germany); Cavotec Germany Gmbh (Germany); Creanex Oy(Finland); Ceske Vysoke Uceni Technicke V Praze (Czech Republic); Deutsches Zentrum Fuer Luft - Und Raumfahrt Ev (Germany); Denso Automotive Deutschland Gmbh (Germany); Dr. Steffan Datentechnik Gmbh (Austria); Danmarks Tekniske Universitet (Denmark); Evidence Srl (Italy); Stiftung Fzi Forschungszentrum Informatik Am Karlsruher Institut Fur Technologie (Germany); Gmv Aerospace And Defence Sa (Spain); Gmvis Skysoft Sa (Portugal); Politechnika Gdanska (Poland); Hella Aglaia Mobile Vision Gmbh (Germany); Ibm Ireland Limited (Ireland); Interuniversitair Micro-Electronica Centrum (Belgium); Iminds (Belgium); Institut National De Recherche Eninformatique Et Automatique (France); Instituto Superior De Engenharia Do Porto (Portugal); Instituto Tecnologico De Informatica (Spain); Ixion Industry And Aerospace Sl (Spain); Universitat Linz (Austria); Linz Center Of Mechatronics Gmbh (Austria); Magillem Design Services Sas (France); Magneti Marelli S.P.A. (Italy); Microeletronica Maser Slspain); Mdal (France); Model Engineering Solutions Gmbhgermany); Magna Steyr Engineering Ag & Co Kg (Austria); Nabto Aps (Denmark); Navtor As (Norway); Nm Robotic Gmbh (Austria); Nxp Semiconductors Germany Gmbh(Germany); Offis E.V.(Germany); Philips Medical Systems Nederland Bvnetherlands); Rohde & Schwarz Gmbh&Co Kommanditgesellschaft(Germany);

Reden B.V. (Netherlands); Renault Sas (France); Rugged Tooling Oyfinland); Serva Transport Systems Gmbh(Germany); Siemens Industry Software Nvbelgium); University Of Southampton (Uk); Safetrans E.V. (Germany); Thales Alenia Space Espana, Saspain); Fundacion Tecnalia Research & Innovationspain); Thales Austria Gmbh (Austria); The Motor Insurance Repair Researchcentre (Uk); Toyota Motor Europe (Belgium); Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek Tno (Netherlands); Ttcontrol Gmbh (Austria); Tttech Computertechnik Ag (Austria); Technische Universiteit Eindhoven (Netherlands); Technische Universitat Darmstadt (Germany); Technische Universitaet Graz (Austria); Twt Gmbh Science & Innovation (Germany); University College Dublin, National University Of Ireland, Dublin (Ireland); Universidad De Las Palmas De Gran Canaria (Spain); Universita Degli Studi Di Modena E Reggio Emilia (Italy); Universidad Politecnica De Madrid (Spain); Valeo Autoklimatizace K.S. (Czech Republic); Valeo Comfort And Driving Assistance (France); Valeo Schalter Und Sensoren Gmbh (Germany); Kompetenzzentrum - Das Virtuelle Fahrzeug, Forschungsgesellschaft Mbh (Austria); Vires Simulationstechnologie Gmbh (Germany); Teknologian Tutkimuskeskus Vtt Oy (Finland); Tieto Finland Support Services Oy (Finland); Zilinska Univerzita V Ziline (Slovakia);

Inria contact: Olivier Zendra

The objective of ENABLE-S3 (http://www.enable-s3.eu) is to establish cost-efficient cross-domain virtual and semi-virtual V&V platforms and methods for ACPS. Advanced functional, safety and security test methods will be developed in order to significantly reduce the verification and validation time but preserve the validity of the tests for the requested high operation range. ENABLE-S3 aspires to substitute today's physical validation and verification efforts by virtual testing and verification, coverage-oriented test selection methods and standardization. ENABLE-S3 is use-case driven; these use cases represent relevant environments and scenarios. Each of the models, methods and tools integrated into the validation platform will be applied to at least one use case (under the guidance of the V&V methodology), where they will be validated (TRL 5) and their usability demonstrated (TRL6). Representative use cases and according applications provide the base for the requirements of methods and tools, as well as for the evaluation of automated systems and respective safety. This project is industry driven and has the objective of designing new technologies for autonomous transportation, including to secure them. TAMIS tests its results on the case studies of the project.

Within ENABLE-S3, the contribution of the TAMIS team consists in in proposing a generic method to evaluate complex automotive-oriented systems for automation (perception, decision-making, etc.). The method is based on Statistical Model Checking (SMC), using specifically defined Key Performance Indicators (KPIs), as temporal properties depending on a set of identified metrics. By feeding the values of these metrics during a large number of simulations, and the properties representing the KPIs to our statistical model checker, we evaluate the probability to meet the KPIs. We applied this method to two different subsystems of an autonomous vehicles: a perception system (CMCDOT framework) and a decision-making system. We show that the methodology is suited to efficiently evaluate some critical properties of automotive systems, but also their limitations.

In 2019, in TAMIS, Olivier Zendra and Eduard Baranov were involved in this project. The project supported one postdoc in TAMIS starting in 2017.

8.2.2. TeamPlay (653)

Title: TeamPlay: Time, Energy and security Analysis for Multi/Many-core heterogeneous PLAtforms

Program: H2020

Duration: 01/2018 - 12/2020

Coordinator: Inria

Partners:

Absint Angewandte Informatik Gmbh (Germany), Institut National De Recherche en Informatique et Automatique (France), Secure-Ic Sas (France), Sky-Watch A/S (Danemark), Syddansk Universitet (Danemark), Systhmata Ypologistikis Orashs Irida Labs Ae (Greece), Technische Universität Hamburg-Harburg (Germany), Thales Alenia Space Espana (Spain), Universiteit Van Amsterdam (Netherlands), University Of Bristol (UK), University Of St Andrews (UK)

Inria contact: Olivier Zendra

The TeamPlay (Time, Energy and security Analysis for Multi/Many-core heterogeneous PLAtforms) project federates 6 academic and 5 industrial partners and aims to develop new, formally-motivated, techniques that will allow execution time, energy usage, security, and other important non-functional properties of parallel software to be treated effectively, and as first- class citizens. We will build this into a toolbox for developing highly parallel software for low-energy systems, as required by the internet of things, cyber-physical systems etc. The TeamPlay approach will allow programs to reflect directly on their own time, energy consumption, security, etc., as well as enabling the developer to reason about both the functional and the non-functional properties of their software at the source code level. Our success will ensure significant progress on a pressing problem of major industrial importance: how to effectively manage energy consumption for parallel systems while maintaining the right balance with other important software metrics, including time, security etc. The project brings together leading industrial and academic experts in parallelism, energy modeling/ transparency, worst-case execution time analysis, non-functional property analysis, compilation, security, and task coordination. Results will be evaluated using industrial use cases taken from the computer vision, satellites, flying drones, medical and cyber security domains. Within TeamPlay, Inria and TAMIS coordinate the whole project, while being also in charge of aspects related more specifically to security.

The permanent members of TAMIS who are involved are Olivier Zendra and Annelie Heuser.

8.2.3. SUCCESS

Title: SUCCESS: SecUre aCCESSibility for the internet of things

Program: CHIST-ERA 2015

Duration: 10/2016 - 10/2019

Coordinator: Middlesex University (UK)

Partners:

Middlesex University, School of Science and Technology (UK); Inria, TAMIS (France); Université Grenoble Alpes, Verimag (France); University of TWENTE, (Netherlands)

Inria contact: Ioana Cristescu

The objectives of the SUCCESS project is to use formal methods and verification tools with a proven track record to provide more transparency of security risks for people in given IoT scenarios. Our core scientific innovation will consist on the extension of well-known industry-strength methods. Our technological innovation will provide adequate tools to address risk assessment and adaptivity within IoT in healthcare environments and an open source repository to foster future reuse, extension and progress in this area. Our project will validate the scientific and technological innovation through pilots, one of which will be in collaboration with a hospital and will allow all stakeholders (e.g. physicians, hospital technicians, patients and relatives) to enjoy a safer system capable to appropriately handle highly sensitive information on vulnerable people while making security and privacy risks understandable and secure solutions accessible.

Within SUCCESS, the contribution of the TAMIS team consists in a framework for analyzing the security of a given IOT system, and notably whether it resists to attack. Our approach is to build a high-level model of the system, including its vulnerabilities, as well as an attacker. We represent

the set of possible attacks using an attack tree. Finally, we evaluate the probability that an attack succeeds using Statistical Model Checking.

In 2019, in the TAMIS team, Delphine Beaulaton, Najah Ben Said, Ioana Cristescu and Olivier Zendra were involved in this project.

TEA Project-Team

9. Partnerships and Cooperations

9.1. International Initiatives

9.1.1. Inria International Labs

Sino-European Laboratory in Computer Science, Automation and Applied Mathematics
Associate Team involved in the International Lab:

9.1.1.1. CONVEX

Title: Compositional Verification of Cyber-Physical Systems

International Partner (Institution - Laboratory - Researcher):

CAS (China) - State Key Laboratory of Computer Science - Naijun Zhan

Start year: 2018

See also: http://convex.irisa.fr

Formal modeling and verification methods have successfully improved software safety and security in vast application domains in transportation, production and energy. However, formal methods are labor-intensive and require highly trained software developers. Challenges facing formal methods stem from rapid evolution of hardware platforms, the increasing amount and cost of software infrastructures, and from the interaction between software, hardware and physics in networked cyber-physical systems.

Automation and expressivity of formal verification tools must be improved not only to scale functional verification to very large software stacks, but also verify non-functional properties from models of hardware (time, energy) and physics (domain). Abstraction, compositionality and refinement are essential properties to provide the necessary scalability to tackle the complexity of system design with methods able to scale heterogeneous, concurrent, networked, timed, discrete and continuous models of cyber-physical systems.

Project CONVEX wants to define a CPS architecture design methodology that takes advantage of existing time and concurrency modeling standards (MARTE, AADL, Ptolemy, Matlab), yet focuses on interfacing heterogeneous and exogenous models using simple, mathematically-defined structures, to achieve the single goal of verified integration of CPS components.

Inria@SiliconValley
Associate Team involved in the International Lab:

9.1.1.2. Composite

Title: Compositional System Integration

International Partners (Institution - Laboratory - Researcher):

University of California, San Diego (United States) - Microelectronic Embedded Systems Laboratory - Rajesh Gupta

Start year: 2017

See also: http://www.irisa.fr/prive/talpin/composite

Most applications that run somewhere on the internet are not optimized to do so. They execute on general purpose operating systems or on containers (virtual machines) that are built with the most conservative assumptions about their environment. While an application is specific, a large part of the system it runs on is unused, which is both a cost (to store and execute) and a security risk (many entry points).

A unikernel, on the contrary, is a system program object that only contains the necessary the operating system services it needs for execution. A unikernel is build from the composition of a program, developed using high-level programming language, with modules of a library operating system (libOS), to execute directly on an hypervisor. A unikernel can boot in milliseconds to serve a request and shut down, demanding minimal energy and resources, offering stealthiest exposure time and surface to attacks, making them the ideal platforms to deploy on sensor networks, networks of embedded devices, smart grids and clouds.

The goal of COMPOSITE is to develop the mathematical foundations for sound and efficient composition in system programming: analysis, verification and optimization technique for modular and compositional hardware-system-software integration of unikernels. We intend to further this development with the prospect of an end-to-end co-design methodology to synthesize lean and stealth networked embedded devices.

9.1.1.3. Inria International Chairs

IIC GUPTA Rajesh

Title: End-to-end system co-design

International Partner (Institution - Laboratory - Researcher):

University of California, San Diego (United States) - Rajesh Gupta

Duration: 2017 - 2021

Start year: 2017

9.1.1.4. Insa-Inria International Chair

Shuvra Bhattacharyya

Title: System design methodologies for real-time signal and information processing

International Partner (Institution - Laboratory - Researcher):

University of Maryland (United States) - Shuvra Bhattacharyya

Duration: 2018 - 2021

Start year: 2017

9.2. International Research Visitors

9.2.1. Visits of International Scientists

- Shuvra Bhattacharyya (UMD) visited project-team TEA and IETR in the context of his Insa-Inria Chair in May, July and December. He gave numerous talks and organized a workshop for the preparation of a European project proposal.
- Rajesh Gupta (UCSD) visited project-team TEA in the context of his Inria Chair in July and gave a seminar entitled: programming human spaces.
- Niki Vazou (IMDEA) visited project-team TEA in May and gave a presentation on her POPL'20 paper: "Liquidate your assets: reasoning about resource usage in Liquid Haskell".
- Yamine Ait Ameur (IRIT) visited project-team TEA in January on the occasion of Simon Lunel's Thesis defense.
- Naijun Zhan (ISCAS) visited project-team TEA in July, in the context of associate-project CONVEX.

- Delegates of the Sheng Yuan Honors College (BUAA) visited Inria-Irisa and Ecole Normale Supérieur de Rennes for the prospect of initiating an exchange program for graduate students, which will start in 2020.
- Zhang Bojun and Wang Zikai (BUAA) visited project-team TEA in July for an internship on verified modeling of blockchain protocols in Coq.
- Shenghao Yuan (NUAA) visited project-team TEA in July, in the context of associate-team CONVEX, and gave a presentation of the verified mini-Signal code generator developed at Nanhang University.

9.2.2. Visits to International Teams

Jean-Pierre Talpin visited UC San Diego in March, in the context of the associate-team Composite, and visited ISCAS, Beijing, in May and October, in the context of the associate-team CONVEX.

I4S Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. SYSIFE

Participant: Ivan Guéguen.

Type: CPER + REVES project funding

Objectif: Development of a test bench for railways testing

Duration: 2019 - 2020

Coordinator : IFSTTAR

Partners: Cerema, ColasRail, Edilon, SNCF Réseau, Railenium, Vossloh

Inria contact: Ivan Guéguen

8.1.2. SHM-TGROUT

Participant: Xavier Chapeleau.

Type: Weamec regional cluster

Objectif: to assess the suitability of several non-destructive methods to detect and track the damage for metal pipes.

Duration: 2019 - 2020

Coordinator : IFSTTAR

Partners: University of Nantes, STX

Inria contact: Xavier Chapeleau

Abstract:

The cement bond between metal pipes is a very common technique in the offshore environment, particularly in the "oil and gas" sector. This technique has been used in the offshore wind sector installed to connect the structure (jacket or monopile) to its foundation. A small-scale sample of this type of cement connection was sized, and instrumented it with several technologies. sensors (including fiber optic sensors) and subjected it to axial fatigue stresses. Although the results of the instrumentation are still in operation, the damage could be detected by the various methods tested. A new trial is planned in the first half of 2020 to confirm the results obtained.

8.1.3. MUSIWIND

Participants: Xavier Chapeleau, Laurent Mevel, Frederic Gillot.

Type: RFI WIZE

Objectif: Qualify a very high precision sensor for vibratory monitoring of wind turbines, develop monitoring algorithms using SSI methods and validation indicators

Duration: 12 months in 2020

Coordinator : IFSTTAR

Partners: Inria, SERCELL, VALOREM

Inria contact: Xavier Chapeleau

Abstract: Structural health monitoring of wind turbines is becoming a real economic issue for the managers of these structures. Indeed, they are more and more demanding of new structural health control techniques that enable the implementation of an automated and planned monitoring strategy to ensure the structural integrity of their wind turbines throughout their lifetime, particularly in the case of exceptional events such as storm or earthquake. In this business sector where innovation is crucial to stay competitive, the project MusiWind aims at the hardware, software and scientific development of a new device for monitoring the structural integrity of wind turbines and their qualification in real conditions. Through a multi-sensor approach, the project integrates in particular the newQuietSeisTM low-noise accelerometer (developed by SERCEL) with a generic data acquisition card Pegase 3 (developed by IFSTTAR) on which is embedded innovative signal processing (data analysis) developed by the Ifsttar / Inria I4S joint research team. Statistical inference algorithms meant to extract structural information under ambient excitation. The originality of the project will be to develop identification methods as well as multi-varied damage indicators that merge data froms ensors of different types and qualities, as well as the fusion of complementary physical characteristics.

8.1.4. SURFEOL: SURveillance et Fiabilité des Fondations d'EOLiennes

Participants: Xavier Chapeleau, Michael Doehler, Laurent Mevel, Flavien Bouché.

The regional project SURFEOL was in collaboration with les Chantiers de l'Atlantique and ended in 2017. Many months of data were collected. Three main axes were investigated.

- Study of monitoring of off shore wind turbines
- Laboratory experiments for fatigue monitoring using fiber optic sensors
- Development of a monitoring system based on optical gages and test in real conditions on a marine buoy

A Master 2 internship was dedicated on the analysis of multiple months of data by means of data analysis and subspace identification techniques.

8.1.5. Collaboration with IETR

Participants: Vincent Le Cam, David Pallier.

The thesis is directed by Sébastien Pillement at IETR. It is funded by RFI WISE Electronique Professionnelle within the SENTAUR project. The objective is to correct the time drift of the quartz in wireless sensor networks. Quartz modelizations, test platforms under real GPS conditions have been built. First results are based on Kalman algorithms to correct drift[34].

8.1.6. Collaboration with GeM

Participants: Laurent Mevel, Michael Doehler.

I4S' PhD student Md Delwar Hossain Bhuyan has done his PhD on damage localization on civil structures in collaboration with GeM (Institute of Civil and Mechanical Engineering), Université de Nantes, and successfully defended in November 2017. In the follow-up, a mockup of the Saint Nazaire bridge has been funded by GeM in 2018 for damage localization, and tests on it are ongoing [25].

8.1.7. Vibration analysis by video image processing for civil engineering structure monitoring

Participants: Bian Xiong, Qinghua Zhang.

- Type: ARED (Allocations de Recherche Doctorale)
- Objective: to develop video-based methods for civil engineering structure monitoring.
- Duration: 2018 - 2021
- Coordinator : Inria
- Partners: IFSTTAR
- Inria contact: Qinghua Zhang
- Abstract:

The I4S team develops real-time vibration analysis methods for the monitoring of civil engineering structures (bridges, buildings, etc.), usually based on mechanical sensors integrated into the monitored structures. In parallel, the team works also on image processing techniques for non-destructive testing of civil engineering construction materials. This PhD project, co-supervised with Vincent Baltazart (IFSTTAR researcher), aims to combine the two approaches in order to develop a method of vibration analysis based on image processing. Given a sequence of images of the structure to be monitored, the motion signal of the structure is derived from video image analysis, then methods of vibration analysis are applied to this motion signal. Such a solution will have the advantage of avoiding the integration of mechanical sensors into monitored structures and simplifying the maintenance of the monitoring system

8.2. National Initiatives

8.2.1. CEA List : Acoustic High Frequency synchronous and wireless

Participants: Vincent Le Cam, Arthur Bouché.

In the area of infrastructure, strengthening links with CEA-LIST and Alstom-Rail will focus on non-destructive ultrasonic testing methods for rails. We will focus in particular on the opening of cracks in the passage of the trains, which requires a very precise synchronization of the various sensors. In 2019 the first tests of validation on the site of Bar le Duc with the help of the prototype were conclusive: capacities to emit and receive ultrasonic waves in 1.4 km of rail by perfectly synchronized materials (until the microsecond UT). In 2020 the objectives of the future contract will be:

- make several boxes to carry out more complete tests
- conducting qualification test campaigns (according to CDC Alstom)
- upgrade the high frequency daughter card (with PEGASE 3 more globally)

8.2.2. ANR Resbati

Participants: Ludovic Gaverina, Jean Dumoulin.

Type: ANR

Objectif: In-situ measurements of thermal wall resistance

Duration: 10/2016 to 10/2019

Coordinator: Laurent Ibos

Partners : IFSTTAR, CERTES, CEREMA, CSTB, LNE, THEMACS, AFNOR

Inria contact: Jean Dumoulin

Abstract: RESBATI is an applied research project whose objective is to develop a field measurement device that meets precise specifications to systematically measure the level of thermal insulation of building walls. The preferred metrological tool is infrared thermography. A smart logger and a protype have been developed and presented. A full autonomous system has been studied and developed for in-situ measurement on existing building envelope. In parallel, thermal resistance estimation method was studied. First experiments were carried out with a first generation prototype in 2019. For this purpose different instrumented building walls were built and qualified at CSTB before carrying out in-situ evaluations of the prototype.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

8.3.1.1. INFRASTAR(Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk)

Participants: Xavier Chapeleau, Antoine Bassil.

Call: H2020-MSCA-ITN-2015 (Horizon 2020 Marie-Sklodowska Curie Actions Innovative Training Networks)

Type of Action: MSCA-ITN-ETN

Objective: Improve energy performance of building design

Duration: 48 months since 2016 May 1st

Coordinator: Odile Abraham (IFSTTAR)

Academic and industrial Partners: IFSTTAR, UNIVERSITY OF AALBORG, BAM, EPFL, GuD Consult Gmbh, COWI A/S, NeoStrain, PHIMECA

Inria contact: X. Chapeleau

Website: http://infrastar.eu/

Abstract: This thesis work aims to develop and validate a method for monitoring crack openings using distributed fiber optics strain measurements. First, the various existing theories on strain transfer from the host material to the optical fiber are presented, with their validity domain. The problem of perfect interfacial bonding is then studied and a three-layer analytical model capable of handling imperfect bonding case is proposed. This model is then generalized to multi-layer systems. Experimental studies validating this new model are presented. They show that it is possible to monitor crack openings up to 1 mm with an error of less than 10% for a fiber optic cable glued on the surface. Cables embedded in concrete show less accurate results. The type of cable, the bonding length and the hardening of the concrete material also influence the accuracy of the estimated crack openings. Finally, the results of case studies on laboratory-size reinforced concrete samples are presented. They show the optical fibers capacity to detect cracks as early as ultrasonic sensors and to monitor the opening of multiple micro cracks.

8.3.1.2. DESDEMONA(DEtection of Steel Defects by Enhanced MONitoring and Automated procedure for self-inspection and maintenance)

Participants: Jean Dumoulin, Laurent Mevel, Michael Doehler, Xavier Chapeleau.

Call: H2020 -Call: RFCS-2017 (Call of the research programme of the Research Fund for Coal and Steel - 2017)

Type of Action: RFCS-RPJ (Research project)

Objective: DESDEMONA objective is the development of novel design methods, systems, procedure and technical solution, to integrate sensing and automation technologies for the purpose of self-inspection and self-monitoring of steel structures.

Duration: 36 months since 2018 June 1st

Coordinator: Pr. Vincenzo Gatulli (La Sapienza University of Rome)

Academic and industrial Partners: Sapienza Università di Roma (Italy), Universidad de Castilla – La Mancha, (Spain), Universidade do Porto (Portugal), Università di Pisa (Italy), IFSTTAR (France), Aiviewgroup srl (Italy), Sixense systems (France), Ecisa compania general de construcciones sa (Spain), Università di Cassino e del Lazio Meridionale (Italy), Universidad de Alicante (Spain), Inria (France).

Inria contact: J. Dumoulin and L. Mevel

Website: http://www.desdemonaproject.eu

Abstract: DESDEMONA objective is the development of novel design methods, systems, procedure and technical solution, to integrate sensing and automation technologies for the purpose of self-inspection and self-monitoring of steel structures. The approach will lead to an increment of the service life of existing and new steel civil and industrial infrastructure and to a decrease in the cost associated to inspections, improving human activities performed in difficult conditions, safety and workers' potential by the use of advanced tools. The research aims to expand beyond the current state-of-the-art new high-quality standard and practices for steel structure inspection and maintenance through the interrelated development of the following actions: i) steel structure geometry and condition virtualization through data fusion of image processing, thermography and vibration measurements; ii) developing a procedure for steel defect detection by robotic and automatic systems such as Unmanned Aerial Vehicles (UAV) and ground mobile robots iii) embedding sensor systems to revalorize and transform steel elements and structures into self-diagnostic (smart) elements and materials even through nanotechnologies, iv) realizing an experimental lab-based apparatus and a series of case studies inspected by intelligent and robotic systems. The project outcome will have an impact on the reduction of the cost of steel structures inspection and maintenance and on the increase of user safety and comfort in industrial and civil environment. The proposal with a multidisciplinary approach fulfils the objectives of the Strategic Research Agenda of the European Steel Technology Platform.

8.3.2. Collaborations in European Programs, Except FP7 & H2020

8.3.2.1. COST Action TU 1402

Participants: Michael Doehler, Laurent Mevel.

L. Mevel is member of the management committee of the COST Action.

M. Doehler is co-leader of working group 2 "SHM strategies and structural performance" and member of the steering committee.

Type: COST

Objective: Quantifying the value of structural health monitoring

Duration: 11/2014 - 4/2019

Coordinator: S. Thoens (DTU Denmark)

Partner: 29 countries, see https://www.cost.eu/actions/TU1402

Inria contact: Laurent Mevel

Abstract: Since 2014, until 2018, the COST Action has altogether around 120 participants from over 25 countries. This Action aims to develop and describe a theoretical framework, together with methods, tools, guidelines, examples and educational activities, for the quantification of the value of SHM.

8.4. International Initiatives

8.4.1. Collaboration with University of British Columbia, Canada

Participants: Laurent Mevel, Michael Doehler, Alexander Mendler.

Alexander Mendler's PhD thesis started in September 2018 co-supervised by M. Doehler and C. Ventura. A. Mendler spent 6 months in Rennes in 2019 thanks to a MITACS grant.

8.4.2. Collaboration with BAM, Germany

Participants: Laurent Mevel, Michael Doehler, Eva Viefhues.

Eva Viefhues is currently PhD student of Laurent Mevel and Michel Doehler in Berlin, financed by BAM. M. Doehler is also associate researcher at BAM since 2016. Besides the supervision of the PhD, collaboration on temperature robustness is ongoing with BAM [18], [24].

8.4.3. Collaboration with Technical University of Denmark (DTU)

Participants: Michael Doehler, Laurent Mevel.

During COST Action TU 1402 and previously at BAM, collaboration with Sebastian Thöns from DTU in Denmark started on risk analysis and SHM based reliability updating. Also, Aalborg University's PhD student Lijia Long is involved.

8.4.4. Collaboration with Aalborg University, Denmark

Participant: Michael Doehler.

Together with Structural Vibration Solutions, collaboration with Aalborg University (professor Lars Damkilde, Department of Civil Engineering) happened during the PhD of Szymon Gres on damage detection methods, with current conference publications [29], [30]. The PhD has been defended on November 19, 2019.

8.4.5. Collaboration with Laval University, Canada

Participant: Jean Dumoulin.

In the Framework of On Duty Project (http://www.ondutycanada.ca) we are working on Non Destructive Testing techniques and automation of inspection process. Jean Dumoulin spent 10 days in Canada in 2019 devoted to corrosion detection by active infrared thermography NDT approach.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

Szymon Gres visited us for 2 months from January to February 2019 during his thesis.

A. Mendler got a 6 month MITACS grant to visit us from May to October 2019.

8.5.1.1. Research Stays Abroad

J. Dumoulin was with University Laval and with CNR IREA in Fall 2019.

MINGUS Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

- M. Lemou and N. Crouseilles are head of the project "MUNIQ" of ENS Rennes. This two-years project (2018-2019) intends to gather multiscale numerical methods and uncertainty quantification techniques. The MINGuS members are P. Chartier, N. Crouseilles, M. Lemou and F. Méhats and colleagues from university of Madison-Wisconsin also belong to this project.

8.2. National Initiatives

8.2.1. ANR

8.2.1.1. MOONRISE: 2015-2019

Participants: François Castella, Philippe Chartier, Nicolas Crouseilles, Mohammed Lemou, Florian Méhats.

The project *Moonrise* submitted by Florian Méhats has been funded by the ANR for 4 years, for the period 2015-2019. This project aims at exploring modeling, mathematical and numerical issues originating from the presence of high-oscillations in nonlinear PDEs from the physics of nanotechnologies (quantum transport) and from the physics of plasmas (magnetized transport in tokamaks). The partners of the project are the IRMAR (Rennes), the IMT (Toulouse) and the CEA Cadarache. In the MINGuS team, François Castella, Philippe Chartier, Nicolas Crouseilles and Mohammed Lemou are members of the project Moonrise.

Postdocs

- Loïc Le Treust has been hired as a Postdoc, under the supervision of Philippe Chartier and Florian Méhats. His contract started in september 2015 and ended in august 2016. Loïc Le Treust is now assistant professor at the university of Marseille.
- Yong Zhang has been hired as a Postdoc, under the supervision of Philippe Chartier and Florian Méhats. His contract started in september 2015 and ended in august 2016. Yong Zhang is now professor at the Tianjin university (China).
- Xiaofei Zhao has been hired as a Postdoc from september 2015 to september 2016 under the supervision of Florian Méhats. Xiaofei Zhao is now postdoc assistant professor in the Wuhan University (China).

8.2.1.2. MFG: 2016-2020

Participant: Arnaud Debussche.

Mean Field Games (MFG) theory is a new and challenging mathematical topic which analyzes the dynamics of a very large number of interacting rational agents. Introduced ten years ago, the MFG models have been used in many areas such as, e.g., economics (heterogeneous agent models, growth modeling,...), finance (formation of volatility, models of bank runs,...), social sciences (crowd models, models of segregation) and engineering (data networks, energy systems...). Their importance comes from the fact that they are the simplest (“stochastic control"-type) models taking into account interactions between rational agents (thus getting beyond optimization), yet without entering into the issues of strategic interactions. MFG theory lies at the intersection of mean field theories (it studies systems with a very large number of agents), game theory, optimal control and stochastic analysis (the agents optimize a payoff in a possibly noisy setting), calculus of variations (MFG equilibria may arise as minima of suitable functionals) and partial differential equations (PDE): In the simplest cases, the value of each agent is found by solving a backward Hamilton-Jacobi equation whereas the distribution of the agents’ states evolves according to a forward Fokker-Planck equation. The “Master" equation (stated in the space of probability measures) subsumes the individual and collective

behaviors. Finally, modeling, numerical analysis and scientific computing are crucial for the applications. French mathematicians play a world-leading role in the research on MFG: The terminology itself comes from a series of pioneering works by J.-M. Lasry and P.-L. Lions who introduced most of the key ideas for the mathematical analysis of MFG; the last conference on MFG was held last June in Paris and organized by Y. Achdou, P. Cardaliaguet and J.-M. Lasry. As testifies the proposal, the number of researchers working on MFG in France (and also abroad) is extremely fast-growing, not only because the theoretical aspects are exciting and challenging, but also because MFG models find more and more applications. The aim of the project is to better coordinate the French mathematical research on MFG and to achieve significant progress in the theory and its applications.

The partners of the project are the CEREMADE laboratory (Paris Dauphine), the IRMAR laboratory (Rennes I), the university of Nice and of Tours.

8.2.1.3. ADA: 2019-2023

Participant: Arnaud Debussche.

The aim of this project is to treat multiscale models which are both infinite-dimensional and stochastic with a theoretic and computational approach. Multiscale analysis and multiscale numerical approximation for infinite-dimensional problems (partial differential equations) is an extensive part of contemporary mathematics, with such wide topics as hydrodynamic limits, homogenization, design of asymptotic-preserving scheme. Multiscale models in a random or stochastic context have been analysed and computed essentially in finite dimension (ordinary/stochastic differential equations), or in very specific areas, mainly the propagation of waves, of partial differential equations. The technical difficulties of our project are due to the stochastic aspect of the problems (this brings singular terms in the equations, which are difficult to understand with a pure PDE's analysis approach) and to their infinite-dimensional character, which typically raises compactness and computational issues. Our main fields of investigation are: stochastic hydrodynamic limit (for example for fluids), diffusion-approximation for dispersive equations, numerical approximation of stochastic multiscale equations in infinite dimension. Our aim is to create the new tools - analytical, probabilistic and numerical - which are required to understand a large class of stochastic multiscale partial differential equations. Various modelling issues require this indeed, and are pointing at a new class of mathematical problems that we wish to solve. We also intend to promote the kind of problems we are interested in, particularly among young researchers, but also to recognized experts, via schools, conference, and books.

The partners are ENS Lyon (coordinator J. Vovelle) and ENS Rennes (Coordinator A. Debussche).

8.2.2. Fédération de Recherche : Fusion par Confinement Magnétique

We are involved in the national research multidisciplinary group around magnetic fusion activities. As such, we answer to annual calls.

8.2.3. IPL SURF

A. Debussche and E. Faou are members of the IPL (Inria Project Lab) SURF: Sea Uncertainty Representation and Forecast. Head: Patrick Vidard.

8.2.4. AdT J-Plaff

This AdT started in october 2019 and will be finished in september 2021. An engineer has been hired (Y. Mocquard) to develop several packages in the Julia langage. The J-Plaff is shared with the Fluminance team.

8.3. European Initiatives

8.3.1. Collaborations in European Programs, Except FP7 & H2020

Program: Eurofusion

Project acronym: MAGYK

Project title:

Duration: january 2019-december 2020

Coordinator: E. Sonnendrücker

Other partners: Switzerland, Germany, France, Austria, Finland.

Abstract: This proposal is aimed at developing new models and algorithms that will be instrumental in enabling the efficient and reliable simulation of the full tokamak including the edge and scrape-off layer up to the wall with gyrokinetic or full kinetic models. It is based on a collaboration between applied mathematicians and fusion physicists that has already been very successful in a previous enabling research project and brings new ideas and techniques into the magnetic fusion community. New modelling and theoretical studies to extend the modern gyrokinetic theory up to the wall including boundary conditions will be addressed, and the limits of gyrokinetics will be assessed. New multiscale methods will enable to efficiently and robustly separate time scales, which will on the one hand make gyrokinetic codes more efficient and on the other hand enable full implicit kinetic simulations. Difficult algorithmic issues for handling the core to edge transition, the singularities at the O- and X-points will be addressed. And finally, pioneering work based on recent (deep) machine learning techniques will be performed, on the one hand to automatically identify a Partial Differential Equation (PDE) from the data, which can be used for verification and sensitivity analysis purposes, and on the other hand to develop reduced order models that will define a low- cost low-fidelity model based on the original high-fidelity gyrokinetic or kinetic model that can be used for parameter scans and uncertainty quantification.

8.4. International Initiatives

8.4.1. Inria Associate Teams Not Involved in an Inria International Labs

8.4.1.1. ANTIpODE

Title: Asymptotic Numerical meThods for Oscillatory partial Differential Equations with uncertainties

International Partner (Institution - Laboratory - Researcher):

University of Wisconsin-Madison, USA (United States)

Start year: 2018

See also: https://team.inria.fr/antipode/

The proposed associate team assembles the Inria team IPSO and the research group led by Prof. Shi Jin from the Department of Mathematics at the University of Wisconsin, Madison. The main scientific objective of ANTIpODE consists in marrying uniformly accurate and uncertainty quantification techniques for multi-scale PDEs with uncertain data. Multi-scale models, as those originating e.g. from the simulation of plasma fusion or from quantum models, indeed often come with uncertainties. The main scope of this proposal is thus (i) the development of uniformly accurate schemes for PDEs where space and time high oscillations co-exist and (ii) their extension to models with uncertainties. Applications to plasmas (Vlasov equations) and graphene (quantum models) are of paramount importance to the project.

8.4.2. Inria International Partners

8.4.2.1. Informal International Partners

The members of MINGuS have several interactions with the following partners

- Europe: University of Geneva (Switzerland), University of Jaume I (Spain), University of Basque Country (Spain), University of Innsbruck (Austria), University of Ferrare (Italy), Max Planck Institute (Germany), SNS Pisa (Italy)
- USA: Georgia Tech, University of Maryland, University of Wisconsin, NYU
- Asia: Chinese Academy of Science (China), University of Wuhan (China), shanghai jiao tong university (China), National University of Singapore (Singapore)

8.4.3. Participation in Other International Programs

- SIMONS project. Erwan Faou is one of the Principal investigators of the Simons Collaboration program *Wave Turbulence*. Head: Jalal Shatah (NYU).

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Fernando Casas (University of Jaume I, Spain) was invited in the MINGuS team during 6 months (september 2018 to february 2019), funded by the Labex (CHL) Center Henri Lebesgue.
- Yingzhe Li (University of Chinese Academy of Sciences, China) is visiting the IRMAR laboratory during one year (March 2019-February 2020) thanks to a chinese grant. He is currently a PhD student advised by Yajuan Sun, professor at CAS.
- Xiaofei Zhao (University of Wuhan, China) was invited in the MINGuS team during 2 weeks (july 2019).
- Yoshio Tsutsumi (Kyoto University, Japan) was invited in the IRMAR laboratory during 2 months (october-november 2019).

8.5.1.1. Internships

- G. Barrué: Master 2 internship, A. Debussche.
- Q. Chauleur: Master 2 internship, R. Carles (CNRS, Rennes) and E. Faou.
- U. Léauté: Master 1 internship, B. Boutin (University Rennes I and N. Crouseilles).
- A. V. Tuan: Master 2 internship, M. Lemou and F. Méhats.

8.5.2. Visits to International Teams

8.5.2.1. Sabbatical programme

P. Chartier was on a sabbatical visit from the 1st of February to the 30th of September 2019 at the University of the Basque Country, Spain.

8.5.2.2. Research Stays Abroad

- P. Chartier was invited by G. Vilmart, University of Geneva, Geneva, Switzerland, January 2019.
- P. Chartier was invited by F. Casas at the university of Jaume I, Castellon, Spain, July 2019.
- P. Chartier was Invited by Q. Li at the university of Wisconsin, Madison, USA, September 2019.
- P. Chartier was Invited by M. Tao at Georgia Tech, Atlanta, USA, August 2019.
- A. Debussche was invited by G. Da Prato at Scuola Normale Superiore, Pise, Italy, April 2019.
- E. Faou was a participant of the Semester *Geometry, compatibility and structure preservation in computational differential equations*, Isaac Newton Institute, Cambridge, UK (3 months stay, September-December 2019).
- M. Lemou was invited by J. Joudioux and L. Anderson, at the Albert Einstein Institute, Golm, Germany, February 2019.
- M. Lemou was invited by A. M. M. Luz at the Universidade Federal Fluminense, Rio de Janeiro, Brazil, April 2019.
- M. Lemou was invited by S. Jin at Shanghai Jiao Tong University, Shanghai, China, April 2019.
- M. Lemou was invited by J. Ben-Artzi at the university of Cardiff, Cardiff, UK, May 2019.
- M. Lemou was invited by G. Vilmart, University of Geneva, Geneva, Switzerland, January 2019.
- M. Lemou was Invited by Q. Li at the university of Wisconsin, Madison, USA, September 2019.
- M. Lemou was Invited by M. Tao at Georgia Tech, Atlanta, USA, August 2019.
- F. Méhats was invited by A. de la Luz at the Universidade Federal Fluminense, Rio de Janeiro, Brazil, April 2019.
- F. Méhats was invited by G. Vilmart, University of Geneva, Geneva, Switzerland, January 2019.

SIMSMART Project-Team

7. Partnerships and Cooperations

7.1. Regional Initiatives

Inter-Labex SEACS: V. Monbet, F. Le Gland, C. Herzet and Thi Tuyet Trang Chau (PhD student) are part of the *inter Labex Cominlabs-Lebesgue-Mer SEACS, http://www.seacs.cominlabs.ueb.eu/fr*, which stands for Stochastic modEl-dAta-Coupled representationS for the analysis, simulation and reconstruction of upper ocean dynamics. This project which concerns mainly Objectives 2 and 3, aims at exploring novel statistical and stochastic methods to address the emulation, reconstruction and forecast of fine-scale upper ocean dynamics.maths-computer-sea science for ocean dynamics.

CMEMS 3DA (2018-2019): C. Herzet is part of the project *CMEMS 3DA* on data assimilation of oceanographic events with non-parametric data assimilation methods. The goal of the project is to demonstrate the relevance of data-driven strategies to improve satellite derived interpolated products and especially the geostrophic surface currents. The project is made in collaboration with IMT Atlantique Brest, Ifremer and the Institue of Geosciences and Environment in Grenoble.

Action Exploratoire – Labex Cominlabs: C. Herzet is part of a project on sparse representations in continuous dictionaries. Partners: R. Gribonval (Inria Rennes PANAMA), A. Drémeau (IMT Atlantique) and P. Tandeo (IMT Atlantique).

7.2. National Initiatives

7.2.1. ANR

ANR BECOSE (2016-2020): Beyond Compressive Sensing: Sparse approximation algorithms for ill-conditioned inverse problems.

Cédric Herzet is part of the BECOSE project. The BECOSE project aims to extend the scope of sparsity techniques much beyond the academic setting of random and well-conditioned dictionaries. In particular, one goal of the project is to step back from the popular L1-convexification of the sparse representation problem and consider more involved nonconvex formulations, both from a methodological and theoretical point of view. The algorithms will be assessed in the context of tomographic Particle Image Velocimetry (PIV), a rapidly growing imaging technique in fluid mechanics that will have strong impact in several industrial sectors including environment, automotive and aeronautical industries.

ANR Melody (2020-2024): Bridging geophysics and MachinE Learning for the modeling, simulation and reconstruction of Ocean DYnamics.

Cédric Herzet is part of the MELODY project. The MELODY project aims to bridge the physical model-driven paradigm underlying ocean/atmosphere science and AI paradigms with a view to developing geophysically-sound learning-based and data-driven representations of geophysical flows accounting for their key features (e.g., chaos, extremes, high-dimensionality).

7.3. European Initiatives

7.3.1. FP7 & H2020 Projects

ERC MsMaths (2015-2019): M. Rousset is part of *ERC MSMaths* on molecular simulation (PI T. Lelièvre). With the development of large-scale computing facilities, simulations of materials at the molecular scale are now performed on a daily basis. The objective of the MSMath ERC project is to develop and study efficient algorithms to simulate such high-dimensional systems over very long, macroscopic times. ERC MsMaths especially focus on the computational issues related to 'metastable' states, that is to say specific molecular configurations that do evolve only on very large time scales. This results in a multi-timescale computational bottleneck that needs to be addressed by specific algorithms.

7.3.2. Collaborations with Major European Organizations

The agency European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) of Darmstadt. The transfer focuses on the estimation of atmospheric 3D winds from the future hyperspectral instrument (IRS on MTG-S, developed by ESA and IASI-NG on Metop-SG developed by CNES).

7.4. International Initiatives

7.4.1. Participation in Other International Programs

ECOS ARGENTINE (2018-2021): V. Monbet has obtained a funding program through the ECOS Sud - MINCyT intiative (http://www.univ-paris13.fr/cofecub-ecos/). The program involves a collaboration with the French-Argentinian Climate Institute (http://www.cima.fcen.uba.ar/UMI/), and focuses on non-parametric, analog methods, combined with data assimilation techniques to reconstruct complex meteorological dynamics (Objective 3).

DYLISS Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. MoDaL (Brittany and Pays de la Loire regions)

Participant: Olivier Dameron.

The MoDaL project is a federated project funded by BioGenOuest (Région Bretagne-Pays de la Loire) project involving scientists and engineers from IRISA/inria rennes (Genouest, Empenn, Dyliss) and the Institut du Thorax lab in Nantes. The project aims to decompartmentalize the resources dedicated to biomedical imaging and genetics. MoDaL focuses on i) establishing an inventory of the actors and infrastructures available at the inter-regional level, ii) proposing technological demonstrators that address the management, analysis and reuse of multi-infrastructure data (in-vivo, in-vitro and genomic imaging).

2019-2020. Total grant (hosted in the Empenn team): 100,000€.

9.1.2. PhenoMiR (European Maritime and Fisheries Fund)

Participant: Emmanuelle Becker.

The PhenoMiR project is a collaboration between Fishes Physiology and Genomics Laboratory (LPGP - INRAE), eight other laboratories of the INRAE, and the Dyliss team. Its objective is first (i) to settle the first complete repository of microRNAs for the trout, exploring different physiological and breeding conditions, and then (ii) to study the potentiality of some micro-RNAs to act as bio-markers of trout breeding and development condition. The Dyliss team is responsible for the design and development of the analysis pipeline of the genomics data, including the search of potential bio-markers.

2019-2022. Total grant: 495,000€. Dyliss grant: 33,000€.

9.1.3. UBIQUITIN

Participant: Emmanuelle Becker.

The Ubiquitin project is a collaboration between G. Rabut's team at the Institute of Developmental Biology of Rennes and the Dyliss team. It was funded as a cross-disciplinary emerging project by the University of Rennes 1.

G. Rabut's team is developing a new method to detect weak affinity protein-protein interactions based on protein complemantation with Luciferase. However the method may generate a very noisy signal depending on the *in-vivo* concentration of the partners. In the Ubiquitin project, we developped a R workflow to separate the signal from the noise in the experiments. As an application, this allowed us to decipher the intricate interplay between E2 and E3 enzymes during ubiquitination process in Yeast. This work was done during a master 2 internship. We are now continuing the project in two directions : (i) comparing the interactions identified with previously known databases, using web semantic technologies and ontologies describing protein interaction detection methods, and (ii) using formal classification to understand the structural properties of E2 and E3 that lead to their interactions. 2019-2020. Total grant: 7,000€. Dyliss grant: 4,200€.

9.1.4. Ph.D. fundings from Université, Inria Rennes and Inserm

The team benefits from PhD. theses fundings by Univ. Rennes (L. Bourneuf, 2016-2019 – H. Talibart, 2017-2020 – N. Guillaudeux, 2018-2021), by Inria (A. Belcour, 2019-2022 – V. Kmetzsch, 2019–2022), by Inserm (M. Louarn, 2017-2020, Inria-Inserm PhD Grant program), and by our collaborators from IRSET (M. Conan, 2017-2020 – P. Vignet, 2018-2020, O. Dennler, 2019–2022).

9.2. National Initiatives

9.2.1. IDEALG (ANR/PIA-Biotechnology and Bioresource)

Participant: Méziane Aite.

The project gathers 18 partners from Station Biologique de Roscoff (coordinator), CNRS, IFREMER, UEB, UBO, UBS, ENSCR, University of Nantes, INRA, AgroCampus, and the industrial field in order to foster biotechnology applications within the seaweed field. Dyliss is co-leader of the WP related to the establishment of a virtual platform for integrating omics studies on seaweed and the integrative analysis of seaweed metabolism. Major objectives are the building of brown algae metabolic maps, metabolic flux analysis and the selection of symbiotic bacteria for brown algae. We will also contribute to the prediction of specific enzymes (sulfatases and haloacid dehalogenase) [More details]. 2012–20. Total grant: 11M€. Dyliss grant: 534k€.

9.2.2. TGFSysBio (ITMO Cancer)

Participant: Olivier Dameron.

Partners are INSERM (coordinator) (IRSET, Univ. Rennes 1) CNRS (Dyliss team) and Inria (Antique, Paris). The TGFSYSBIO project aims at developing the first model of extracellular and intracellular TGF-beta system by combining a ruled-based modelling approach (kappa) and a Petri net modelling approach (cadbiom). 2015–18, extended in 2019. Total grant: 418k€. Dyliss grant: 129k€.

9.2.3. Programs funded by Inria

9.2.3.1. IPL Neuromarkers

Participant: Emmanuelle Becker.

This project involves mainly the Inria teams Aramis (coordinator) Dyliss, Genscale and Bonsai. The project aims at identifying the main markers of neurodegenerative pathologies through the production and the integration of imaging and bioinformatics data. Dyliss is in charge of facilitating the interoperability of imaging and bioinformatics data. In 2019 V. Kmetzsch started his PhD (supervized by E. Becker from Dyliss and O. Colliot from Aramis). 2017–20.

9.2.3.2. Askomics (ADT)

Participant: Olivier Dameron.

AskOmics [url] is a visual SPARQL query interface supporting both intuitive data integration and querying while avoiding the user to face most of the technical difficulties underlying RDF and SPARQL. The underlying motivation is that even though Linked (Open) Data now provide the infrastructure for accessing large corpora of data and knowledge, life science end-users seldom use them, nor contribute back their data to the LOD cloud by lack of technical expertise. AskOmics aims at bridging the gap between end users and the LOD cloud. 2018–2020.

9.3. European Initiatives

9.3.1. Collaborations in European Programs, Except FP7 & H2020

- Program: Polish National Science Center
- Project acronym: NCN 2016/21/B/ST6/02158
- Project title: Grammatical inference methods in classification of amyloidogenic proteins
- Duration: January 2017 - January 2020
- Coordinator: Olgierd Unold, Politechnika Wroclawska
- Other partners: Politechnika Wroclawska (Polland)
- Abstract: The objective is to develop the methods for induction of context-free and probabilistic grammars to describe a language matching amyloidogenic protein sequences.

9.3.2. Collaborations with Major European Organizations

Partner: Potsdam (Germany)

Title: Modeling combinatorial and hybrid optmization problems with Answer Set Programming

9.4. International Initiatives

9.4.1. Informal International Partners

We have a cooperation with Univ. of Chile (MATHomics, A. Maass) on methods for the identification of biomarkers and software for biochip design. It aims at combining automatic reasoning on biological sequences and networks with probabilistic approaches to manage, explore and integrate large sets of heterogeneous omics data into networks of interactions allowing to produce biomarkers, with a main application to biomining bacteria. The program is co-funded by Inria and CORFO-chile from 2012 to 2016. In this context, Integrative-BioChile was an Associate Team between Dyliss and the Laboratory of Bioinformatics and Mathematics of the Genome hosted at Univ. of Chile funded from 2011 to 2016. The collaboration is now supported by Chilean programs.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- **Niger:** Oumarou Abdou-Arbi (University of Maradi)

9.5.1.1. Research Stays Abroad

- **Germany:** Maël Conan visited the Zentrum für Bioinformatik at Hamburg University with Prof. Johannes Kirchmair for 2 months. During this stay, he learned how to predict metabolism sites using the tool developped in Pr. Kirchmair unit (FAME2/FAME3) and initiated the development of a new method to predict xenobiotics metabolism.
- **Germany:** Clémence Frioux visited the lab of Oliver Ebenoh (Heidelberg) for one week.

EMPENN Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Défis scientifiques 2019 of University of Rennes 1: Compensating analytic variability for a better use of open data (2019, 6500€).

Participant: Camille Maumet.

In neuroimaging, open data are now well developed with hundred of thousands of images available for the research community. However, those data are still mainly studied in isolation, limiting the potential for new discoveries. Here we focus our efforts on developing neuroinformatics standards and algorithms that will support publication and combination of open datasets.

9.1.2. Region Bretagne: project VARANASI

Participants: Christian Barillot, Camille Maumet, Xavier Rolland.

Thanks to the development of open science practices, more and more public datasets are available to the research community. In the field of brain imaging, these data, combined, bring a critical increase in sample size, necessary to build robust models of the typical and atypical brain. However, in order to build valid inferences on these data, we need to take into account their heterogeneity. Variability can arise due to multiple factors such as: differences in imaging instruments, in acquisitions protocols and even, in post-processing pipelines. In particular, the expansion of open source machine learning workflows creates a multitude of possible outputs out of the same dataset. The variations induced by this methodological plurality can be reFerréd to as 'analytic variability' which will be the focus of the thesis funded in half by region Bretagne. The thesis of Xavier Rolland (2018-2021) will address two challenges: 1) How to combine neuroimaging data generated by different analysis pipelines? 2) How to publish neuroimages with an adequate level of metadata to enable their reuse? Methodological developments will combine machine learning techniques with methods from knowledge representation.

9.2. National Initiatives

9.2.1. Projet Fondation de France: PERINE: 99k€ (33 k€ for IRM acquisition and 22 k€ for image analysis) for 2011-2021

Participants: Élise Bannier, Isabelle Corouge, Julie Coloigner, Maia Proisy, Jean-Christophe Ferré, Christian Barillot.

The PELAGIE cohort evaluates the effect of prenatal exposure to neurotoxicants on child development. Following previous studies, the PERINE study focuses on the assessment of brain developement at 10-12 years old using MRI (ASL, Diffusion imaging, Working memory as well as motor inhibition BOLD fMRI together with neuropsychological tests). A total of 101 children were included. A PhD of Anne-Claire Binter was defended in December 2019 linking epidemiology with functional imaging during a GoNoGo task and neuropsychological scores. This work is done in collaboration with Fabienne Pele´ and Ce´cile Chevrier (IRSET).

9.2.2. Fondation de l'Avenir: EPMR-MA

Participants: Pierre-Yves Jonin, Élise Bannier, Christian Barillot, Quentin Duché.

Recognition memory refers to our ability to discriminate between previously experienced vs. unexperienced stimuli. It is impaired very early in the course of Alzheimer's Disease (AD), both regarding behavioural performance and related brain activity. When the memoranda is associated or with existing knowledge, subsequent memory increases in healthy subjects. Moreover, existing knowledge related to prior exposures may alter the brain network underlying successful memory formation. While much is known regarding the brain substrates of recognition memory in early AD, little is known about the impact of prior exposure. Yet, this factor could both enhance memory formation in patients, and highlight a pattern of memory impairments and related brain activity that might accurately discriminates between early AD, before dementia, and healthy aging. The present task-based fMRI study aims at assessing the influence of prior exposures on recognition memory and its neural underpinnings in patients with Mild Cognitive Impairment due to AD. Inclusions were performed between 2016 and 2017 and data analysis is ongoing.

9.2.3. Projet Fondation de France: Connectivity of the amygdala in depression: (PI: M.-L. Paillère Martinot, Paris Descartes University), €200k for 2018-2021

Participants: Christian Barillot, Olivier Commowick, Emmanuel Caruyer, Julie Coloigner.

The onset of depression in teenagers and young adults increases the risk to develop a drug-resistant depression in the adulthood. This project aims at evaluating the role of early changes in the microstructure and connectivity of the amygdala. Using a cohort of drug-resistant patients (N=30), non drug-resistant patients (N=30) and controls (N=30), the aim is to identify imaging biomarkers of the pathology and to compare these with emotional and cognitive phenotypes in this population, searching for early differences in the development of the amygdala connectivity.

9.2.4. CNRS-Inserm Défi Santé numérique – AAP 2019: Imagerie Multimodale de l'Amygdale limbiquE pour le pronostic de la Dépression (IMpAirED): 19k€ for 2019

Participants: Julie Coloigner, Olivier Commowick, Élise Bannier, Emmanuel Caruyer, Christian Barillot.

This grant is an extension of the Projet Fondation de France: Connectivity of the amygdala in depression.

In order to identify early features of this depression disease, the aim of this project is to develop multimodal modeling of the limb amygdala and its network from MR imaging combining activation and rest functional imaging and MR brain microstructure imaging quantitative (diffusion and relaxometry). The development of this model will allow us to define three imaging biotypes corresponding to depressed adult patients responding to antidepressant treatments, depressed resistant patients and controls. These multimodal imaging biomarkers will be used to stratifie a large longitudinal cohort of young adults into three sub-groupsgroups, in order to retrospectively identify early differences in development trajectories of amygdala.

Inclusions of the patients will begin in early 2020.

9.2.5. ANR "MAIA", generic projects program: €150k for 2016-2019 (PI: F. Rousseau, IMT Atlantique, Brest)

Participants: Maia Proisy, Pierre Maurel, Antoine Legouhy, Olivier Commowick, Isabelle Corouge, Jean-Christophe Ferré, Christian Barillot.

Each year in France, 55 000 children are born prematurely, i.e., before the 37th week of gestation. Long-term studies of the outcome of prematurely born infants have clearly documented that the majority of such infants may have significant motor, cognitive, and behavioral deficits.

However, there is a limited understanding of the nature of the cerebral abnormality underlying these adverse neurologic outcomes. In this context, the emergence of new modalities of 3D functional MRI, e.g., Arterial Spin Labeling (ASL), or optical imaging technologies, e.g., Near InfraRed Spectroscopy (NIRS), brings new perspectives for extracting cognitive information, via metabolic activity measures. Other classical techniques devoted to cerebral signal measurement, such as ElectroEncephaloGraphy (EEG), provide cognitive information at the cortical level. Each of these various non-invasive imaging technologies brings substantial and specific information for the understanding of newborn brain development.

This project is developing innovative approaches for multi-image / multi-signal analysis, in order to improve neurodevelopment understanding methods. From a fundamental point of view, mathematics and computer science have to be considered in association with imaging physics and medicine, to deal with open issues of signal and image analysis from heterogeneous data (image, signal), considered in the multiphysics contexts related to data acquisition (magnetic, optic, electric signals) and biophysics modeling of the newborn brain. A sustained synergy between all these scientific domains is then necessary.

Finally, the sine qua non condition to reach a better understanding of the coupled morphological cognitive development of premature newborns, is the development of effective software tools, and their distribution to the whole medical community. The very target of this project is the design of such software tools for medical image / signal analysis, actually operational in clinical routine, and freely available. Academic researchers and industrial partners are working in close collaboration to reach that ambitious goal.

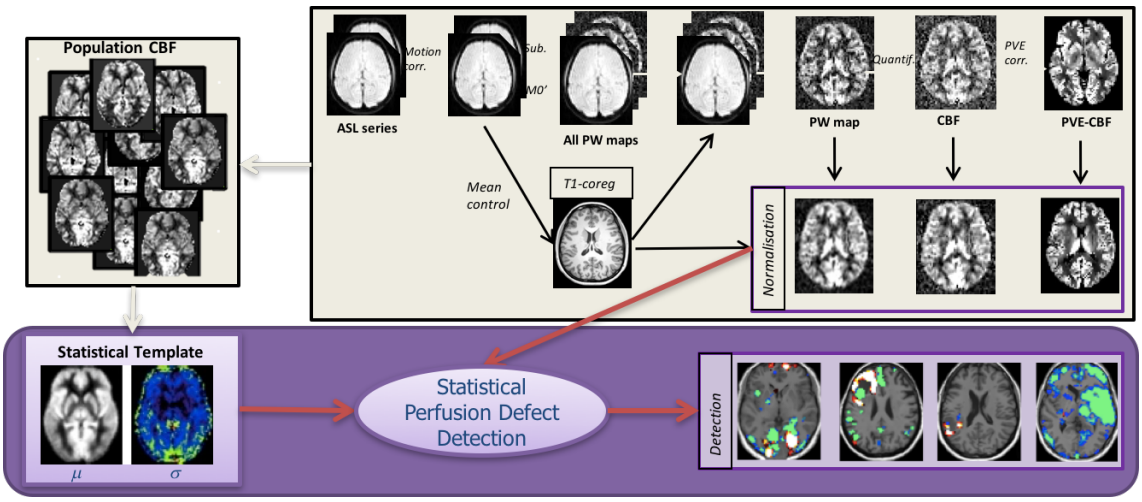

Figure 2. Processing workflow for quantification of Arterial Spin Labelling Cerebral Blood Flow with detection of abnormal perfusion

9.2.6. Fondation pour la recherche médicale (FRM) - Project Hybrid EEG/IRM Neurofeedback for rehabilitation of brain pathologies: 370k€ (2017-2021)

Participants: Élise Bannier, Isabelle Bonan, Isabelle Corouge, Jean-Christophe Ferré, Jean-Yves Gauvrit, Pierre Maurel, Mathis Fleury, Giulia Lioi, Christian Barillot.

The goal of this project is to make full use of neurofeedback (NF) paradigm in the context of brain rehabilitation. The major breakthrough will come from the coupling associating functional and metabolic information from Magnetic Resonance Imaging (fMRI) to Electro-encephalography (EEG) to "optimize" the neurofeedback protocol. We propose to combine advanced instrumental devices (Hybrid EEG and MRI platforms), with new hybrid Brain computer interface (BCI) paradigms and new computational models to provide novel therapeutic and neuro-rehabilitation paradigms in some of the major mental and neurological disorders of the developmental and the aging brain (stroke, language disorders, Mood Depressive Disorder (MDD), ...). Though the concept of using neurofeedback paradigms for brain therapy has somehow been experimented recently (mostly through case studies), performing neurofeedback through simultaneous fMRI and EEG has almost never been done before so far (two teams in the world including us within the HEMISFER CominLabs project). This project will be conducted through a very complementary set of competences over

the different involved teams: Empenn U1228, HYBRID and PANAMA Teams from Inria/Irisa Rennes and EA 4712 team from University of Rennes I.

9.2.7. PHRC EMISEP: Evaluation of early spinal cord injury and late physical disability in Relapsing Remitting Multiple Sclerosis: €200k for 2016-2019

Participants: Élise Bannier, Christian Barillot, Emmanuel Caruyer, Benoit Combès, Olivier Commowick, Gilles Edan, Jean-Christophe Ferré, Haykel Snoussi.

Multiple Sclerosis (MS) is the most frequent acquired neurological disease affecting young adults (1 over 1000 inhabitants in France) and leading to impairment. Early and well adapted treatment is essential for patients presenting aggressive forms of MS. This PHRC (Programme hospitalier de recherche clinique) project focuses on physical impairment and especially on the ability to walk. Several studies, whether epidemiologic or based on brain MRI, have shown that several factors are likely to announce aggressive development of the disease, such as age, number of focal lesions on baseline MRI, clinical activity. However, these factors only partially explain physical impairment progression, preventing their use at the individual level. Spinal cord is often affected in MS, as demonstrated in postmortem or imaging studies. Yet, early radiological depiction of spinal cord lesions is not always correlated with clinical symptoms. Preliminary data, on reduced number of patients, and only investigating the cervical spinal cord, have shown that diffuse spinal cord injury, observed via diffusion or magnetisation transfer imaging, would be correlated with physical impairment as evaluated by the (EDSS) Expanded Disability Status Scale score. Besides, the role of early spinal cord affection (first two years) in the evolution of physical impairment remains unknown.

In this project, we propose to address these different issues and perform a longitudinal study on Relapsing Remitting Multiple Sclerosis (RRMS) patients, recruited in the first year of the disease. Our goal is to show that diffuse and focal lesions detected spinal cord MRI in the first two years can be used to predict disease evolution and physical impairment at 5 years. Twelve centers are involved in the study to include 80 patients.

To date, all subjects have been included. Haykel Snoussi defended his PhD Thesis on diffusion imaging in the spinal cord starting with distortion correction.

B. Combe`s started as a post-doc in November 2016 to process the EMISEP imaging data, starting with morphological data processing (registration, segmentation) and magnetization transfer data processing.

9.2.8. MS-TRACTS (ARSEP and COREC funding): Estimating the impact of multiple sclerosis lesions in motor and proprioceptive tracts, from the brain to the thoracic spinal cord, on their functions, assessed from clinical tests and electrophysiological measurements: 45k€ (2019-2021).

Participants: Élise Bannier, Benoit Combès.

Previous studies, whether epidemiologic or based on brain MRI, have shown that several factors were likely to announce aggressive development of the disease, such as age, clinical relapses, number of focal lesions on baseline MRI. However, these factors only partially explain physical disability progression, preventing their use at the individual level. The access to advanced brain and cord MR images, the development of associated processing tools combined. We hypothesize that a fine assessment of damage on specific networks, from the brain to the thoracic cord, offers a relevant biomarker of disability progression in MS. Such damage assessments must take into account both lesion location, assessed on structural brain and cord MR images and lesion severity, assessed using quantitative MR images. We propose to test this hypothesis by combining assessments of lesion location and severity on corticospinal and proprioceptive tracts from the brain to the thoracic cord with clinical and electrophysiological measurements. This study includes two French centers (Rennes, Marseille) and includes a total of 60 patients. The expected outcome is to obtain early biomarkers of physical impairment evolution in RRMS patients, first treated with immunomodulatory treatment. The long-term goal is to provide the clinician with biomarkers able to anticipate therapeutic decisions and support the switch to alternative more aggressive treatment.

9.2.9. PIA projects

9.2.9.1. The HEMISFER Project: (€400k for 2017-2019)

Participants: Élise Bannier, Isabelle Bonan, Isabelle Corouge, Claire Cury, Jean-Christophe Ferré, Jean-Yves Gauvrit, Pierre Maurel, Christian Barillot.

The HEMISFER project ("Hybrid Eeg-MrI and Simultaneous neuro-FEedback for brain Rehabilitation") is conducted at Inria Rennes with the support of the Labex "CominLabs" [0]. The goal of HEMISFER is to make full use of the neurofeedback paradigm in the context of rehabilitation and psychiatric disorders. The major breakthrough will come from the use of a coupling model associating functional and metabolic information from Magnetic Resonance Imaging (fMRI) to Electro-encephalography (EEG) to "enhance" the neurofeedback protocol. We combine advanced instrumental devices (Hybrid EEG and MRI platforms), with new man-machine interface paradigms (Brain computer interface and serious gaming) and new computational models (source separation, sparse representations and machine learning) to provide novel therapeutic and neuro-rehabilitation paradigms in some of the major neurological and psychiatric disorders of the developmental and the aging brain (stroke, attention-deficit disorder, language disorders, treatment-resistant mood disorders, etc.). This project involves with the HYBRID and PANAMA Teams from Inria Rennes, the EA 4712 team from University of Rennes I and the ATHENA team from Inria Sophia-Antipolis. This work benefits from the research 3T MRI and MRI-compatible EEG systems provided by the NeurInfo in-vivo neuroimaging platform on which these new research protocols aree set up. A budget of 500K€ is provided by CominLabs to support this project (through experimental designs, PhDs, post-docs and expert engineers).

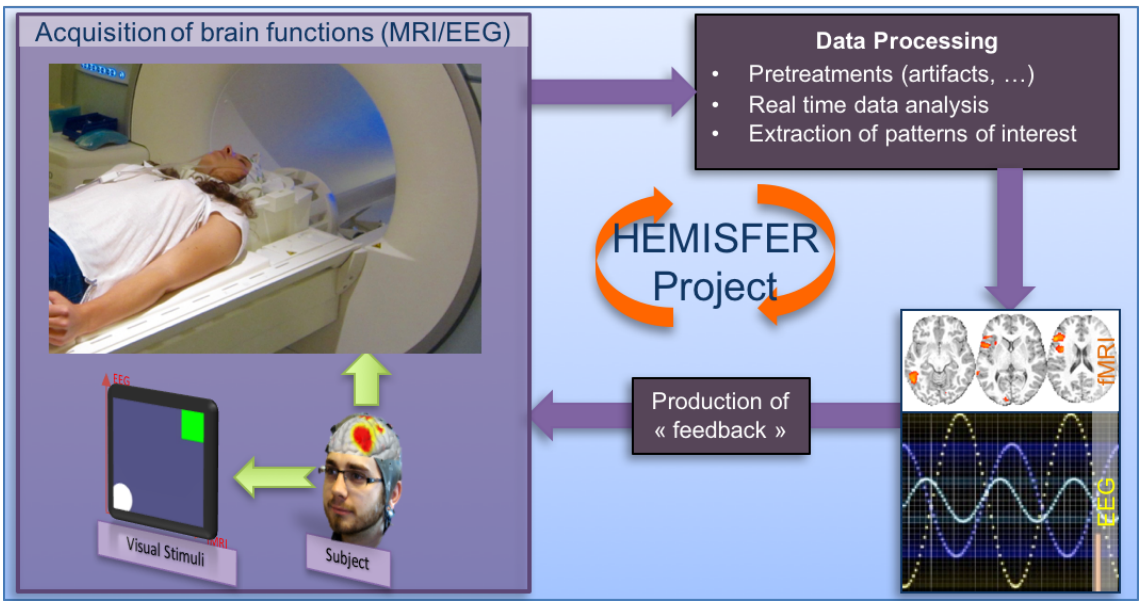

Figure 3. Principle of the Hemisfer project.

9.2.9.2. France Life Imaging (FLI): 2012-2023, €2000k (phase 1) + €1200k (phase 2)

Participants: Christian Barillot, Olivier Commowick.

[0] https://iww.inria.fr/cominlabs-newsletter/april-2013-four-projects-selected/#hemisfer

France Life Imaging (FLI) is a large-scale research infrastructure project to establish a coordinated and harmonized network of biomedical imaging in France. This project was selected by the call "Investissements d'Avenir - Infrastructure en Biologie et Santé". One node of this project is the node Information Analysis and Management (IAM), a transversal node built by a consortium of teams that contribute to the construction of a network for data storage and information processing. Instead of building yet other dedicated facilities, the IAM node use already existing data storage and information processing facilities (LaTIM Brest; CREATIS Lyon; CIC-IT Nancy; Empenn U1228 Inria Rennes; CATI CEA Saclay; ICube Strasbourg) that increase their capacities for the FLI infrastructure. Inter-connections and access to services are achieved through a dedicated software platform that is developed based on the expertise gained through successful existing developments. The IAM node has several goals. It is building a versatile facility for data management that inter-connects the data production sites and data processing for which state-of-the-art solutions, hardware and software, are available to infrastructure users. Modular solutions are preferred to accommodate the large variety of modalities acquisitions, scientific problems, data size, and to be adapted for future challenges. Second, it offers the latest development that are made available to image processing research teams. The team Empenn fulfills multiple roles in this nation-wide project. Christian Barillot is the chair of the node IAM, Olivier Commowick is participating in the working group workflow and image processing and Michael Kain is the technical manager. Apart from the team members, software solutions like MedInria and Shanoir are part of the software platform.

9.2.9.3. OFSEP: €175k for 2017-2019

Participants: Élise Bannier, Christian Barillot, Olivier Commowick, Gilles Edan, Jean-Christophe Ferré, Francesca Galassi.

The French Observatory of Multiple Sclerosis (OFSEP) is one of ten projects selected in January 2011 in response to the call for proposal in the "Investissements d'Avenir - Cohorts 2010" program launched by the French Government. It allows support from the National Agency for Research (ANR) of approximately 10 million € for 10 years. It is coordinated by the Department of Neurology at the Neurological Hospital Pierre Wertheimer in Lyon (Professor Christian Confavreux), and it is supported by the EDMUS Foundation against multiple sclerosis, the University Claude Bernard Lyon 1 and the Hospices Civils de Lyon. OFSEP is based on a network of neurologists and radiologists distributed throughout the French territory and linked to 61 centers. OFSEP national cohort includes more than 50,000 people with Multiple Sclerosis, approximately half of the patients residing in France. The generalization of longitudinal monitoring and systematic association of clinical data and neuroimaging data is one of the objectives of OFSEP in order to improve the quality, efficiency and safety of care and promote clinical, basic and translational research in MS. For the concern of data management, the Shanoir platform of Inria has been retained to manage the imaging data of the National OFSEP cohort in multiple sclerosis.

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

9.3.1.1. OpenAire-Connect

Participants: Christian Barillot, Camille Maumet, Xavier Rolland.

Project title: **OpenAire-Connect**

Partners: PI: CNR, Italy; Athena Research And Innovation Center In Information Communication & Knowledge Technologies, Greece; Uniwersytet Warszawski, Poland; JISC LBG, UK; Universitaet Bremen, Germany; Universidade Do Minho, Portugal; CNRS (Empenn, Creatis), France; Universita Di Firenze, Italy; Institut De Recherche Pour Le Developpement (IRD), France; European Organization For Nuclear Research (CERN), Switzerland; International Center For Research On The Environment And The Economy, Greece

Budget: 2M € (120k€ for CNRS)

The OpenAire-Connect H2020 project introduces and implements the concept of Open Science as a Service (OSaaS) on top of the existing OpenAIRE infrastructure, delivering out-of-the-box, on-demand deployable tools. OpenAIRE-Connect adopts an end-user driven approach (via the involvement of five prominent research communities), and enriches the portfolio of OpenAIRE infrastructure production services with a Research Community Dashboard Service and a Catch-All Notification Broker Service. The first offers publishing, interlinking, packaging functionalities to enable them to share and re-use their research artifacts (introducing methods, e.g., data, software, protocols). This effort, supported by the harvesting and mining "intelligence" of the OpenAIRE infrastructure, provides communities with the content and tools they need to effectively evaluate and reproduce science. OpenAIRE-Connect combines dissemination and training with OpenAIRE's powerful NOAD network engaging research communities and content providers in adopting such services. These combined actions bring immediate and long-term benefits to scholarly communication stakeholders by affecting the way research results are disseminated, exchanged, evaluated, and re-used. In this project Empenn is acting, through CNRS, as the French coordinator to develop the link with the Neuroimaging research community. This is performed in the context of the FLI-IAM national infrastructure.

9.3.1.2. EIT-Health

Participant: Christian Barillot.

EIT Health aims to promote entrepreneurship and develop innovations in healthy living and active ageing, providing Europe with new opportunities and resources. EIT Health will enable citizens to lead healthier and more productive lives by delivering products, services and concepts that will improve quality of life and contribute to the sustainability of healthcare across Europe. EIT Health is a strong, diverse and balanced partnership of best-in-class organisations in education, research, technology, business creation and corporate and social innovation. EIT Health intends to foster cooperation and unlock Europe's innovation and growth potential – developing and retaining the best talents, creating high-quality jobs and boosting the global competitiveness of European industry. Empenn is involved in this project through the Inserm and Inria institutions. Christian Barillot is representing Inria as one expert in the dedicated WG "Healthy Brain". Empenn is also concerned by the WG "big data".

9.4. International Initiatives

9.4.1. Inria International Labs

9.4.1.1. MMINCARAV

EPFL-Inria

Associate Team involved in the International Lab:

Title: Multimodal Microstructure-Informed Neuronal Connectivity: Acquisition, Reconstruction, Analysis and Validation

International Partner (Institution - Laboratory - Researcher):

Ecole Polytechnique Fédérale de Lausanne (Switzerland) - Laboratoire de Traitement du Signal 5 - Jean-Philippe Thiran

Start year: 2019

See also: https://team.inria.fr/empenn/research/mmincarav-inria-epfl/

Participants: Emmanuel Caruyer, Olivier Commowick, Julie Coloigner, Élise Bannier and Christian Barillot.

The objectives of this associate team will be to address new scientific challenges related to the use of multimodal magnetic resonance imaging (MRI) to derive microstructure indices and apply them to the measure of brain connectivity. We will focus on 4 aspects of this: first we will develop novel sampling techniques, with the objective to reduce acquisition time for the accurate reconstruction of microstructure indices using diffusion MRI; next we will propose joint T2 relaxometry and diffusion models for the description of microstructure, to take advantage of the complementarity of both modalities in the estimation of microstructure indices; in continuation, we will propose new statistical and network analysis methods using the microstructure-informed connectome, and evaluate its potential to reduce bias and false positives; last we will develop a realistic simulation tool combining a fine macroscopic description of fiber bundles, with a fast and realistic simulator at the mesoscopic scale developed by LTS5.

9.4.1.2. Other projects

Participants: Pierre Maurel, Christian Barillot, Claire Cury.

Gundishapur Program (Partenariat Hubert Curien franco-iranien)

This project is a collaboration between the Empenn team and the Institute of medical science and technologies (Shahid Beheshti university, Iran).

Combining EEG (Electroencephalogram) and fMRI (functional Magnetic Resonance Imaging) shows great promise in helping scientists to better understand the complex function of the brain. It can also be used in understanding the brain dysfunctions or specific behaviors. The integration of these two modalities can provide a good spatio-temporal resolution of the neuronal activities, and therefore, it can bring a good insight on the brain function. EEG is the recording of the electrical activity of the brain through scalp surface electrodes. We are already working in this area through the HEMISFER project, whose goal is to make full use of neurofeedback paradigm by using a coupling model associating functional and metabolic information from Magnetic Resonance Imaging (fMRI) and Electro-encephalography (EEG) to “enhance” the neurofeedback protocol. A former member of our team, Dr. Noorzadeh, has already worked on a part of this project, and is now in IMSAT (Iran). He is our main contact for this collaboration.

This project works on the integration methods, in order to first acquire the simultaneous data of high quality with the minimum possible artifacts, and also on biomedical applications in this regard. One of these applications is the source localization using the multi-modal data. Identifying neuronal sources in both high spatial and temporal resolution can open up a bright way to understand lots of diseases, among which epilepsy is the main one. The epileptic seizures or the inter-ictal discharges are nowadays only detected by EEG, but the origin of the activity is only inferred in terms of brain lobes. This spatial precision can be augmented and the method can be used in the precise detection of the focal points of epilepsy for the pre-surgical evaluations.

9.4.1.3. Informal International Collaborations

- Emmanuel Caruyer collaborates with Alice Bates, research fellow at Australian National University, Canberra, on "Dimensionality sampling for B-tensor encoding in diffusion MRI".
- Camille Maumet collaborates with Prof. Thomas Nichols and his group, NISOx at the Oxford Big Data Institute, with Prof. Jean-Baptiste Poline and his group at McGill University, with Prof. Satrajit Ghosh and his group at MIT, with Dr David Keator at UCI Irvine, with Dr. Karl Helmer at MGH, with Dr Tristan Glatard and his group at Concordia University and with international members of the INCF on neuroimaging data sharing.
- Julie Coloigner collaborates with Prof. Natasha Leporé and Dr. John Wood, Children’s hospital Los Angeles, University Southern California.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- David Kennedy, Professor at University of Massachusetts Medical School, US visited the team on Feb 27 and gave a talk on Repronim: a center for reproducible neuroimaging.

- Natasha Leporé, Professor at Children's hospital Los Angeles, University of Southern California, US visited the team on April 4-5. She gave a talk on "Understanding pediatric brain anatomy through MRI".
- Jan Petr, Researcher at the HZDR in Dresden visited the team in March 1st, 2019 and give a talk on "Processing ASL data with ExploreASL - technical improvement and clinical applications".

9.5.2. Visits to International Teams

9.5.2.1. Research Stays Abroad

- Corentin Vallée visited Brainnetome center, Institute of Automation, Chinese Academy of Science, Beijing from June 1, 2019 to July 31, 2019; he was awarded a grant for international mobility from the MathSTIC doctoral school.

FLUMINANCE Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. Comins'lab: SEACS : Stochastic modEl-dAta-Coupled representationS for the analysis, simulation and reconstruction of upper ocean dynamics

Participant: Etienne Mémin.

duration 48 months. The SEACS project whose acronym stands for: "Stochastic modEl-dAta-Coupled representationS for the analysis, simulation and reconstruction of upper ocean dynamics" is a Joint Research Initiative between the three Britanny clusters of excellence of the "Laboratoires d'Excellence" program: Cominlabs, Lebesgue and LabexMer centered on numerical sciences, mathematics and oceanography respectively. Within this project we aim at studying the potential of large-scale oceanic dynamics modeling under uncertainty for ensemble forecasting and satellite image data assimilation.

8.1.2. ANR BECOSE : Beyond Compressive Sensing: Sparse approximation algorithms for ill-conditioned inverse problems.

Participant: Dominique Heitz.

duration 48 months. The BECOSE project aims to extend the scope of sparsity techniques much beyond the academic setting of random and well-conditioned dictionaries. In particular, one goal of the project is to step back from the popular L1-convexification of the sparse representation problem and consider more involved nonconvex formulations, both from a methodological and theoretical point of view. The algorithms will be assessed in the context of tomographic Particle Image Velocimetry (PIV), a rapidly growing imaging technique in fluid mechanics that will have strong impact in several industrial sectors including environment, automotive and aeronautical industries. The consortium gathers the Fluminance and Panama Inria research teams, the Research Center for Automatic Control of Nancy (CRAN), The Research Institute of Communication and Cybernetics of Nantes (IRCCyN), and ONERA, the French Aerospace Lab.

8.1.3. IFPEN project

Participants: Jocelyne Erhel, Bastien Hamlat.

Contract with IFPEN (Institut Français du Pétrole et Energies Nouvelles) Duration: three years from October 2016. Title: Fully implicit Formulations for the Simulation of Multiphase Flow and Reactive Transport Coordination: Jocelyne Erhel. Contract with IFPEN (Institut FranÃ§ais du Pétrole et Energies Nouvelles). Duration: three years October 2016-September 2019. Title: Fully implicit Formulations for the Simulation of Multiphase Flow and Reactive Transport. Coordination: Jocelyne Erhel. Abstract: Modeling multiphase flow in porous media coupled with fluid-rock chemical reactions is essential in order to understand the origin of sub-surface natural resources and optimize their use. This project focused on chemistry models, with kinetic reactions. We developed a mathematical tool, which can be embedded into a reactive transport code.

8.1.4. GDR MANU

Participants: Yvan Crenner, Jocelyne Erhel, Bastien Hamlat.

Title: Mathematics for Nuclear industry
Duration: From 2016 to 2019
Coordination: C. Cancès
Webpage: http://gdr-manu.math.cnrs.fr/

Abstract: The working group MANU is a follow-up to the group MOMAS. It covers many subjects related to mathematical modeling and numerical simulations for problems arising from nuclear industry and nuclear waste disposal. We participated in a workshop on reactive transport (SITRAM), Pau, December 2019.

8.1.5. LEFE MANU: MSOM

Participants: Etienne Mémin, Long Li.

Title: Multiple Scale Ocean Model
Duration: From 2018 to 2021
Coordination: Bruno Deremble (CNRS LMD/ENS Paris)
Abstract: The objective of this project is to propose a numerical framework of a multiscale ocean model and to demonstrate its utility in the understanding of the interaction between the mean current and eddies.

8.2. International Initiatives

8.2.1. Inria International Partners

8.2.1.1. Informal International Partners

Imperial College, London (UK), Collaboration with Dan Crişan and Darryl Holm on Stochastic transport for the upper ocean dynamics

Chico California State University (USA), We have pursued our collaboration with the group of Shane Mayor on the GPU implementation of wavelet based motion estimator for Lidar data. This code is developped in coproperty between Inria and Chico.

8.2.1.2. International Initiatives

MATH-GEO

Title: MATHematical methods for GEOphysical flows

International Partners (Institution - Laboratory - Researcher):

Universidad de Buenos Aires (Argentina) - CIMA - Juan Ruiz

Universidad de la Republica Uruguay (Uruguay) - IMFIA, INCO

CMM (Chile) - Center for Mathematical Modeling - Axel Osses

Universidad San Ignacio de Loyola (USIL) (Peru) - Faculty of Engineering Alejandro Paredes

Duration: 2018 - 2019

Start year: 2018 http://mathgeo.cima.fcen.uba.ar

Nonlinear processes, such as advection and turbulent mixing, play a central role in geophysical sciences. The theory of nonlinear dynamical systems provides a systematic way to study these phenomena. Its stochastic extension also forms the basis of modern data analysis techniques, predictability studies and data assimilation methods. Contributions in the field of Topology and Dynamics of Chaos include methods conceived to unveil the structure organizing flows in phase space, building the gap between data and l ow-dimensional modeling. Low-order models in climate dynamics are highly desirable, since they can provide solutions in cases where high-resolution numerical simulations cannot be implemented, as in short-term wind forecasting. At the same time, the procedure provides a tool-kit for model validation, emulation or inter-model comparison, with interesting prospects in all fields of oceanographic and atmospheric sciences, including climate detection and attribution. The strategy constitutes an unprecedented and promising perspective, offering an original approach to the subject, with mathematical concepts that are not necessarily widespread in the geophysics scientific community. This proposal gathers specialists with a know-how in the most challenging aspects of the focused research field: coherent structure detection in fluid flows for the exploration and interactive visualization of scientific data (LIMSI France), data assimilation and fluid motion analysis from image sequences (Inria Rennes), numerical models

and data assimilation (CMM-Chile) stochastic models for climate dynamics with application to El Niño Ocean models (USIL-Peru), mathematical methods for weather and climate (CIMA-UBA & IMIT / IFAECI, Argentina), geophysical flows and dynamical systems (LMD France), mixing structures and Lagrangian analysis of multisatellite data (LOCEAN France), marine and estuarine hydrodynamic and water properties numerical models (INCO & IMFIA-Uruguay), in situ measurements of oceanographic conditions (CEBC France, in program with CNES France and CONAE Argentina), global modelling technique and topological characterization of flows (CORIA with CESBIO, France).

8.3. International Research Visitors

8.3.1. Visits of International Scientists

- 1 week visit of Alejandro Paredes Universidad San Ignacio de Loyola (USIL) (Peru) to work with Etienne Mémin
- 1 week visit of André Cavaleri (Instituto Tecnologico de Aeronautica, SP, Brésil) to work with Gilles Tissot
- 3 months visit of Ruediger Brecht (May to August), PhD student at Memorial University of Newfoundland, Canada, supported by funding from Inria-Mitacs Globalink.

GENSCALE Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Project Thermin: Differential characterization of strains of a bacterial species, Streptococcus thermophilus, with a Nanopore MinION

Participants: Jacques Nicolas, Emeline Roux, Grégoire Siekaniec, Dominique Lavenier.

Coordinator: J. Nicolas (Inria/Irisa, GenScale, Rennes)
Duration: 36 months (Oct. 2018 – Sept. 2021)
Partners: INRA (STLO, Agrocampus Rennes, E. Guédon and Y. Le Loir).

The Thermin project aims at exploring the capacities of a low cost third generation sequencing device, the Oxford Nanopore MinION, for rapid and robust pan-genome discrimination of bacterial strains and their phenotypes. It started with the recruitments of E. Roux (délégation Inria, Oct, 2018), a biochemist from Lorraine University, and G. Siekaniec (INRA -Inria collaboration, INRA grant), a new PhD student. We study pan-genomic representations of multiple genomes and the production of characteristic signatures of each genome in this context.

9.1.2. Project DNA-Store: Advanced error correction scheme for DNA-based data storage using nanopore technology

Participants: Dominique Lavenier, Emeline Roux.

Coordinator: L. Conde-Canencia (UBS, Lab-STCC, IAS)
Duration: 12 months (Feb. 2019 - Feb. 2020)
Partners: UBS (Lab-STCC, IAS, L. Conde-Canencia)

The DNA-Store project is funded by the Labex CominLabs. The goal is to explore the possibility to store information on DNA molecules. As DNA sequencing (the reading process) is performed with the Oxford Nanopore technology, powerful error correcting codes need to be developed together with dedicated genomic data processing.

9.2. National Initiatives

9.2.1. ANR

9.2.1.1. Project HydroGen: Metagenomics applied to ocean life study

Participants: Dominique Lavenier, Pierre Peterlongo, Claire Lemaitre.

Coordinator: P. Peterlongo (Inria/Irisa, GenScale, Rennes)
Duration: 42 months (Nov. 2014 – Apr. 2019)
Partners: CEA (Genoscope, Evry), INRA (AgroParisTech, Paris – MIG, Jouy-en-Jossas).

The HydroGen project aims to design new statistical and computational tools to measure and analyze biodiversity through comparative metagenomic approaches. The support application is the study of ocean biodiversity based on the analysis of seawater samples generated by the Tara Oceans expedition.

9.2.1.2. Project SpeCrep: speciation processes in butterflies

Participants: Dominique Lavenier, Fabrice Legeai, Claire Lemaitre, Pierre Peterlongo.

Coordinator: M. Elias (Museum National d'Histoire Naturelle, Institut de Systématique et d'Evolution de la Biodiversité, Paris)
Duration: 48 months (Jan. 2015 – Jul. 2019)

Partners: MNHN (Paris), INRA (Versailles-Grignon), Genscale Inria/IRISA Rennes.

The SpeCrep project aims at better understanding the speciation processes, in particular by comparing natural replicates from several butterfly species in a suture zone system. GenScale's task is to develop new efficient methods for the assembly of reference genomes and the evaluation of the genetic diversity in several butterfly populations.

9.2.1.3. Project Supergene: The consequences of supergene evolution.

Participants: Anne Guichard, Dominique Lavenier, Fabrice Legeai, Claire Lemaitre, Pierre Peterlongo.

Coordinator: M. Joron (Centre d'Ecologie Fonctionnelle et Evolutive (CEFE) UMR CNRS 5175, Montpellier)
Duration: 48 months (Nov. 2018 – Oct. 2022)
Partners: CEFE (Montpellier), MNHN (Paris), Genscale Inria/IRISA Rennes.

The Supergene project aims at better understanding the contributions of chromosomal rearrangements to adaptive evolution. Using the supergene locus controlling adaptive mimicry in a polymorphic butterfly from the Amazon basin (*H. numata*), the project will investigate the evolution of inversions involved in adaptive polymorphism and their consequences on population biology. GenScale's task is to develop new efficient methods for the detection and genotyping of inversion polymorphism with several types of re-sequencing data.

9.2.1.4. Project SeqDigger: Search engine for genomic sequencing data

Participants: Dominique Lavenier, Claire Lemaitre, Pierre Peterlongo.

Coordinator: P. Peterlongo
Duration: 48 months (jan. 2020 – Dec. 2024)
Partners: Genscale Inria/IRISA Rennes, CEA genoscpoe, MIO Marseille, Institut Pasteur Paris

https://www.cesgo.org/seqdigger/

The central objective of the SeqDigger project is to provide an ultra fast and user-friendly search engine that compares a query sequence, typically a read or a gene (or a small set of such sequences), against the exhaustive set of all available data corresponding to one or several large-scale metagenomic sequencing project(s), such as New York City metagenome, Human Microbiome Projects (HMP or MetaHIT), Tara Oceans project, Airborne Environment, etc. This would be the first ever occurrence of such a comprehensive tool, and would strongly benefit the scientific community, from environmental genomics to biomedicine.

9.2.2. PIA: Programme Investissement d'Avenir

9.2.2.1. RAPSODYN: Optimization of the rapeseed oil content under low nitrogen

Participants: Dominique Lavenier, Claire Lemaitre, Pierre Peterlongo, Gwendal Virlet.

Coordinator: N. Nesi (Inra, IGEPP, Rennes)
Duration: 99 months (2012-2020)
Partners: 5 companies, 9 academic research labs.

The objective of the Rapsodyn project is the optimization of the rapeseed oil content and yield under low nitrogen input. GenScale is involved in the bioinformatics work package to elaborate advanced tools dedicated to polymorphism detection and their application to the rapeseed plant. (http://www.rapsodyn.fr)

9.2.3. Programs from research institutions

9.2.3.1. Inria Project Lab: Neuromarkers

Participants: Dominique Lavenier, Pierre Peterlongo, Claire Lemaitre, Céline Le Beguec, Téo Lemane.

Coordinator: O. Colliot (Inria, Aramis, Paris)
Duration: 4 years (2017-2020)
Partners: Inria (Aramis, Pasteur, Dyliss, GenScale, XPOP), ICM

The Neuromarkers IPL aims to design imaging bio-markers of neuro-degenerative diseases for clinical trials and study of their genetic associations. In this project, GenScale brings its expertise in the genomics field. More precisely, given a case-control population, a first step is to identify small genetic variations (SNPs, small indels) from their genomes. Then, using these variations together with brain images (also partitioned into case-control data sets), the challenge is to select variants that present potential correlation with brain images.

9.3. European Initiatives

9.3.1. Collaborations in European Programs, Except FP7 & H2020

Program: ITN (Initiative Training Network)

Project acronym: IGNITE

Project title: Comparative Genomics of Non-Model Invertebrates

Duration: 48 months (April 2018, March 2022)

Coordinator: Gert Woerheide

Partners: Ludwig-Maximilians-Universität München (Germany), Centro Interdisciplinar de Investigação Marinha e Ambiental (Portugal), European Molecular Biology Laboratory (Germany), Université Libre de Bruxelles (Belgium), University of Bergen (Norway), National University of Ireland Galway (Ireland), University of Bristol (United Kingdom), Heidelberg Institute for Theoretical Studies (Germany), Staatliche Naturwissenschaftliche Sammlungen Bayerns (Germany), INRA Rennes (France), University College London (UK), University of Zagreb (Croatia), Era7 Bioinformatics (Spain), Pensoft Publishers (Bulgaria), Queensland Museum (Australia), Inria, GenScale (France), Institut Pasteur (France), Leibniz Supercomputing Centre of the Bayerische Akademie der Wissenschaften (Germany), Alphabiotoxine (Belgium)

Abstract: Invertebrates, i.e., animals without a backbone, represent 95 per cent of animal diversity on earth but are a surprisingly underexplored reservoir of genetic resources. The content and architecture of their genomes remain poorly characterised, but such knowledge is needed to fully appreciate their evolutionary, ecological and socio-economic importance, as well as to leverage the benefits they can provide to human well-being, for example as a source for novel drugs and biomimetic materials. IGNITE will considerably enhance our knowledge and understanding of animal genome knowledge by generating and analyzing novel data from undersampled invertebrate lineages and by developing innovative new tools for high-quality genome assembly and analysis.

9.3.2. Collaborations with Major European Organizations

Partner : PHC RILA 2019, Bulgaria

Two years France-Bulgaria bilateral Partnership Hubert Curien (PHC) RILA 2019 (project code : 43196Q). The topic of this project is "Integer Programming Approaches for Long-Reads Genome Assembly". Start year: 2019.

9.4. International Initiatives

9.4.1. HipcoGen

Title: High-Performance Combinatorial Optimization for Computational Genomics

International Partner (Institution - Laboratory - Researcher):

> Information Sciences group of Los Alamos National Laboratory (LANL), Los Alamos, NM 87544, USA. coordinator - Hristo Djidjev

Start year: 2017

See also: https://team.inria.fr/genscale/presentation/associated-team/

Genome sequencing and assembly, the determination of the DNA sequences of a genome, is a core experiment in computational biology. During the last decade, the cost of sequencing has decreased dramatically and a huge amount of new genomes have been sequenced. Nevertheless, most of recent genome projects stay unfinished and nowadays the databases contain much more incompletely assembled genomes than whole stable reference genomes. The main reason is that producing a complete genome, or an as-complete-as-possible-genome, is an extremely difficult computational task (an NP-hard problem) and, in spite of the efforts and the progress done by the bioinformatics community, no satisfactory solution is available today. New sequencing technologies (such as PacBio or Oxford Nanopore) are being developed that tend to produce longer DNA sequences and offer new opportunities, but also bring significant new challenges. The goal of this joint project, a cooperation between Los Alamos National Laboratory, US and Inria, is to develop a new methodology and tools based on novel optimization techniques and massive parallelism suited to these emerging technologies and able to tackle the complete assembly of large genomes.

9.4.2. Inria International Partners

9.4.2.1. Informal International Partners

- Free University of Brussels, Belgium: Genome assembly [P. Perterlongo, D. Lavenier]

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Visit of Hristo Djidjev from Los Alamos National Laboratory, USA, June 2019
- Visit of Alla Lapidus and Anto korobeynikov, Center for Algoritmic Biotechnology, St. Petersburg State University, Russia, October 2019

9.5.2. Visits to International Teams

9.5.2.1. Research Stays Abroad

- Visit of R. Andonov at Los Alamos National Laboratory, USA, from March 23 to April 30th, 2019.
- Visit of D. Lavenier at Los Alamos National Laboratory, USA, from May 13th to May 24th, 2019

SERPICO Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Motion saliency analysis in videos

Participants: Léo Maczyta, Patrick Bouthemy.
Duration: 36 months (Oct 2017 – Sep 2020).

See Section 8.1.2.

Funding: DGA (National Defense Agency) and Région-Bretagne.

9.2. National Initiatives

9.2.1. France-BioImaging project

Participants: Sylvain Prigent, Patrick Bouthemy, Charles Kervrann, Jean Salamero.
Duration: 2011 – 2024.

The goal of the France-BioImaging project (http://france-bioimaging.org/) is to build a distributed coordinated French infrastructure for photonic and electronic cellular bioimaging, dedicated to innovation, training and technology transfer. High-computing capacities are needed to exhaustively analyse image flows. SERPICO is co-head of the IPDM (Image Processing and Data Management) node of the FBI network composed of 6 nodes. In this context, we address the following scientific problems: i/ exhaustive analysis of bioimaging data sets; ii/ deciphering of key steps of biological mechanisms at organ, tissular, cellular and molecular levels through the systematic use of time-lapse 3D microscopy and image processing methods; iii/ storage and indexing of extracted and associated data and metadata through an intelligent data management system. SERPICO recruited R&D engineers to disseminate image processing software, to build the Mobyle@serpico web portal and to manage the IGRIDA-SERPICO cluster (200 nodes; batch scheduler: OAR; File management: Puppet/Git/Capistrano; OS: Linux Debian 7; User connexion: public ssh key) opened for end-users and dedicated to large scale computing and data sets processing (storage: 200 TeraBytes) (see Section 6.13).

Funding: Investissement d'Avenir, ANR INBS-PIA 2011.
Coordinator: CNRS (J. Salamero, UMS 3714 CEMIBIO & CNRS-UMR 144, Institut Curie, PSL Research University).
Partners: CNRS, University of Paris-Diderot-Paris 7, Aix-Marseille University, University of Bordeaux, University of Montpellier, Institut Pasteur, Institut Curie, Inria, ENS Paris, University of Paris Descartes, UPMC, Ecole Polytechnique, INSERM.

9.2.2. ANR NucleoPLASTIC: Plasticity of the Nuclear Pore Complex

Participant: Jean Salamero.
Duration: 48 months (Oct 2015 – Sep 2019).

In this project, we have deciphered molecular/structural changes on the nuclear face of the Nuclear Pore Complex, their dynamics during cell division, and highlighted their role in the dynamics of association with the heart of the pore with consequences on maintaining the integrity of the genome. This was possible through the development of a 3D localization software GenLoc3D (https://team.inria.fr/serpico/software/genloc3d/, FIJI/ImageJ plug-in).

Funding: ANR (Agence Nationale de la Recherche).
Coordinator: C. Dargemont (INSERM, Hopital St Louis, Paris).
Partners: CNRS-UMR 144, Institut Curie, PSL Research, Paris.

9.2.3. ANR DALLISH project: Data Assimilation and Lattice LIght SHeet imaging for endocytosis/exocytosis pathway modeling in the whole cell

Participants: Antoine Salomon, Anca-Georgiana Caranfil, Sandeep Manandhar, Cesar Augusto Valades Cruz, Patrick Bouthemy, Ludovic Leconte, Jean Salamero, Charles Kervrann.
Duration: 48 months (Oct 2016 – Sep 2020).

Cutting-edge Light Lattice Sheet microscopy represents the novel generation of 3D fluorescence microscopes dedicated to single cell analysis, generating extraordinarily high resolved and sharp, but huge 3D images and videos. One single live cell experiment in one single biological condition can result into up to one terabyte of data.The goal of the project is to develop new paradigms and computational strategies for image reconstruction and 3D molecule motion estimation and tracking. Furthermore, establishing correspondences between image-based measurements and features, stochastic motion models, and underlying biological and biophysical information remains a challenging task. In a larger perspective, the quantitative description of image data corresponding to protein transport will be a prerequisite for understanding the functioning of a cell in normal and pathological situations including cancer, viral infection and neurodegenerative diseases (see Sections 7.2–7.6 and 7.8).

Funding: ANR (Agence Nationale de la Recherche) PRC (Collaborative Research Project).
Coordinator: C. Kervrann.
Partners: Inria (SERPICO, BEAGLE, FLUMINANCE teams), INRA MaIAGE Unit Jouy-en-Josas, Institut Curie (CNRS-UMR 144 & U1143 INSERM / UMR 3666) Paris.

9.2.4. Inria Project Labs (IPL / DEFI), Exploratory Research Actions and Technological Development Actions

9.2.4.1. NAVISCOPE: image-guided NAvigation and VISualization of large data sets in live cell imaging and microCOPy

Participants: Gwendal Fouché, Cesar Augusto Valades Cruz, Ludovic Leconte, Anais Badoual, Jean Salamero, Charles Kervrann.
Duration: 60 months (2018 – 2022).

In the frame of the "Naviscope" IPL project (https://project.inria.fr/naviscope/), our objective is to develop original and cutting-edge visualization and navigation methods to assist scientists, enabling semi-automatic analysis, manipulation, and investigation of temporal series of multi-valued volumetric images, with a strong focus on live cell imaging and microscopy application domains. Naviscope, built upon the strength of scientific visualization and machine learning methods, will provide systems capable to assist the scientist to obtain a better understanding of massive amounts of information. Such systems will be able to recognize and highlight the most informative regions of the dataset by reducing the amount of information displayed and guiding the observer attention. We address the three following challenges and issues:

- Novel machine learning methods able to detect the main regions of interest, and automatic quantification of sparse sets of molecular interactions and cell processes during navigation to save memory and computational resources.
- Novel visualization methods able to encode 3D motion and deformation vectors and dynamics features with color and texture-based and non-sub-resolved representations, abstractions, and discretization, as used to display 2D motion and deformation vectors and patterns.
- Effective machine learning-driven navigation and interaction techniques for complex functional 3D+Time data enabling the analysis of sparse sets of localized intra-cellular events and cell processes (migration, division, etc.) (see Section 7.9).

Meanwhile, we address the technological challenge of gathering up the software developed in each team to provide a unique original tool for users in biological imaging, and potentially in medical imaging.

Funding: Inria (IPL / DEFI).
Coordinator: C. Kervrann.
Partners: AVIZ Inria team (Saclay); BEAGLE Inria team (Lyon), HYBRID Inria team (Rennes), MORPHEME Inria team (Sophia-Antipolis); MOSAIC Inria team (Lyon), PARIETAL Inria team (Saclay), SERPICO Inria team (Rennes); MaIAGE INRA Unit (Jouy-en-Josas); CNRS-UMR 144, Institut Curie, PSL Research University (Paris).

9.3. European Initiatives

9.3.1. Collaborations in European Programs, Except FP7 & H2020

9.3.1.1. ESFRI initiative programm

SERPICO is involved in the ESFRI Euro-BioImaging (https://www.eurobioimaging.eu/) initiative, one of the four new biomedical science projects in the roadmap of the European Strategic Forum on Research Infrastructures (ESFRI). The mission of Euro-BioImaging is to provide access, service and training to state-of-the-art imaging technologies and foster the cooperation and networking at the national and European level including multidisciplinary scientists, industry, regional, national and European authorities. SERPICO is also involved in the French initiative, the so-called "France-BioImaging" (FBI) network which gathers several outstanding cellular imaging centers (microscopy, spectroscopy, probe engineering and signal processing) as described in Section 9.2.1 .

Coordinator: Turku University (J. Eriksson, Turku, Finland).
Funding: Member states of the European Union.
Partners: 15 European countries.

9.3.1.2. EIT Digital program
Participants: Sylvain Prigent, Charles Kervrann.
Duration: 12 months (Nov 2019 – Oct 2020).

SERPICO is involved in a European project which aims at developing a connected wearable device for diagnosis and treatment of photodermatoses. Using the data on skin sun sensitivity and UV exposure habits with machine learning algorithms will enable to make more precise optimal sun exposure predictions for patients. The wearable device will be useful for a larger population to increase awareness around overexposure to UV as a main cause of sun damage and worst-case skin cancer.

Funding: EIT Digital.
Inria coordinator: C. Kervrann.
Partners: UVisio and Nobleo Projects B.V., Eindhoven, The Netherlands.

9.4. International Initiatives

9.4.1. Inria International Partners

9.4.1.1. Informal International Partners

- Collaboration with Max-Planck Institute, Martinsried, Germany (with A. Martinez and W. Baumeister): Detection and segmentation of macromolecules in cryo-electron tomography (project in progress with E. Moebel and C. Kervrann) (see Sections 6.9 [30] and 6.12 [22]).
- Collaboration with University of Texas SouthWestern (UTSW) Medical Center, Dallas, United States (P. Roudot, E. Welf and G. Gaudenz): 3D optical flow for cell migration quantification (project in progress with S. Manandhar, P. Bouthemy and C. Kervrann) (see Sections 6.11 and 7.4 [21]).
- Collaborations with the MRC laboratory of Molecular Biology (with E. Derivery and J. Boulanger) and the Cambridge Advanced Imaging Centre (with L. Muresan), Cambridge, UK (project in progress with A. Salomon and C. Kervrann) (see Section 7.2).
- Collaboration with the PKU University, Institute of Molecular Medicine, Beijing (with L. Chen and Y.M. Liu): 3D reconstitution of the biogenesis of Endoplasmic Reticulum-plasma membrane contact sites (ER-PM MSCs upon Ca2+ store depletion or replenishment) (project in progress with C.A. Valades Cruz and J. Salamero).

9.5. International Research Visitors

9.5.1. Visits to International Teams

- Charles Kervrann visited the MRC laboratory of Molecular Biology and the Cambridge Advanced Imaging Centre (June, 1 week, Cambridge, UK).

DIONYSOS Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

- Yann Busnel is a member of the ONCOSHARe project (ONCOlogy bigdata SHARing for Research) funded by Brittany and Pays de la Loire regions, with 280.000 k€ for 24 months.
- Bruno Sericola continues to work on the analysis of fluid queues with Fabrice Guillemin from Orange Labs in Lannion, France.

9.2. National Initiatives

ANR

- Yassine Hadjadj-Aoul, Sofiene Jelassi and Gerardo Rubino are participating at 20% of their time to the IRT BCOM granted by the ANR.
- Yann Busnel is a member of the two following projects: INSHARE granted by the ANR (ANR-15-CE19-0024) and BigClin granted by the LabEx CominLabs (ANR-10-LABX-07-01).

IPL (Inria Project Lab) BetterNet

Yassine Hadjadj-Aoul, Gerardo Rubino and Bruno Tuffin are members of the IPL (Inria Project Lab) BetterNet: An Observatory to Measure and Improve Internet Service Access from User Experience, 2016-2020.

BetterNet aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks. Our observatory can be defined as a vantage point, where: 1) tools, models and algorithms/heuristics will be provided to collect data, 2) acquired data will be analyzed, and shared appropriately with scientists, stakeholders and civil society, and 3) new value-added services will be proposed to end-users.

Inria Exploratory Action SNIDE We are leading of the Inria Exploratory Action SNIDE (Search Non neutratlIty DEtection) 2019-2023, involving Dionysos and MIMR (Grenoble).

Search engines play a key role to access content and are accused to bias their results to favor their own services among others. This has led to the sensitive search neutrality debate, similar to the network neutrality debate currently discussed on the role of ISPs. Our goal in this project is to develop and apply a methodology aiming at highlighting a bias and quantifying its impact.

An initial version of our meta-engine (which will be further develop by incorporating outlier detection tests) can be found at https://snide.irisa.fr/.

9.3. European Initiatives

- Bruno Sericola continues to work on the analysis of fluid queues with Marie-Ange Remiche from the university of Namur in Belgium.
- Gerardo Rubino has a long collaboration with Sebastián Basterrech at the VSB-Technical University of Ostrava, Czech Republic, on Machine Learning.

9.4. International Initiatives

9.4.1. Inria International Partners

9.4.1.1. Informal International Partners

We keep a long collaboration in research with the CalPoly at Pomona, USA, on the transient analysis of Markovian models.

9.4.2. Participation in Other International Programs

9.4.2.1. Ecos Sud program

Project "Masc"

Title: Mathematical Algorithms for Semantic Cognition

International Partner (Institution - Laboratory - Researcher):

Universidad de la República (Uruguay) - Biophysics - Eduardo Mizraji, Jorge Graneri

Universidad de la República (Uruguay) - Computer science - Pablo Rodríguez-Bocca

Duration: 2018 – 2020

Start year: 2018

MASC is a three-year project (code U17E03) with the Faculty of Sciences of the university of the Republic, in Uruguay, on the application of mathematical modeling tools to a better understanding of a cognitive disease called semantic dementia. This involves Prof. Eduardo Mizraji and Jorge Graneri, a PhD student whose co-advisors are Prof. Mizraji and G. Rubino from Dionysos, plus Pablo Rodríguez Bocca, from the Engineering Faculty of the university of the Republic. Our contribution to this project is around the use of mathematical tools applied to the analysis of cognition pathologies.

9.4.2.2. Math and Stic AmSud programs

Project "RareDep"

Title: Rare events analysis in multi-component systems with dependent components

International Partner (Institution - Laboratory - Researcher):

Universidad Adolfo Ibañez (Chile) - Faculty of Engineering and Sciences - Javiera Barrera

Universidad de la República Uruguay (Uruguay) - Computer Science - Héctor Cancela

Universidade Federal de Pernambuco (Brazil) - Mathematics - Pablo Martín Rodríguez

Duration: 2019 – 2020

Start year: 2019

See also: http://mansci-web.uai.cl/raredep/RareDep/Welcome.html

The RareDep project focus on developing new techniques addressing two central elements for the improvement of the available tools for risk analysis of complex systems. One is the case of rare events, occurring both in performance and in dependability evaluation of systems modeled as made of many components. Rare events preclude the use of Monte Carlo techniques when the event of interest has a small probability of occurring, and specific methods are necessary, with many open problems in the area. Independence is the usual assumption when building models (more precisely, in almost all works in the field make this assumption), but we know that the assumption is almost never satisfied. We often are constrained by the necessity of assuming independent components in order to be able to use the available methods. In RareDep, we intend to address both problems simultaneously. This needs to develop new variance reduction techniques, for instance in the Importance Sampling family, or in the Splitting one, to be able to exploit data concerning dependencies between the components of the models. This will be built on top of our accumulated experience in the Monte Carlo area (and related fields, such as Quasi-Monte Carlo, numerical integration, etc.), and a starting effort to begin the exploration of what happens when we relax the omnipresent independence hypothesis. We will also explore what happens if we consider new ideas (several coming from the participants of the proposal) for defining new metrics in some specific areas. In these cases, everything is to be done: procedures to deal with rare events, modeling techniques to deal with dependencies between the system's components, and then, both issues at the same time. Our main application area will concern different types of modern networks (in communications, or in energy distribution, for instance).

Project "ACCON"

Title: Algorithms for the Capacity Crunch problem in Optical Networks

International Partner (Institution - Laboratory - Researcher):

Universidad de la República Uruguay (Uruguay) - Computer Science - Héctor Cancela

UTFSM (Chile) - Télématica - Reinaldo Vallejos

Universidad de Valparaiso (Chile) - Computer Science - Marta Barría

Duration: 2019 – 2020

Start year: 2019

See also: http://accon.elo.usm.cl/

The rapid increase in demand for bandwidth from existing networks has caused a growth in the use of telecommunications technologies, especially WDM optical networks. So far, communication technologies have been able to meet the bandwidth demand. Nevertheless, this decade researchers have anticipated a coming "Capacity Crunch" potential problem associated with these networks. It refers to fact that the transmission capacity limit on optical fibers is close to be reached in the near future. It is then urgent to make the current network architectures evolve, in order to satisfy the relentless exponential growth in bandwidth demand. In other words, the performance bottleneck for optical infrastructures is concentrated around this limiting situation, and the most efficient way of preparing the future of these fundamental technological systems that support the backbone of the Internet is to focus on solving the related management problems. In the previously described scientific context, the ACCON project has a main scientific goal: the development of new strategies capable to provide better resource management techniques to face the threat of the Capacity Crunch. To this end, we will explore the utilization of different analytical techniques to evaluate the performance of several network architecture paradigms, in order to assess their viability in the near future. This will provide us the needed insight leading to finding new strategies for efficiently managing the network resources, and consequently, to contribute addressing this coming Capacity Crunch problem.

9.4.2.3. PHC Ulysses

Project "AFFINE"

Title: Achieving Energy Efficient Communication in Future Networks by Supporting Multi-Access Edge Computing in Internet of Things (IoT)

International Partners (Institution - Laboratory - Researcher):

University College Dublin (Ireland) - Computer Science - Lina Xu

Duration: 1 year

Start year: January 2019

Yassine Hadjadj-Aoul and Lina Xu received a grant from the PHC Ulysses (for French-Irish collaboration). The aim of this project is to improve the energy efficiency for data transmission and communication in IoT networks and therefore to reduce electricity consumption and CO_2 emissions.

Yann Busnel has taken part in several events to develop Indo-French collaborations, notably within the framework of Campus France. In particular, he led the round table on Artificial Intelligence and Mathematics at the Knowledge Summit 2 in Lyon in October 2019, in the presence of the Minister, Frédérique Vidal.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

We have received the following international scientists:

- M. Nakayama (New Jersey Institute of Technology, USA): one week in July 2019.
- DanHua ShangGuan (Institute of Applied Physics and Computational Mathematics, Beijing, China), one month in September 2019.
- Vamsi Bulusu from VJTI Mumbai visited us for 4 months between August and Novembre 2019.
- Jorge Graneri (Sep.–Oct.) and Eduardo Mizraji (Sep.), UDELAR, Uruguay, in the context of the MASC project.
- Nicolás Jara, UTFSM, Chile, Dec., in the context of the ACCON project.
- Franco Robledo, UDELAR, Uruguay, in Feb.

DIVERSE Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. PEC – Pôle d'Excellence Cyber

- Coordinator: Université de Rennes 1
- Dates: 2016-2019
- Abstract: Formal and Executable Specification of domain-specific language families.

8.2. National Initiatives

8.2.1. ANR

8.2.1.1. VaryVary ANR JCJC

- Coordinator: Mathieu Acher
- DiverSE, Inria/IRISA Rennes
- Dates: 2017-2021
- Abstract: Most modern software systems (operating systems like Linux, Web browsers like Firefox or Chrome, video encoders like x264 or ffmpeg, servers, mobile applications, etc.) are subject to variation or come in many variants. Hundreds of configuration options, features, or plugins can be combined, each potentially with distinct functionality and effects on execution time, memory footprint, etc. Among configurations, some of them are chosen and do not compile, crash at run time, do not pass a test suite, or do not reach a certain performance quality (e.g., energy consumption, security). In this JCJC ANR project, we follow a thought-provocative and unexplored direction: We consider that the variability boundary of a software system can be specialized and should vary when needs be. The goal of this project is to provide theories, methods and techniques to make vary variability. Specifically, we consider machine learning and software engineering techniques for narrowing the space of possible configurations to a good approximation of those satisfying the needs of users. Based on an oracle (e.g., a runtime test) that tells us whether a given configuration meets the requirements (e.g., speed or memory footprint), we leverage machine learning to retrofit the acquired constraints into a variability that can be used to automatically specialize the configurable system. Based on a relative small number of configuration samples, we expect to reach high accuracy for many different kinds of oracles and subject systems. Our preliminary experiments suggest that varying variability can be practically useful and effective. However, much more work is needed to investigate sampling, testing, and learning techniques within a variety of cases and application scenarios. We plan to further collect large experimental data and apply our techniques on popular, open-source, configurable software (like Linux, Firefox, ffmpeg, VLC, Apache or JHipster) and generators for media content (like videos, models for 3D printing, or technical papers written in LaTeX).

8.2.2. DGA

8.2.2.1. LangComponent (CYBERDEFENSE)

- Coordinator: DGA
- Partners: DGA MI, Inria
- Dates: 2019-2022

- Abstract: in the context of this project, DGA-MI and the Inria team DiverSE explore the existing approaches to ease the development of formal specifications of domain-Specific Languages (DSLs) dedicated to paquet filtering, while guaranteeing expressiveness, precision and safety. In the long term, this work is part of the trend to provide to DGA-MI and its partners a tooling to design and develop formal DSLs which ease the use while ensuring a high level of reasoning.

8.2.3. Cominlabs

8.2.3.1. PROFILE

- Coordinator: Université de Rennes 1
- Partners: Inria, Université de Rennes 2
- Dates: 2016-2019
- Abstract: The PROFILE project brings together experts from law, computer science and sociology to address the challenges raised by online profiling, following a multidisciplinary approach. More precisely, the project will pursue two complementary and mutually informed lines of research: (i) Investigate, design, and introduce a new right of opposition into the legal framework of data protection to better regulate profiling and to modify the behavior of commercial companies towards being more respectful of the privacy of their users; (ii) Provide users with the technical means they need to detect stealthy profiling techniques as well as to control the extent of the digital traces they routinely produce. As a case study, we focus on browser fingerprinting, a new profiling technique for targeted advertisement. The project will develop a generic framework to reason on the data collected by profiling algorithms, to uncover their inner workings, and make them more accountable to users. PROFILE will also propose an innovative protection to mitigate browser fingerprinting, based on the collaborative reconfiguration of browsers.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

8.3.1.1. H2020 ICT-10-2016 STAMP

- Coordinator: Inria Rennes
- Other partners: ATOS, ActiveEon, OW2, TellU, Engineering, XWiki, TU Delft, SINTEF
- Dates: 2016-2019
- Abstract: Leveraging advanced research in automatic test generation, STAMP aims at pushing automation in DevOps one step further through innovative methods of test amplification. It reuse existing assets (test cases, API descriptions, dependency models), in order to generate more test cases and test configurations each time the application is updated. Acting at all steps of development cycle, STAMP techniques aim at reducing the number and cost of regression bugs at unit level, configuration level and production stage.

  STAMP raises confidence and foster adoption of DevOps by the European IT industry. The project gathers 3 academic partners with strong software testing expertise, 5 software companies (in: e-Health, Content Management, Smart Cities and Public Administration), and an open source consortium. This industry-near research addresses concrete, business-oriented objectives. All solutions are open source and developed as microservices to facilitate exploitation, with a target at TRL 6.

8.3.2. Collaborations with Major European Organizations

SINTEF, ICT (Norway): Model-driven systems development for the construction of distributed, heterogeneous applications. We collaborate since 2008 and are currently in two FP7 projects together.

Université du Luxembourg, (Luxembourg): Models runtime for dynamic adaptation and multi-objective elasticity in cloud management; model-driven development.

KTH, the Royal Institute of Technology (Sweden): continuous software testing, perturbation and diversification.

McGill University (Canada): language reuse, model composition, and models for sustainability.

CWI (The Netherlands): language engineering.

JKU Linz (Austria): model analysis and Model-Based DevOps.

RWTH Aachen (Germany): models for industry 4.0

8.4. International Initiatives

8.4.1. Inria International Labs

IIL CWI-Inria

Associate Team involved in the International Lab:

8.4.1.1. ALE

- Title: Agile Language Engineering
- International Partner (Institution - Laboratory - Researcher):
  - CWI (Netherlands) Tijs van der Storm
- Start year: 2017
- See also: http://gemoc.org/ale/
- Software engineering faces new challenges with the advent of modern software-intensive systems such as complex critical embedded systems, cyber-physical systems and the Internet of things. Application domains range from robotics, transportation systems, defense to home automation, smart cities, and energy management, among others. Software is more and more pervasive, integrated into large and distributed systems, and dynamically adaptable in response to a complex and open environment. As a major consequence, the engineering of such systems involves multiple stakeholders, each with some form of domain-specific knowledge, and with an increasingly use of software as an integration layer.

  Hence more and more organizations are adopting Domain Specific Languages (DSLs) to allow domain experts to express solutions directly in terms of relevant domain concepts. This new trend raises new challenges about designing DSLs, evolving a set of DSLs and coordinating the use of multiple DSLs for both DSL designers and DSL users.

  ALE will contribute to the field of Software Language Engineering, aiming to provide more agility to both language designers and language users. The main objective is twofold. First, we aim to help language designers to leverage previous DSL implementation efforts by reusing and combining existing language modules. Second, we aim to provide more flexibility to language users by ensuring interoperability between different DSLs and offering live feedback about how the model or program behaves while it is being edited (aka. live programming/modeling).

8.4.2. Inria International Partners

8.4.2.1. Informal International Partners

- Université de Montréal (Canada)
- McGill University (Canada)
- University of Alabama (USA)
- University of Lancaster (UK)
- University of Namur (Belgium)
- Universita degli Studi di Cagliari (Italy)
- Università degli Studi dell'Aquila (Italy)

- JKU Linz (Austria)
- TU Wien (Austria)
- Michigan State University (MSU)
- RWTH Aachen University (Germany)
- KTH (Sweden)

8.4.3. Participation in Other International Programs

The GEMOC studio has been sustained through the creation of a Research Consortium at the Eclipse Foundation.

8.4.3.1. International initiative GEMOC

The GEMOC initiative (cf. http://www.gemoc.org) is an open and international initiative launched in 2013 that coordinate research partners worldwide to develop breakthrough software language engineering (SLE) approaches that support global software engineering through the use of multiple domain-specific languages. GEMOC members aim to provide effective SLE solutions to problems associated with the design and implementation of collaborative, interoperable and composable modeling languages.

The GEMOC initiative aims to provide a framework that facilitates collaborative work on the challenges of using of multiple domain-specific languages in software development projects. The framework consists of mechanisms for coordinating the work of members, and for disseminating research results and other related information on GEMOC activities. The framework also provides the required infrastructure for sharing artifacts produced by members, including publications, case studies, and tools.

The governance of the GEMOC initiative is provided by the Advisory Board. The role of the Advisory Board is to coordinate the GEMOC work and to ensure proper dissemination of work products and information about GEMOC events (e.g., meetings, workshops).

Benoit Combemale is a GEMOC co-founder and currently acts as principal coordinator of the GEMOC initiative. Benoit Combemale and Jean-Marc Jézéquel are part of the Advisory Board, and 9 DIVERSE members are part of the GEMOC initiative.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Yves Le Traon, Professor at the University of Luxembourg, visited the team in June, July and October 2019.
- Nelly Bencomo, Lecturer in Computer Science Aston University, UK, visited the team from October 2019 to June 2020.
- Martin Montperrus, Professor at KTH, Sweden, visited the team in December 2019.
- Nicolas Harrand, PhD Student at KTH, Sweden, visited the team in December 2019.
- Paul Temple, postdoc at University de Namur, visited the team in February 2019.
- Thomas Degueule, postdoc at CWI, visited the team in December 2019
- Alfonso Pierantonio, Associate Professor at Università degli Studi dell'Aquila, visited the team in June 2019
- Mark van den Brand, Professor at Eindhoven University of Technology, visited the team in June 2019

8.5.2. Visits to International Teams

- Pierre JeanJean visited CWI for 1 week in December 2019 in the context of the Associated Team ALE.
- Benoit Combemale made several short visits at CWI in the context of the Associated Team ALE, visited McGill University in June 2019, and visited TU Eindhoven in November 2019.
- Olivier Barais made several short visits at KTH in the context of a collaboration with Prof Monperrus and Prof Baudry.
- Djamel E. Khelladi made a one week research visit in December 2019 to the DIRO laboratory at University of Montreal, Canada.

EASE Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

Chantier 3.0

Coordinator: JM. Bonnin

Starting: Jan 2019; Ending : Dec 2021

Partners: Agemos, YoGoKo, IMT Atlantique

Abstract: Co-founded by "Région Bretagne" Chantier 3.0 is a "PME Project" aiming at increasing safety of workers in construction sites and road works. In these scenarios, vehicles represent a danger for the workers. Knowing the position of the vehicles and workers, it is possible to alert workers who are located in a safety perimeter around the vehicles. The project addresses the challenges of 1) precise localisation with low or medium cost wearable devices and 2) of dynamically setting up a reliable communication network in harsh environments mixing indoor and outdoor conditions. The key technologies used to solve theses issues include: fusion of localisation data (GPS, acceleration integration, location anchors, angle of arrival and time of flight of radio signals), opportunistic short range broadcast communications, ITS communication protocols and system integration. EASE brings it expertise in all of theses domains in order to enhance the reliability of the system, to make it affordable and to pave the way for its standardisation.

8.2. National Initiatives

SCOOP@F part 2

Coordinator: JM. Bonnin

Starting: Jan 2016; Ending: Dec 2019

Partners: MEDE, Renault, PSA, IMT Atlantique

Abstract: SCOOP@F is a Cooperative ITS pilot deployment project that intends to connect approximately 3000 vehicles with 2000 kilometers of roads. It consists of 5 specific sites with different types of roads: Ile-de-France, "East Corridor" between Paris and Strasbourg, Brittany, Bordeaux and Isère. SCOOP@F is composed of SCOOP@F Part 1 from 2014 to 2015 and SCOOP@F Part 2 from 2016 to 2019. Its main objective is to improve the safety of road transport and of road operating staff during road works or maintenance. The project includes the validations of Cooperative ITS services in open roads, cross border tests with other EU Member States (Spain, Portugal and Austria) and development of a hybrid communication solution (3G-4G/ITS G5). We are involved in the project to study the security and privacy properties of the hybrid architecture that allow to use non dedicated communication networks (WiFi, 5G) as well as the vehicular dedicated communication technologies (G5). The second phase of SCOOP will end up in 2019. As a partner of the InDiD consortium, we proposed a follow up for this project to the EC for the period 2020-2023.

InDiD

Coordinator: JM. Bonnin

Starting: mid 2019; Ending: Dec 2023

Partners: 20+ French partners including cities (Paris, Grenoble...), road operators, transport operators, academics (incl. IMT Atlantique) and industrials

Abstract: InDiD is one of 13 French projects out of 148 European projects selected by the European Commission within the framework of the last Connecting Europe Facility (CEF) call for proposals. The project benefits from a co-funding rate of 50% on behalf of the European Union. It follows the Smart Cooperative Transport Systems projects SCOOP@F, C-ROADS France and InterCor. The project aims at expanding the coverage of use cases deployed in previous projects (emergency braking, accident, work...) and develop new use cases dealing with urban area, but also use cases of increased perception for autonomous vehicle. In addition, it deals with high definition digital mapping of the infrastructure. Connectivity along with mapping shape the digital infrastructure of tomorrow, an essential addition to the physical infrastructure. InDiD aims at continuing the deployment of Cooperatives Intelligent Transport Systems on new road experimentation sites in order to expand the services coverage offered by the infrastructure. Pilot sites are located on 4 main French geographic areas, on the Mediterranean side, in the south-west area, at the centre and in the north of France.

TAGRI

Coordinator: P. Couderc

Starting: Nov 2019; Ending: Nov 2020

Abstract: Tagri is a 12 months innovation action supported by a CominLabs grant, started on 2019-11-01 and ending on October 2020. It follows up the previous Pervasive_RFID project, a joint Inria - IETR collaboration. Tagri aims at developing an operational UHF RFID solution for agricultural applications where tags are used as a pervasive storage to track important data related to the production. Tagri is using the RFID research facility from Pervasive_RFID project to study the behavior and performance level of UHF RFID in the context of agricultural applications, which is new as the the standard RFID technology used in farming is LF based: historically, LF was selected because it was reliable for bio-tags attached to animal, and the driver application for RFID in smart farming was breeding. A new research engineer, Alexis Girard, has integrated the team in November 2019 on this project.

8.3. International Research Visitors

8.3.1. Informal International Partners

Three years ago we initiated a collaboration with Valerie Gay and Christopher Lawrence (UTS / Australia) on adapting smart spaces for eHealth applications. We continued the collaboration and Jean-Marie Bonnin visited UTS last August. He participated in the definition of research IoT infrastructure for a new maternity clinic dedicated to aboriginal community. The goal was to design an efficient research infrastructure to study how pervasive technologies could be used to adapt the environment to the people. To prepare this visit, Christopher Lawrence came in France and visit the team in March 2019.

8.3.2. Visits of International Scientists

Christopher Lawrence, Associate Professor, University of Technology Sydney, visited the team in March/April 2019.

KERDATA Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

8.1.1.1. OverFlow (2015–2019)

Participants: Alexandru Costan, Pedro de Souza Bento Da Silva, Paul Le Noac'h.

Project Acronym: OverFlow

Project Title: Workflow Data Management as a Service for Multisite Applications

Coordinator: Alexandru Costan

Duration: October 2015–October 2019

Other Partners: None (Young Researcher Project, JCJC)

External collaborators: Kate Keahey (University of Chicago and Argonne National Laboratory), Bogdan Nicolae (Argonne National Lab)

Web site: https://sites.google.com/view/anroverflow

This project investigates approaches to data management enabling an efficient execution of geographically distributed workflows running on multi-site clouds.

In 2019, we focused on the challenges of stream processing at the Edge. In particular, Edge computing presents a significant opportunity to realize the potential of distributed ML models with regards to low latency, high availability and privacy. It allows for instance inferences on simple image, video or audio classification; as only the final result is transmitted, delays are minimized, while privacy and bandwidth are preserved in IoT applications. Also, neural networks could be partitioned such that some layers are evaluated at the Edge and the rest in the cloud.

In this context we proposed an architecture in which the initial layers can be used for feature-abstraction functions: as data travels through the neural network, they abstract into high-level features, which are more lightweight, helping reduce latency.

8.1.2. Other National Projects

8.1.2.1. HPC-Big Data Inria Project Lab (IPL)

Participants: Gabriel Antoniu, Alexandru Costan, Daniel Rosendo, Pedro de Souza Bento Da Silva.

Project Acronym: HPC-BigData

Project Title: The HPC-BigData Inria Project Lab

Coordinator: Bruno Raffin

Duration: 2018–2022

Web site: https://project.inria.fr/hpcbigdata/

The goal of this HPC-BigData IPL is to gather teams from the HPC, Big Data and Machine Learning (ML) areas to work at the intersection between these domains. Research is organized along three main axes: high performance analytics for scientific computing applications, high performance analytics for big data applications, infrastructure and resource management. Gabriel Antoniu is a member of the Advisory Board and leader of the Frameworks work package.

In 2019, Daniel Rosendo, who was hired in the context of this IPL project, focused on assessing the state of the art in high performance analytics on hybrid HPC/Big Data infrastructure. In particular, a new path for future work was identified: running Machine Learning algorithm at the Edge.

8.1.2.2. ADT Damaris 2

Participants: Ovidiu-Cristian Marcu, Gabriel Antoniu, Luc Bougé.

Project Acronym: ADT Damaris
Project Title: Technology development action for the Damaris environment
Coordinator: Gabriel Antoniu
Duration: 2019–2021
Web site: https://project.inria.fr/damaris/

This action aims to support the development of the Damaris software. Inria's *Technological Development Office* (D2T, *Direction du Développement Technologique*) provided 2 years of funding support for a senior engineer.

Ovidiu Marcu has been funded through this project to document, test and extend the Damaris software and make it a safely distributable product. In 2019, the main goal was to add Big Data analytics support in Damaris. We have extended Damaris with a streaming interface for writing and analyzing in real-time simulation data through KerA, a distributed streaming storage system.

KerA is further coupled with RAMCloud for in-memory key-value transactions and with Apache Flink for streaming analytics in an architecture that leverages Apache Arrow as in-memory columnar data representation for co-located streaming. This hybrid HPC-Big Data architecture is subject to further exploration within the ZettaFlow.io startup.

8.1.2.3. Grid'5000

We are members of Grid'5000 community and run experiments on the Grid'5000 platform on a daily basis.

8.2. European Initiatives

8.2.1. Collaborations in European Programs, Except FP7 & H2020

8.2.1.1. ZettaFlow: Unified Fast Data Storage and Analytics Platform for IoT

Program: EIT Digital Innovation Factory
Project acronym: ZettaFlow
Project title: ZettaFlow: Unified Fast Data Storage and Analytics Platform for IoT
Duration: October 2019–December 2020
Technical Coordinator: Ovidiu Marcu
Other partners: Technische Universität Berlin and System@tic
Web site: https://zettaflow.io/

The objective of this project is to create a startup in order to commercialize the ZettaFlow platform: a dynamic, unified and auto-balanced real-time storage and analytics industrial IoT platform. ZettaFlow is based on KerA, a streaming storage system prototype developed within the KerData team. ZettaFlow will provide real-time visibility into machines, assets and factory operations and will automate data driven decisions for high-performance industrial processes.

8.2.1.2. FlexStream: Automatic Elasticity for Stream-based Applications

Program: PHC PROCOPE 2020
Project acronym: FlexStream
Project title: Automatic Elasticity for Stream-based Applications
Duration: January 2020–December 2021
Coordinator: Alexandru Costan
Other partners: University of Dusseldorf (UDUS)

Elasticity is one of the key features of cloud computing providing virtual resources as needed according to dynamically changing workloads. This allows to minimize costs and reduce time-to-decision of IoT edge-cloud applications. However, while the underlying resources may easily be scaled many applications and services are not designed to support elastic scalability or require an administrator to manually control elastic scaling.

This project aims at developing concepts providing automatic scaling for stream processing applications. In particular, FlexStream aims at developing and evaluating a prototype which will integrate a stream ingestion-system from IRISA and an in-memory storage from UDUS. For this approach a tight cooperation is mandatory in order to be successful which in turn requires visits on both sides and longer exchanges, especially for the involved PhD students, in order to allow an efficient integrated software design, development as well as joint experiments on large platforms and preparing joint publications.

8.2.2. Collaborations with Major European Organizations

8.2.2.1. BDVA and ETP4HPC

Gabriel Antoniu (as a working group leader) and Alexandru Costan (as a working group member) contributed to the new Strategic Research Agenda (version 4) of European Technology Platform in the area of High-Performance Computing (ETP4HPC).

Gabriel Antoniu and Alexandru Costan are serving as Inria representatives in the working group dedicated to *HPC-Big Data* convergence within the Big Data Value Association (BDVA).

8.2.2.2. International Initiatives

8.2.2.2.1. BDEC: Big Data and Extreme Computing

Since 2015, Gabriel Antoniu has been invited to participate to the yearly workshops of the international Big Data and Extreme-scale Computing (BDEC) working group focused on the convergence of Extreme Computing (the latest incarnation of High-Performance Computing - HPC) and Big Data. BDEC is organized as series of invitation-based international workshops.

In 2019 Gabriel Antoniu was invited again to contribute to the second and third workshops of the BDEC2 series, where he presented two white papers on HPC-Big Data convergence at the level of data processing.

8.3. International Initiatives

8.3.1. Inria International Labs

8.3.1.1. UNIFY: An associated team involved in the JLESC international lab

Title: UNIFY: Intelligent Unified Data Services for Hybrid Workflows Combining Compute-Intensive Simulations and Data-Intensive Analytics at Extreme Scales

Inria International Lab: JLESC: Joint Laboratory for Extreme Scale Computing

International Partner: Argonne National Laboratory (USA) — Department of Mathematics, Symbolic Computation Group — Tom Peterka

Start year: 2019

See also: https://team.inria.fr/unify

The landscape of scientific computing is being radically reshaped by the explosive growth in the number and power of digital data generators, ranging from major scientific instruments to the Internet of Things (IoT) and the unprecedented volume and diversity of the data they generate. This requires a rich, extended ecosystem including simulation, data analytics, and learning applications, each with distinct data management and analysis needs.

Science activities are beginning to combine these techniques in new, large-scale workflows, in which scientific data is produced, consumed, and analyzed across multiple distinct steps that span computing resources, software frameworks, and time. This paradigm introduces new data-related challenges at several levels.

The UNIFY Associate Team aims to address three such challenges. First, to allow scientists to obtain fast, real-time insight from complex workflows combining extreme-scale computations with data analytics, we will explore how recently emerged Big Data processing techniques (e.g., based on stream processing) can be leveraged with modern in situ/in transit processing approaches used in HPC environments.

Second, we will investigate how to use transient storage systems to enable efficient, dynamic data management for hybrid workflows combining simulations and analytics.

Finally, the explosion of learning and AI provides new tools that can enable much more adaptable resource management and data services than available today, which can further optimize such data processing workflows.

8.3.2. Inria Associate Teams Not Involved in an Inria International Labs

8.3.2.1. SmartFastData

Title: Efficient Data Management in Support of Hybrid Edge/Cloud Analytics for Smart Cities

International Partner: Instituto Politécnico Nacional (Mexico) — Centro de Investigación en Computación — Rolando Menchaca-Mendez

- Start year: 2019
- See also: https://team.inria.fr/smartfastdata/

The proliferation of small sensors and devices that are capable of generating valuable information in the context of the Internet of Things (IoT) has exacerbated the amount of data flowing from all connected objects to private and public cloud infrastructures. In particular, this is true for Smart City applications, which cover a large spectrum of needs in public safety, water and energy management. Unfortunately, the lack of a scalable data management subsystem is becoming an important bottleneck for such applications, as it increases the gap between their I/O requirements and the storage performance.

The vision underlying the SmartFastData associated team is that, by smartly and efficiently combining the data-driven analytics at the edge and in the cloud, it becomes possible to make a substantial step beyond state-of-the-art prescriptive analytics through a new, high-potential, faster approach to react to the sensed data.

The goal is to build a data management platform that will enable comprehensive joint analytics of past (historical) and present (real-time) data, in the cloud and at the edge, respectively, allowing to quickly detect and react to special conditions and to predict how the targeted system would behave in critical situations.

In 2019, the first objective of the associated team (i.e., exploring analytical models for performance evaluation of stream storage and ingestion systems) was achieved by means of the two internships of José Canepa and Edgar Romo (described in the New Results section) as well as the visit of Mario Rivero as an Invited Professor, who set up the main research agenda for those internships.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

Rosa Badia: Barcelona Supercomputing Center, Spain. Dates: 13-14 March 2019

Michael Schottner: University of Dusseldorf, Germany. Dates: 13-15 March 2019

Valentin Cristea: Politehnica University of Bucharest, Romania. Dates: 13-15 March 2019

Toni Cortés: Universitat Politècnica Catalunya, Spain. Dates: 4-5 November 2019

Kate Keahey: Argonne National Lab, USA. Dates: 4-5 November 2019

Matthieu Dorier: Argonne National Lab, USA. Dates: 4-5 November 2019

8.4.1.1. Invited Professors

Mario Rivero (Professor, Instituto Politécnico Nacional, Mexico) was an invited professor in the KerData team from June to July 2019, through the *Scientist Invitation Program* of IRISA and ISTIC. During his stay, he gave several talks at Inria/IRISA and worked on the modeling Smart City applications, laying the path for the work program of the upcoming internships of José Aguilar-Canepa and Edgar Romo.

8.4.1.2. Internships

Jose Aguilar-Canepa (PhD student, Instituto Politécnico Nacional, Mexico) has done a 3-month internship within the team, working with Alexandru Costan and Pedro Silva on hybrid Edge/Cloud stream processing. This work is validated through large scale experiments on Grid'5000 and is subject to a journal paper in submission, currently on the works, to be submitted by January 2020.

Edgar Romo (PhD student, Instituto Politécnico Nacional, Mexico) did a 3-month internship at KerData from September to November 2019. He worked on Objective 2 of the SmartFastData Associate Team, specifically on designing a complex model for predicting the stream arrival rates for vehicular networks in Smart Cities. To validate this proposal, he carried out several experiments on Grid'5000; this work is currently the topic of a workshop paper submission.

8.4.2. Visits to International Teams

Alexandru Costan and Gabriel Antoniu visited the NDS-Lab team at Instituto Politécnico Nacional from October 24 to November 3, 2019, in the context of the SmartFastData associate team. Working closely with Rolando Menchaca, they defined the work program for the upcoming year with respect to the team's objectives. They also presented KerData's vision on future hybrid analytics combining Edge, Cloud and HPC computing.

Myriads Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. INDIC - Cybersecurity Pole of Excellence (2014-2020)

Participants: Clément Elbaz, Christine Morin, Louis Rilling, Amir Teshome Wonjiga.

Our study carried out in the framework of a collaboration with DGA-MI aims at defining and enforcing SLA for security monitoring of virtualized information systems. To this aim we study three topics:

- defining relevant SLA terms for security monitoring,
- enforcing and evaluating SLA terms,
- making the SLA terms enforcement mechanisms self-adaptable to cope with the dynamic nature of clouds.

The considered enforcement and evaluation mechanisms should have a minimal impact on performance. The funding from DGA funded the PhD of Anna Giannakou (defended in 2017) and Amir Teshome Wonjiga (defended in 2019). Clément Elbaz is partially funded by the Brittany Regional Council in the PEC framework.

8.2. National Initiatives

8.2.1. ADEME RennesGrid (2017-2020)

Participants: Anne Blavette, Benjamin Camus, Anne-Cécile Orgerie, Martin Quinson.

The aim of the RennesGrid project is to design and implement a large-scale preindustrial microgrid demonstrator in the territory of Rennes Metropole to organize the shared self-consumption of a group of photovoltaic panels coupled to stationary storage devices. Traditional approaches to power grid management tend to overlook the costs, both energy and economic, of using computers to ensure optimal electricity network management. However, these costs can be significant. It is therefore necessary to take them into account along with the design of IT tools during studies of optimal energy management of smart grids. In addition, telecommunication networks are generally considered to have an ideal functioning, that is to say they can not negatively affect the performance of the electricity network. However, this is not realistic and it is necessary to analyze the impact of phenomena such as congestion, latency, failures related to computer equipment or impact on the batteries of sensors, etc. on strategies for optimal management of the electricity network. In this project, we closely collaborate with Anne Blavette (CR CNRS in electrical engineering, SATIE, Rennes) and co-supervise the post-doc of Benjamin Camus who started in April 2018 on evaluating the impact of the IT infrastructure in the management of smart grids.

8.2.2. Inria ADT Mc SimGrid (2019-2021)

Participants: Ehsan Azimi, Martin Quinson.

The Mc SimGrid technological development action funded by INRIA targets the refactoring of model checker that is integrated to the SimGrid simulation framework. Its software quality should be improved to be on par with the rest of the SimGrid framework. Our ultimate goal is to make this model-checker usable in production, both to assess real-size applications and as a workbench for the researchers designing new techniques and algorithms for the verification of distributed asynchronous applications and algorithms.

The technical actions envisioned for this ADT are the complete re-factoring of this software module, and the exposure of a sensible python interface to experiment with new exploration algorithms. This work is lead by Ehsan Azimi, in collaboration with Thierry Jéron from the Sumo team.

8.2.3. Inria IPL Discovery (2015-2019)

Participants: Anne-Cécile Orgerie, Matthieu Simonin, Genc Tato, Cédric Tedeschi.

The Inria IPL Discovery officially started in September 2015. It targets the design, development and deployment of a distributed Cloud infrastructure within the network's backbone. It will be based upon a set of building blocks whose design will take locality as a primary constraint, so as to minimize distant communications and consequently achieve better network traffic, partition management and improved availability.

Its developments are planned to get integrated within the OpenStack framework. Myriads is involved in the design of new overlay networks for such environments so as to support efficient messaging and routing. Myriads is also involved in the energy/cost benefit analysis of distributed edge-cloud architectures.

8.2.4. Inria IPL Hac Specis (2016-2020)

Participants: Dorra Boughzala, Anne-Cécile Orgerie, The Anh Pham, Martin Quinson.

The goal of the HAC SPECIS (High-performance Application and Computers: Studying PErformance and Correctness In Simulation) project (http://hacspecis.gforge.inria.fr/) is to answer methodological needs of HPC application and runtime developers and to allow to study real HPC systems both from the correctness and performance point of view. To this end, we gather experts from the HPC, formal verification and performance evaluation community.

The Anh Pham defended his thesis on December 6., on techniques to mitigate the state space explosion while verifying asynchronous distributed applications. He proposed a new algorithm to mitigate the state space explosion problem (published this year [19]), using event folding structures to efficiently compute how to not explore equivalent execution traces more than once. This work, co-advised by Martin Quinson with Thierry Jéron (team SUMO, formal methods), was important to bridge the gap between the involved communities.

During her PhD thesis, Dorra Boughzala studied the energy consumption of GPU and the simulation tools of the literature related to this aspect. Her work is co-advised by Laurent Lefèvre (Avalon team, Lyon), Martin Quinson and Anne-Cécile Orgerie.

8.2.5. SESAME ASTRID project (2016-2019)

Participants: Mehdi Belkhiria, Pascal Morillon, Christine Morin, Matthieu Simonin, Cédric Tedeschi.

The Sesame project (http://www.agence-nationale-recherche.fr/Project-ANR-16-ASTR-0026) led by IMT Atlantique aims at develop efficient infrastructures and tools for the maritime traffic surveillance. The role of Myriads is to define a robust and scalable infrastructure for the real-time and batch processing of vessel tracking information. In 2019, we focused on autoscaling and placement for Stream Processing applications.

In 2019, we investigated the dynamic, decentralized scaling of stream processing applications. Also, we collaborated with the Inria OBELIX team to scale and deploy a machine learning application they developed to build a model of a *normal* vessel trajectory.

8.2.6. CNRS GDS EcoInfo

Participant: Anne-Cécile Orgerie.

The EcoInfo group deals with reducing environmental and societal impacts of Information and Communications Technologies from hardware to software aspects. This group aims at providing critical studies, lifecycle analyses and best practices in order to improve the energy efficiency of printers, servers, data centers, and any ICT equipment in use in public research organizations.

8.3. European Initiatives

8.3.1. H2020 Projects

8.3.1.1. H2020 MSCA FogGuru

Participants: Hamidreza Arkian, Davaadorj Battulga, Mozhdeh Farhadi, Julie Montégu, Guillaume Pierre, Mulugeta Ayalew Tamiru, Cédric Tedeschi, Paulo Rodrigues de Souza Junior.

Title: FogGuru – Training the Next Generation of European Fog Computing Experts

Program: H2020 MSCA ITN EID

Duration: September 2017 - August 2021

Coordinator: Guillaume Pierre

Participants:

University of Rennes 1, France (coordinator)

Technische Universität Berlin, Germany

Elastisys AB, Sweden

U-Hopper srl, Italy

EIT Digital Rennes, France

Las Naves, Spain

Abstract: FogGuru is a doctoral training project which aims to to train eight talented PhD students with an innovative and inter-sectoral research program to constitute the next generation of European Cloud and Fog computing experts. Besides their scientific and technical education, FogGuru's PhD students will receive extensive training in technological innovation and entrepreneurship as well as soft skills. These combined skills will enable them to fully master the innovation process stemming from fundamental research towards invention and development of innovative products and services, and to real-life deployment, experimentation and engagement with beta-testers.

8.3.2. Collaborations in European Programs, Except FP7 & H2020

8.3.2.1. EIT Digital DriveTrust

Participant: Guillaume Pierre.

Program: EIT Digital

Project acronym: DriveTrust

Project title: AI-Powered Driving Evaluation

Duration: January 2019 - December 2019

Coordinator: University of Rennes 1, France

Other partners:

Eurapco, Switzerland

Achmea, the Netherlands

Imec, Belgium

Abstract: This project aims to develop and commercialize an AI-powered dash cam with short range V2X and LTE communication capabilities. The product uses the newest AI capable hardware for real-time object detection. The device can detect street signs, traffic lights, other cars, and pedestrians. Combined with sensor data from the accelerometer, GPS and weather data from the cloud we use the data to calculate different dimensions of driving profiles. In addition the V2X and object detection capabilities allow us to warn the driver in real-time about dangers on the road.

8.3.3. Inria Associate Teams Not Involved in an Inria International Labs

8.3.3.1. FogCity

Participants: Ayan Mondal, Nikos Parlavatzas, Guillaume Pierre.

Title: QoS-aware Resource Management for Smart Cities

International Partner (Institution - Laboratory - Researcher):

IIT Kharagpur (India) - Department of Computer Science and Engineering - Sudip Misra

IIT Kanpur (India) - Department of Industrial and Management Engineering - Subhas Chandra Misra

Start year: 2018

See also: https://team.inria.fr/myriads/projects/fogcity/

Abstract: The FogCity associate team proposal concerns a collaboration between the Myriads project-team, and two research teams at Indian Institute of Technology Kharagpur and Indian Institute of Technology Kanpur. The proposal focuses on a smart city scenario in which data from static and mobile sensors is routed to appropriate fog data centres based on application QoS requirements. The main goal of the research is to select suitable nodes within the fog data centers to optimize the QoS of the applications in terms of latency. The different teams have complementary expertise in theoretical research (Indian partners) and system research (Inria Myriads project-team) and share a strong research interest in IoT and Fog Computing.

8.3.3.2. FogRein

Participants: Anne-Cécile Orgerie, Martin Quinson.

Title: Steering Efficiency for Distributed Applications

International Partner: Gene Cooperman, College of Computer and Information Science, Northeastern University (USA).

Start year: 2019

In Fog Computing, the Internet of Things (IoT), and Intermittent Computing, low-power devices migrate geographically, and are required to rapidly assimilate new data in a power-efficient manner. This is a key component of any Smart Interfaces solution as devices migrate from the IT infrastructure to the Edge of the Cloud in order to provide Function-as-a-Service, High-availability mobility, and IT infrastructure malleability. A three-tier strategy is proposed toward steering Fog applications in order to optimize the energy efficiency and sustainability. The strategy will leverage the backgrounds of the participants in Fog Computing, checkpointing, scheduling, Green Levers within the IT infrastructure, and a simulation infrastructure for predicting and efficiently steering such distributed applications. The Inria team and the Northeastern team are uniquely positioned to make rapid progress due to their long history of collaborative research based on visits by both permanent members and PhD students in the two directions.

8.3.4. Inria International Partners

8.3.4.1. Informal International Partners

UC Louvain (Belgium): We collaborate with Prof. Etienne Riviere on legacy application edgification. Genc Tato spent six month at UCL.

Tlemcen University (Algeria): We collaborate with Dr. Djawida Dib on energy-efficient and fault-tolerant resource management in containerized clouds. Christine Morin and Nikos Parlavantzas are co-advising Yasmina Bouizem, who is enrolled in both Tlemcen University and University of Rennes 1.

University of Bologna (Italy): We collaborate with Prof. Paolo Bellavista on the design of performance-efficient fog computing platforms. Lorenzo Civolani from University of Bologna spent 6 months in the Myriads team to complete his master thesis internship. A paper on his work has been accepted for publication [14].

Umeå University (Sweden): We collaborate with Prof. Erik Elmroth on the control of large-scale cloud and fog computing platforms. Ali Fahs spent 6 months at Umeå University where he worked on autoscaling techniques for future fog computing platforms.

Rutgers University (USA): We collaborate with Prof. Manish Parashar on improving the energy efficiency of distributed data-intensive applications. This collaboration is outlined by a joint publication in [20].

University of Hawaii (USA): We collaborate with Prof. Henri Casanova on simulating the energy consumption of scientific workflows. This collaboration is outlined by a joint publication in [16].

University of Southern California (USA): We collaborate with Dr. Rafael Ferreira da Silva and Prof. Ewa Deelman on simulating the energy consumption of scientific workflows. This collaboration is outlined by a joint publication in [16].

8.3.5. Participation in Other International Programs

8.3.5.1. Inria International Chairs

Deborah AGARWAL

Title: Workflow, user centered design, and data management as well as mobile applications for data science

International Partner (Institution - Laboratory - Researcher):

Université californienne de Santa Barbara (United States) - Computational Research Division - Deborah Agarwal

Duration: 2015 - 2019

Start year: 2015

8.4. International Research Visitors

8.4.1. Visits of International Scientists

8.4.1.1. Internships

Lorenzo CIVOLANI

Date: Sep 2018 - Feb 2019

Institution: University of Bologna (Italy)

Supervisor: Guillaume Pierre

Adrien GOUGEON

Date: Feb 2019 - Jun 2019

Institution: ENS Rennes

Supervisors: Anne-Cécile Orgerie and Benjamin Camus

Archana WALE

Date: Jan 2019 - Jun 2019

Institution: University of Rennes 1

Supervisor: Guillaume Pierre

Romain Olivo

Date: Juin 2019 - Aug 2019

Institution: Inria

Supervisor: Matthieu Simonin

STACK Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. SysMics

Participants: Jean-Marc Menaud, Mario Südholt [coordinator].

The SysMics project aims at federating the NExT scientific community toward a common objective: anticipate the emergence of systems medicine by co-developing 3 approaches in population-scale genomics: genotyping by sequencing, cell-by-cell profiling and microbiome analysis. STACK investigates new means for secure and privacy-aware computations in the context of personalized medecine, notably genetic analyses.

This project is financed by the Nantes excellency initiative in Medecine and Informatics (NExT) from 2018-22.

9.1.2. SHLARC

Participants: Mario Südholt [coordinator], Sirine Sayadi.

The SHLARC project is an international network involving more than 20 partners from more than 15 countries located on four continents. The network aims at improving HLA imputation techniques in the domain of immunobiology, notably by investigation better computational methods for the correspoding biomedical analyses.

The ambition of the SHLARC is to bring together international expertise to solve essential questions on immune-related pathologies through innovative algorithms and powerful computation tool development. To achieve this goal, we determined 3 main objectives

- Data. By bringing together scientists from around the world, we will collectively increase the amount of SNP+HLA data available, both in terms of quantity and diversity.
- Applied mathematical and computer sciences. We will further optimize SNP-HLA imputation methods using the attribute-bagging HIBAG tool, and particularly for genetically diverse and admixed populations.
- Accessibility and service to the scientific community. Following the Haplotype Reference Consortium (HRC) initiative, the network envisions building a free, user-friendly webserver where researchers can access improved imputation protocols by simply uploading their data and obtaining the best possible HLA imputation for their dataset.

In this context, the STACK team is working on improved analysis techniques that harness distributed infrastructures.

This project is financed by the Nantes excellency initiative in Medecine and Informatics (NExT) from 2019-22.

9.1.3. Oncoshare

Participant: Mario Südholt [coordinator].

The ONCOSHARe project (ONCOlogy big data SHAring for Research) will demonstrate, through a multidisciplinary cooperation within the Western CANCEROPOLE network, the feasibility and the added value of a Cancer Patient Centered Information Common for in-silico research. The STACK team will work on challenges to the security and the privacy of user data in this context.

This project is financed by three French regions from 2018-2021.

9.2. National Initiatives

9.2.1. Ademe

9.2.1.1. GL4MA

Participants: Brice Nédelec, Thomas Ledoux [coordinator].

The Green Label for Microservices Architecture (GL4MA) project aims to design and develop a technological platform (tools, framework, dedicated languages) for the self management of eco-responsible micro-service architectures for the Cloud. The experiments will be carried out through case studies provided by Sigma Informatique and the presence of renewable energy will initially be simulated. At the end of the project, the technological platform will be deployed as part of the CPER SeDuCe platform. This project is founded by the Ademe (call Perfecto) running for 18 months (starting in September 2019).

9.2.2. CominLabs laboratory of excellence

9.2.2.1. PrivGen

Participants: Fatima Zahra Boujdad, Mario Südholt [coordinator].

PrivGen ("Privacy-preserving sharing and processing of genetic data") is a three-year project that has been started in Oct. 2016 and is conducted by three partners: a team of computer scientists from the LATIM Inserm institute in Brest mainly working on data watermarking techniques, a team of geneticians from an Inserm institute in Rennes working on the gathering and interpretation of genetic data, and the STACK team. The project provides funding of 330 KEUR altogether with an STACK share of 120 KEUR.

The project considers challenges related to the outsourcing of genetic data that is in the Cloud by different stakeholders (researchers, organizations, providers, etc.). It tackles several limitations of current security solutions in the cloud, notably the lack of support for different security and privacy properties at once and computations executed at different sites that are executed on behalf of multiple stakeholders.

The partners are working on three main challenges:

- Mechanisms for a continuous digital content protection.
- Composition of security and privacy-protection mechanisms
- Distributed processing and sharing of genetic data.

The STACK team is mainly involved in providing solutions for the second and third challenges.

9.2.2.2. SeDuCe++

Participants: Jonathan Pastor, Jean-Marc Menaud [coordinator].

SeDuCe++ is an extended version of the SeDuCe project. Funded by the LS2N (CNRS), an allocated budget of 10K€ for one year, it aims at studying the energy footprint of extreme edge infrastructure.

9.2.3. ANR

9.2.3.1. GRECO (ANR)

Participants: Adrien Lebre [Contact point], Alexandre Van Kempen.

The GRECO project (Resource manager for cloud of Things) is an ANR project (ANR-16-CE25-0016) running for 42 months (starting in January 2017 with an allocated budget of 522K€, 90K€ for STACK).

The consortium is composed of 4 partners: Qarnot Computing (coordinator) and 3 academic research group (DATAMOVE and AMA from the LIG in Grenoble and STACK from Inria Rennes Bretagne Atlantique).

The goal of the GRECO project (https://anr-greco.net) is to design a manager for cloud of things. The manager should act at the IaaS, PaaS and SaaS layer of the cloud. To move forward to this objective, we have been designing a simulator to innovate in designing scheduling and data management systems. This simular leverage the Simgrid/PyBATSIM solution [27].

9.2.3.2. KerStream (ANR)

Participant: Shadi Ibrahim [Coordinator].

The KerStream project (Big Data Processing: Beyond Hadoop!) is an ANR JCJC (Young Researcher) project (ANR-16-CE25-0014-1) running for 48 months (starting in January 2017 with an allocated budget of 238K€).

The goal of the KerStream project is to address the limitations of Hadoop when running Big Data stream applications on large-scale clouds and do a step beyond Hadoop by proposing a new approach, called KerStream, for scalable and resilient Big Data stream processing on clouds. The KerStream project can be seen as the first step towards developing the first French middleware that handles Stream Data processing at Scale.

9.2.4. FSN

9.2.4.1. Hydda (FSN)

Participants: Hélène Coullon, Jean-Marc Menaud [coordinator].

The HYDDA project aims to develop a software solution allowing the deployment of Big Data applications (with hybrid design (HPC/CLoud)) on heterogeneous platforms (cluster, Grid, private Cloud) and orchestrators (Task scheduler like Slurm, Virtual orchestrator (like Nova for OpenStack or Swarm for Docker). The main questions we are investigating are :

- How to propose an easy-to-use service to host (from deployment to elimination) application components that are both typed Cloud and HPC?
- How propose a service that unifies the HPCaaS (HPC as a service) and the Infrastructure as a Service (IaaS) in order to offer resources on demand and to take into account the specificities of scientific applications?
- How optimize resources usage of these platforms (CPU, RAM, Disk, Energy, etc.) in order to propose solutions at the least cost?

9.2.5. CPER

9.2.5.1. SeDuCe

Participants: Adrien Lebre, Jean-Marc Menaud [coordinator], Jonathan Pastor.

The SeDuCe project (Sustainable Data Centers: Bring Sun, Wind and Cloud Back Together), aims to design an experimental infrastructure dedicated to the study of data centers with low energy footprint. This innovative data center will be the first experimental data center in the world for studying the energy impact of cloud computing and the contribution of renewable energy (solar panels, wind turbines) from the scientific, technological and economic viewpoints. This project is integrated in the national context of grid computing (Grid'5000), and the Constellation project, which will be an inter-node (Pays de la Loire, Brittany).

9.2.6. Inria Project Labs

9.2.6.1. DISCOVERY

Participants: Javier Rojas Balderrama, Hélène Coullon, Marie Delavergne, Shadi Ibrahim, Adrien Lebre [coordinator], Ronan-Alexandre Cherrueau, Matthieu Simonin, Alexandre Van Kempen.

To accommodate the ever-increasing demand for Utility Computing (UC) resources, while taking into account both energy and economical issues, the current trend consists in building larger and larger Data Centers in a few strategic locations. Although such an approach enables UC providers to cope with the actual demand while continuing to operate UC resources through centralized software system, it is far from delivering sustainable and efficient UC infrastructures for future needs.

The DISCOVERY initiative [0] aims at exploring a new way of operating Utility Computing (UC) resources by leveraging any facilities available through the Internet in order to deliver widely distributed platforms that can better match the geographical dispersal of users as well as the ever increasing demand. Critical to the emergence of such locality-based UC (also referred as Fog/Edge Computing) platforms is the availability of appropriate operating mechanisms. The main objective of DISCOVERY is to design, implement, demonstrate and promote a new kind of Cloud Operting System (OS) that will enable the management of such a large-scale and widely distributed infrastructure in an unified and friendly manner.

The consortium is composed of experts in the following research areas: large-scale infrastructure management systems, networking and P2P algorithms. Moreover, two key network operators, namely Orange and RENATER, are involved in the project.

By deploying and using a Fog/Edge OS on backbones, our ultimate vision is to enable large parts of the Internet to be hosted and operated by its internal structure itself: a scalable set of resources delivered by any computing facilities forming the Internet, starting from the larger hubs operated by ISPs, governments and academic institutions, to any idle resources that may be provided by end users.

STACK led the DISCOVERY IPL and contributes mainly around two axes: VM life cycle management and deployment/reconfiguration challenges.

The IPL ended in July 2019.

9.2.7. InriaHub

9.2.7.1. Mercury

Participants: Ronan-Alexandre Cherrueau, Adrien Lebre [coordinator], Matthieu Simonin.

STACK, in particular within the framework of the DISCOVERY initiative has been working on the massively distributed use case since 2013. With the development of several proof-of-concepts around OpenStack, the team has had the opportunity to start an InriaHub action. Named Mercury, the goal of this action is twofold: (i) support the research development made within the context of DISCOVERY and (ii) favor the transfer toward the OpenStack community.
Further information available at: http://beyondtheClouds.github.io.

The Mercury action ended in July 2019.

9.2.7.2. Apollo/Soyuz

Participants: Javier Rojas Balderrama, Ronan-Alexandre Cherrueau, Adrien Lebre [coordinator], Matthieu Simonin.

The Apollo/Soyuz is the second InriaHub action attached the DISCOVERY IPL. While Mercury aims mainly at supporting development efforts within the DISCOVERY IPL, the Apollo/Soyuz is focusing on the animation and the dissemination of the DISCOVERY activities within the different open-source ecosystem (*i.e.*, OpenStack, OPNFV, etc.). One additional engineer will join the current team in January 2019.
Further information available at: http://beyondtheClouds.github.io.

The Apollo/Soyuz ended in Dec 2019.

9.2.8. Fonds d'amorçage IMT Industrie du Futur 2017

9.2.8.1. aLIFE

Participants: Hélène Coullon [coordinator], Jacques Noyé.

As a follow-up of the aLIFE workshop (Nantes, Jan. 2018), organized in partnership with colleagues from IMT Atlantique and gathering both academic and industrial partners, we have written a booklet [29] summarizing the workshop discussions and proposing a shared vision of what software research could bring to Industry 4.0 initiatives.

[0] http://beyondtheclouds.github.io

9.2.9. Connect Talent

9.2.9.1. Apollo (Connect Talent)

Participant: Shadi Ibrahim [Coordinator].

The Apollo project (Fast, efficient and privacy-aware Workflow executions in massively distributed Data-centers) is an individual research project "Connect Talent" running for 36 months (starting in November 2017 with an allocated budget of 201K€).

The goal of the Apollo project is to investigate novel scheduling policies and mechanisms for fast, efficient and privacy-aware data-intensive workflow executions in massively distributed data-centers.

9.2.10. Etoiles Montantes

9.2.10.1. VeRDi

Participant: Hélène Coullon [Coordinator].

VeRDi is an acronym for Verified Reconfiguration Driven by execution. The VeRDi project is funded by the French region Pays De La Loire where Nantes is located. The project starts in November 2018 and ends on December 2020 with an allocated budget of 172800€.

It aims at addressing distributed software reconfiguration in an efficient and verified way. The aim of the VeRDi project is to build an argued disruptive view of the problem. To do so we want to validate the work already performed on the deployment in the team and extend it to reconfiguration.

9.3. International Initiatives

9.3.1. Inria International Labs

Inria@SiliconValley
Associate Team involved in the International Lab:

9.3.1.1. Hermes

Title: Accelerating the Performance of Multi-Site Scientific applications through Coordinated Data management.

International Partner (Institution - Laboratory - Researcher):

Lawrence Berkeley National Laboratory (United States) - Scientific Data Management Group - Suren Byna.

Start year: 2019

See also: http://hermes-ea2019.gforge.inria.fr.

Advances in computing, experimental, and observational facilities are enabling scientists to generate and analyze unprecedented volumes of data. A critical challenge facing scientists in this era of data deluge is storing, moving, sharing, retrieving, and gaining insight from massive collections of data efficiently. Existing data management and I/O solutions on high-performance computing (HPC) systems require significant enhancements to handle the three V's of Big Data (volume, velocity, and variety) in order to improve productivity of scientists. Even more challenging, many scientific Big Data and machine learning applications require data to be shared, exchanged, and transferred among multiple HPC sites. Towards overcoming these challenges, in this project, we aim at accelerating scientific Big Data application performance through coordinated data management that addresses performance limitations of managing data across multiple sites. In particular, we focus on challenges related to the management of data and metadata across sites, distributed burst buffers, and online data analysis across sites.

9.3.2. Inria International Partners

9.3.2.1. Informal International Partners

Huazhong university of Science and Technology (HUST): We collaborate on resource management for stream data applications in the edge, I/O scheduling for SDDs and network-aware task scheduling for MapReduce.

National University of Singapore (NUS): We collaborate on resource management for workflows in the clouds and optimizing graph processing in geo-distributed data-centers.

ShenZhen University: We collaborate on resource management for workflows in the clouds and optimizing graph processing in geo-distributed data-centers.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Suren Byna, a Staff Scientist in the Scientific Data Management Group at Lawrence Berkeley National Lab (LBNL), visited the STACK team from September 30 to October 4 2019. This visit was in the context of the Hermes Associate team.
- Twinkle Jain, a PhD student at Northeastern university, visited the STACK team from May 1 to July 31 2019. Twinkle was working with S. Ibrahim on stragglers mitigation in big data systems. The visit was funded by the ANR KerStream and the Apollo Connect Talent projects.

9.4.1.1. Internships

- Asha Begam Mohamed Mubarak, a master student at University of Rennes 1, joined the team as a research intern from April 2019 until August 2019. Her thesis was on fast Container Image Retrieval in the Edge.

9.4.2. Visits to International Teams

9.4.2.1. Research Stays Abroad

HUST, China: From August 23 to September 2, S. Ibrahim visited the Services Computing Technology and System Lab at Huazhong university of Science and Technology.

WIDE Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. Web of Browser's (Brittany Region and Labex CominLabs 2019-2020)

Participant: François Taïani.

Browsers are de facto the most widely deployed execution environments in the world. Initially simple HTML readers, they now run complex applications interacting with humans and web services. The recent introduction of WebRTC has further extended the capability of browsers by introducing support for browser-to-browser communication. This turns browsers into a decentralized execution environment where interactions between human and web services are enabled without third party.

The Web of browsers is a vision where the web is serverless, ephemeral and massively decentralized. Web where pages are hosted by networks of browsers connected through WebRTC. The objective of the project is to build and experiment the Web of Browsers.

8.2. National Initiatives

8.2.1. ANR Project PAMELA (2016-2020)

Participants: Davide Frey, George Giakkoupis, François Taïani.

PAMELA is a collaborative ANR project involving Inria/IRISA, Inria Lille (MAGNET team), UMPC, Mediego and Snips. The project aims at developing machine learning theories and algorithms in order to learn local and personalized models from data distributed over networked infrastructures. This project seeks to provide fundamental answers to modern information systems built by interconnecting many personal devices holding private user data in the search of personalized suggestions and recommendations. A significant asset of the project is the quality of its industrial partners, Snips and Mediego, who bring in their expertise in privacy protection and distributed computing as well as use cases and datasets.

8.2.2. ANR Project OBrowser (2016-2020)

Participants: David Bromberg, Davide Frey, François Taïani.

OBrowser is a collaborative ANR project involving Inria, the University of Nantes, the University of South Brittany, and Orange. The project emerges from the vision of designing and deploying distributed applications on millions of machines using web-enabled technologies without relying on a cloud or a central authority. OBrowser proposes to build collaborative applications through a decentralized execution environment composed of users' browsers that autonomously manages issues such as communication, naming, heterogeneity, and scalability.

8.2.3. ANR Project DESCARTES (2016-2020)

Participants: George Giakkoupis, Michel Raynal, François Taïani.

DESCARTES is a collaborative ANR project involving Inria/IRISA, Labri (U. Bordeaux), IRIF (U. Paris Diderot), Inria Paris (GANG Team), Vérimag (Grenoble), LIF (Marseilles), and LS2N (former LINA, Nantes). The DESCARTES project aims at bridging the lack of a generic theoretical framework in order to unify the large body of fundamental knowledge on distributed computation that has been acquired over the last 40 years. In particular, the project's objective is to develop a systematic model of distributed computation that organizes the functionalities of a distributed computing system into reusable modular constructs assembled via well-defined mechanisms that maintain sound theoretical guarantees on the resulting system.

8.2.4. Labex CominLab PROFILE (2016-2019)

Participants: David Bromberg, Davide Frey, François Taïani.

The PROFILE (2016-2019) project brings together experts from law, computer science (the Inria teams DIVERSE and ASAP/WIDE, the IRISA team DRUID) and sociology to address the challenges raised by online profiling, following a multidisciplinary approach. More precisely, the project will pursue two complementary and mutually informed lines of research: first, the project will investigate, design, and introduce a new right of opposition into privacy Law to better regulate profiling and to modify the behavior of commercial companies. Second, the project aims to provide users with the technical means they need to detect stealthy profiling techniques, and to control the extent of the digital traces they routinely produce.

8.3. International Initiatives

8.3.1. LiDiCo

- Title: Aux limites du calcul réparti
- International Partner (Institution - Laboratory - Researcher):
  - UNAM (Mexico) - Instituto de Matematicas - Sergio Rajsbaum
- Start year: 2017
- See also: https://sites.google.com/site/lidicoequipeassociee/
- Today distributed applications are pervasive, some very successful (e.g., Internet, P2P, social networks, cloud computing), and benefit everyone, but the design and the implementation of many of them still rely on ad-hoc techniques instead of on a solid theory. The next generation of distributed applications and services will be more and more complex and demands research efforts in establishing sound theoretical foundations to be able to master their design, their properties and their implementation. This is a step in this inescapable direction.

8.4. International Research Visitors

Roberto Rodrigues Filho (Lancaster University, UK), July–September 2019.

Mohamed Lechiakh, (ENSIAS, Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes, Rabat, Morocco), March–May 2019.

Hasnaa Dyani, (ENSIAS, Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes, Rabat, Morocco), April–June 2019.

Chaimaa Tarzi, (ENSIAS, Ecole Nationale Supérieure d'Informatique et d'Analyse des Systèmes, Rabat, Morocco), April–June 2019.

Arsany Guirguis, (EPFL, Lausanne, Switzerland), July–September 2019.

Marcus Kaboret, (Laboratoire de Mathématiques et Informatique, Joseph Ki-Zerbo University, Ouagadougou, Burkina Faso), September–October 2019.

Hayk Saribekyan (University of Cambridge, UK), 2-–12 April 2019.

Giorgi Nadiradze (IST Austria), 20–24 May 2019.

Emanuele Natale (CNRS, Sophia-Antipolis), 13–17 March 2019.

8.4.1. Visits to International Teams

Adrien Luxey visited Paulo Ferreira, University of Oslo, Norway, from the 1st May to the 30th of June 2019.

HYBRID Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Labex Cominlabs SUNSET

Participants: Bruno Arnaldi, Valérie Gouranton [contact], Alexandre Audinot, Adrien Reuzeau.

SUNSET is a 4-year Labex Cominlabs project (2016-2020). SUNSET partners are MediCIS-LTSI (coordinator), Hybrid, Hycomes (IRISA/Inria), and CHU Rennes. SUNSET aims at developing an innovative training software suite based on immersive and collaborative virtual reality technology for training and evaluating non-technical skills. This approach will be implemented and evaluated in the context of training neurosurgical scrub nurses. We will notably integrate methods and systems developed in the S3PM project (see bellow). By relying on Human Factors approaches, the project also addresses training and evaluation of interpersonal skills. Whereas the developed technologies and approaches will be generic and adaptable to any surgical specialty, the project will evaluate the developed system within training sessions performed with scrub nurses. We ambition to propose novel approaches for surgical non-technical skill learning and assessment, and to install the developed training factory at the University Hospital of Rennes, and evaluate it with real-scale user studies.

9.1.2. Labex Cominlabs RobotX

Participants: Bruno Arnaldi, Valérie Gouranton [contact], Alexandre Audinot.

RobotX (ROBOT for Intelligent Collaborative Surgery) is a one year Labex Cominlabs project (2019). The partners are MediCIS team from LTSI (INSERM and University of Rennes 1), Hybrid, Rainbow and Hycomes teams from IRISA and Inria Rennes, LP3C Lab - University Rennes 2, REV, ROMAS and PACCE teams from LS2N - Nantes, CHU Rennes, CHU Nantes, ICO (Institut de Cancerologie de l'Ouest). The objective of this exploratory action RobotX was to explore this issue and study initial feasibility of some methodological solutions. The long-term is to develop a new generation of intelligent and collaborative safe surgical robots.

Our contribution in the project was to study the development of Virtual Reality based simulated environments for surgical robotic systems for helping designing, evaluation and training of such systems. The objective was also to evaluate simulations of both technical and non technical. We developed a prototype of the Da Vinci robot with an haptic interface and different simulated tasks. We second studied the relevance of the software environments (#5 and #7) developed in previous projects (S3PM and SUNSET). We set up interactions by adding #5 semantics, which allow the robot arm to pick up objects. We also implemented a "Pick and place" exercise. A #7 scenario has been added to manage the user's actions and know when the exercise is over (Fig. 20).

9.1.3. Labex Cominlabs HEMISFER

Participants: Mathis Fleury, Anatole Lécuyer [contact], Giulia Lioi.

HEMISFER is a 6-year project (2013-2019) funded by Labex CominLabs. It involves 4 Inria/IRISA teams (Hybrid, Visages (lead), Panama, Athena) and 2 medical centers: the Rennes Psychiatric Hospital (CHGR) and the Reeducation Department of Rennes Hospital (CHU Pontchaillou). The goal of HEMISFER is to make full use of neurofeedback paradigm in the context of rehabilitation and psychiatric disorders. The major breakthrough will come from the use of a coupling model associating functional and metabolic information from Magnetic Resonance Imaging (fMRI) to Electro-encephalography (EEG) to "enhance" the neurofeedback protocol. Clinical applications concern motor, neurological and psychiatric disorders (stroke, attention-deficit disorder, treatment-resistant mood disorders, etc).

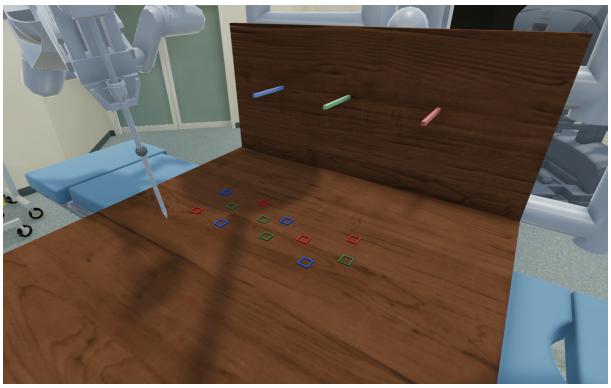

Figure 20. Pick and place exercise using #5 and #7 software

9.1.4. IRT b<>com

Participants: Ferran Argelaguet, Bruno Arnaldi [contact], Valérie Gouranton, Anatole Lécuyer, Maud Marchal, Florian Nouviale.

b<>com is a French Institute of Research and Technology (IRT). The main goal of this IRT is to fasten the development and marketing of tools, products and services in the field of digital technologies. Our team has been regularly involved in collaborations with b<>com within various 3-year projects, such as ImData (on Immersive Interaction) and GestChir (on Augmented Healthcare) which both ended in 2016. Follow-up projects called NeedleWare (on Augmented Healthcare) and VUXIA (on Human Factors) have started respectively in 2016 and 2018.

9.1.5. CNPAO Project

Participants: Valérie Gouranton [contact], Ronan Gaugne.

CNPAO ("Conservatoire Numérique du Patrimoine Archéologique de l'Ouest") is an on-going research project partially funded by the Université Européenne de Bretagne (UEB) and Université de Rennes 1. It involves IRISA/Hybrid and CReAAH. The main objectives are: (i) a sustainable and centralized archiving of 2D/3D data produced by the archaeological community, (ii) a free access to metadata, (iii) a secure access to data for the different actors involved in scientific projects, and (iv) the support and advice for these actors in the 3D data production and exploration through the latest digital technologies, modeling tools and virtual reality systems. This project involves a collaboration with Quentin Petit (SED Inria Rennes).

9.2. National Initiatives

9.2.1. ANR

9.2.1.1. ANR LOBBY-BOT

Participants: Anatole Lécuyer [contact], Maud Marchal, Victor Mercado.

LOBBY-BOT is a 4-year project (2017-2021) funded by the French National Research Agency (ANR). The objective of LOBBY-BOT is to address the scientific challenges of encountered-type haptic devices (ETHD), which are an alternative category of haptic devices relying on a mobile physical prop, usually actuated by a robot, that constantly follows the user hand, and encounter it only when needed. The project follows two research axes: a first one dealing with robot control, and the second one dealing with interaction techniques adapted to ETHD. The involvement of Hybrid relates to the second research axis of the project. The final project prototype will be used to assess the benefits of ETHD when used in an industrial use-case : the perceived quality in an automotive interior.

9.2.2. Inria projects

9.2.2.1. IPL BCI-LIFT

Participants: Anatole Lécuyer [contact], Hakim Si Mohammed.

BCI-LIFT is a 4-year "Inria Project Lab" initiative (2015-2019) funded by Inria for supporting a national research effort on Brain-Computer Interfaces. This joint lab involves several Inria teams: Hybrid, Potioc, Athena, Neurosys, Loki, Demar; as well as external partners: INSERM-Lyon, and INSA Rouen. This project aims at improving several aspects of Brain-Computer Interfaces: learning and adaptation of BCI systems, user interfaces and feedback, training protocols, etc.

9.2.2.2. IPL AVATAR

Participants: Anatole Lécuyer [contact], Ferran Argelaguet, Diane Dewez, Rebecca Fribourg.

AVATAR is a 4-year "Inria Project Lab" initiative (2018-2022) funded by Inria for supporting a national research effort on Avatars and Virtual Embodiment. This joint lab involves several Inria teams: Hybrid, Potioc, Loki, Mimetic, Graphdeco, Morpheo; as well as external partners: Univ. Bacelona, Faurecia and Technicolor companies. This project aims at improving several aspects of Avatars in immersive applications: reconstruction, animation, rendering, interaction, multi-sensory feedback, etc.

9.2.2.3. IPL NAVISCOPE

Participants: Ferran Argelaguet [contact], Gwendal Fouché.

NAVISCOPE is a 4-year "Inria Project Lab" initiative (2018-2022) funded by Inria for supporting a national research effort on image-guided navigation and visualization of large data sets in live cell imaging and microscopy. This joint lab involves several Inria teams: Serpico, Aviz, Beagle, Hybrid, Mosaic, Parietal, Morpheme; as well as external partners: INRA and Institute Curie. This project aims at improving visualization and machine learning methods in order to provide systems capable to assist the scientist to obtain a better understanding of massive amounts of information.

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

9.3.1.1. IMAGINE

Participants: Maud Marchal [contact], Thierry Gaugry, Romain Lagneau, Antonin Bernardin.

Title: IMAGINE - Robots Understanding Their Actions by Imagining Their Effects

Programm: H2020

Duration: January 2017 - December 2020

Coordinator: Univ. Innsbruck (Austria)

Partners:

- Univ. Innsbruck (Austria)
- Univ. Göttingen (Germany)
- Karlsruhe Institute of Technology (Germany)
- INSA Rennes (France)
- Institute of Robotics and Industrial Informatics (Spain)
- Univ. Bogazici (Turkey)
- Electro Cycling (Germany)

Inria contact: Maud Marchal

Abstract: Today's robots are good at executing programmed motions, but they do not understand their actions in the sense that they could automatically generalize them to novel situations or recover from failures. IMAGINE seeks to enable robots to understand the structure of their environment and how it is affected by its actions. "Understanding" here means the ability of the robot (a) to determine the applicability of an action along with parameters to achieve the desired effect, and (b) to discern to what extent an action succeeded, and to infer possible causes of failure and generate recovery actions. The core functional element is a generative model based on an association engine and a physics simulator. "Understanding" is given by the robot's ability to predict the effects of its actions, before and during their execution. This allows the robot to choose actions and parameters based on their simulated performance, and to monitor their progress by comparing observed to simulated behavior. This scientific objective is pursued in the context of recycling of electromechanical appliances. Current recycling practices do not automate disassembly, which exposes humans to hazardous materials, encourages illegal disposal, and creates significant threats to environment and health, often in third countries. IMAGINE will develop a TRL-5 prototype that can autonomously disassemble prototypical classes of devices, generate and execute disassembly actions for unseen instances of similar devices, and recover from certain failures. For robotic disassembly, IMAGINE will develop a multi-functional gripper capable of multiple types of manipulation without tool changes. IMAGINE raises the ability level of robotic systems in core areas of the work programme, including adaptability, manipulation, perception, decisional autonomy, and cognitive ability. Since only one-third of EU e-waste is currently recovered, IMAGINE addresses an area of high economical and ecological impact.

9.3.1.2. H-REALITY

Participants: Anatole Lécuyer, Maud Marchal [contact], Thomas Howard, Gerard Gallagher.

Title: H-REALITY

Programm: H2020 - Fet Open

Duration: 2018 - 2021

Coordinator: Univ. Birmingham (UK)

Partners:

Univ. Birmingham (UK)

CNRS (France),

TU Delft (Netherlands),

ACTRONIKA (France),

ULTRAHAPTICS (UK)

Inria contact: Maud Marchal

Abstract: The vision of H-REALITY is to be the first to imbue virtual objects with a physical presence, providing a revolutionary, untethered, virtual-haptic reality: H-Reality. This ambition will be achieved by integrating the commercial pioneers of ultrasonic "non-contact" haptics, state-of-the-art vibrotactile actuators, novel mathematical and tribological modelling of the skin and mechanics of touch, and experts in the psychophysical rendering of sensation. The result will be a sensory experience where digital 3D shapes and textures are made manifest in real space via modulated, focused, ultrasound, ready for the unteathered hand to feel, where next-generation wearable haptic rings provide directional vibrotactile stimulation, informing users of an object's dynamics, and where computational renderings of specific materials can be distinguished via their surface properties. The implications of this technology will transform online interactions; dangerous machinery will be operated virtually from the safety of the home, and surgeons will hone their skills on thin air.

9.3.1.3. TACTILITY

Participants: Ferran Argelaguet [contact], Anatole Lécuyer, Maud Marchal, Sebastian Vizcay.

Title: Tactility

Programm: H2020 - ICT 25

Duration: July 2019 - June 2022

Coordinator: Fundación Tecnalia Research and Innovation (Spain)

Partners:

Aalborg University (Netherlands)
Universita Degli Studi di Genova (Itali),
Tecnalia Servia (Servia),
Universitat de Valencia (Spain),
Manus Machinae B.V. (Netherlands),
Smartex S.R.L (Italy),
Immersion (France)

Inria contact: Ferran Argelaguet

Abstract: TACTILITY is a multidisciplinary innovation and research action with the overall aim of including rich and meaningful tactile information into the novel interaction systems through technology for closed-loop tactile interaction with virtual environments. By mimicking the characteristics of the natural tactile feedback, it will substantially increase the quality of immersive VR experience used locally or remotely (tele-manipulation). The approach is based on transcutaneous electro-tactile stimulation delivered through electrical pulses with high resolution spatio-temporal distribution. To achieve it, significant development of technologies for transcutaneous stimulation, textile-based multi-pad electrodes and tactile sensation electronic skin, coupled with ground-breaking research of perception of elicited tactile sensations in VR, is needed. The key novelty is in the combination of: 1) the ground-breaking research of perception of electrotactile stimuli for the identification of the stimulation parameters and methods that evoke natural like tactile sensations, 2) the advanced hardware, that will integrate the novel high-resolution electrotactile stimulation system and state of the art artificial electronic skin patches with smart textile technologies and VR control devices in a wearable mobile system, and 3) the novel firmware, that handles real-time encoding and transmission of tactile information from virtual objects in VR, as well as from the distant tactile sensors (artificial skins) placed on robotic or human hands. Proposed research and innovation action would result in a next generation of interactive systems with higher quality experience for both local and remote (e.g., tele-manipulation) applications. Ultimately, TACTILITY will enable high fidelity experience through low-cost, user friendly, wearable and mobile technology.

9.3.1.4. Interreg ADAPT

Participants: Valérie Gouranton [contact], Bruno Arnaldi, Ronan Gaugne, Florian Nouviale, Yoren Gaffary, Alexandre Audinot.

Program: Interreg VA France (Channel) England

Project acronym: ADAPT

Project title:Assistive Devices for empowering disAbled People through robotic Technologies

Duration: 01/2017 - 06/2021

Coordinator: ESIGELEC/IRSEEM Rouen

Other partners: INSA Rennes - IRISA, LGCGM, IETR (France), Université de Picardie Jules Verne - MIS (France), Pôle Saint Hélier (France), CHU Rouen (France), Réseau Breizh PC (France), Ergovie (France), Pôle TES (France), University College of London - Aspire CREATE (UK), University of Kent (UK), East Kent Hospitals Univ NHS Found. Trust (UK), Health and Europe Centre (UK), Plymouth Hospitals NHS Trust (UK), Canterbury Christ Church University (UK), Kent Surrey Sussex Academic Health Science Network (UK), Cornwall Mobility Center (UK).

Inria contact: Valérie Gouranton

Abstract: The ADAPT project aims to develop innovative assistive technologies in order to support the autonomy and to enhance the mobility of power wheelchair users with severe physical/cognitive disabilities. In particular, the objective is to design and evaluate a power wheelchair simulator as well as to design a multi-layer driving assistance system.

Collaboration with Rainbow team.

9.4. International Initiatives

9.4.1. Informal International Partners

- Dr. Takuji Narumi and Prof. Michitaka Hirose from University of Tokyo (Japan), on "Virtual Embodiment"
- Dr. Hannes Kaufmann from Technical University Wien (Austria), on "3D Navigation in Virtual Environments"
- Prof. Reinhold Scherer from Graz University (Austria), on "Brain-Computer Interfaces and Augmented Reality"
- Prof. Jose Millan from Ecole Polytechnique Fédérale de Lausanne (Switzerland), on "Brain-Computer Interfaces and Sports"
- Dr. Mai Otsuki from AIST (Japan) on "Mixed Reality for Cultural Heritage"
- Dr. Karina Rodriguez Echavarria from University of Brighton (UK) on "Mixed Reality for Cultural Heritage"
- Prof. Franz Fischnaller from Albertina Academia of Fine Art of Torino (Italy) on "Immersive Art"
- Dr. Yuta Itoh from Tokyo Institute of Technology (Japan) on "Perception in Augmented Reality"

9.4.2. Participation in Other International Programs

9.4.2.1. ANR-FRQSC INTROSPECT

Participants: Valérie Gouranton [contact], Bruno Arnaldi, Ronan Gaugne, Flavien Lécuyer, Adrien Reuzeau.

INTROSPECT is a 3-year project funded by French ANR and "Fonds de Recherche Société et Culture" (FRQSC) from Quebec region, Canada. This international collaboration involves researchers in computer science and archeology from France and Canada : Hybrid (Inria-IRISA), CReAAH, Inrap, company Image ET, University Laval and INRS-ETE. INTROSPECT aims to develop new uses and tools for archaeologists that facilitate access to knowledge through interactive numerical introspection methods that combine computed tomography with 3D visualization technologies, such as Virtual Reality, tangible interactions and 3D printing. The scientific core of the project is the systematization of the relationship between the artefact, the archaeological context, the digital object and the virtual reconstruction of the archaeological context that represents it and its tangible double resulting from the 3D printing. This axiomatization of its innovative methods makes it possible to enhance our research on our heritage and to make use of accessible digital means of dissemination. This approach changes from traditional methods and applies to specific archaeological problems. Several case studies will be studied in various archaeological contexts on both sides of the Atlantic. Quebec museums are also partners in the project to spread the results among the general public.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Visit from Yutaro Hirao, Master Student at University of Tokyo (topic: “Virtual Embodiment”). Feb. 2019.
- Visit from Felix Putze, Researcher at University of Bremen (topic: “BCI and AR”). Feb. 2019.

- Visit from Franz Fischnaller, Professor at Academia of Fine Arts Albertina, Torino, Italy (topic: “Cultural Heritage”). From Jun. until Jul. 2019
- Visit from Marie-Anne Paradis, Master Student at University Laval, Québec, Canada (topic: “Cultural Heritage”). From Sept. 2018 until Mar. 2019.
- Visit from Nadia Zenati, Researcher at CDTA, Algeria (topic: “VR and AR”). Oct. 2019

9.5.2. Visits to International Teams

- Jean-Marie Normand spent 2 weeks (1 week in July 2019 and 1 week in September 2019) in the Augmented Vision Laboratory, Tokyo Institute of Technology, Tokyo, Japan.
- Valérie Gouranton and Ronan Gaugne spent 2 weeks, in May 2019, in the Eau-Terre-Environment laboratory of INRS, Québec, Canada where they presented INTROSPECT results in the GMPCA conference organized by the University of Montreal, and in the days of the Canadian Association of Archaeology, organized by the University Laval of Québec.

9.5.2.1. Research Stays Abroad

- Etienne Peillard spent 4 months (from June to October 2019) in the Augmented Vision Laboratory, Tokyo Institute of Technology, Tokyo, Japan.
- Flavien Lécuyer spent 3 months (From May to August 2019) in Vision and Numeric Systems Laboratory (LVSN), Québec, Canada.

LACODAM Project-Team

9. Partnerships and Cooperations

9.1. National Initiatives

- **HyAIAI: Hybrid Approaches for Interpretable AI**
  Participants: E. Fromont (leader), A. Termier, L. Galárraga
  The Inria Project Lab HyAIAI is a consortium of Inria teams (Sequel, Magnet, Tau, Orpailleur, Multispeech, and LACODAM) that work together towards the development of novel methods for machine learning, that combine numerical and symbolic approaches. The goal is to develop new machine learning algorithms such that (i) they are as efficient as current best approaches, (ii) they can be guided by means of human-understandable constraints, and (iii) its decisions can be better understood.
- **Hyptser: Hybrid Prediction of Time Series**
  Participants: T. Guyet, S. Malinowski (LinkMedia), V. Lemaire (Orange)
  HYPTSER is a collaborative project between Orange Labs and LACODAM funded by the Fondation Mathématique Jacques Hadamard (PGMO program). It aims at developping new hybrid time series prediction methods in order to improve capacity planning for server farms. Capacity planning is the process of determining the infrastructure needed to meet future customer demands for online services. A well-made capacity planning helps to reduce operational costs, and improves the quality of the provided services. Capacity planning requires accurate forecasts of the differences between the customer demands and the infrastructure theoretical capabilities. The HYPTSER project makes the assumption that this information is captured by key performance indicators (KPI), that are measured continuously in the service infrastructure. Thus, we expect to improve capacity planning capabilities by making accurate forecasts of KPI time series. Recent methods about time series forecasting make use of ensemble models. In this project, we are interested in developing hybrid models for time series forecasting. Hybrid models aim at jointly partitioning the data, learning forecasting models in each partition and learning how to combine their outputs. We are currently developing two different approaches for that purpose, one based on the MODL framework and the other based on neural networks. We describe these approaches below:
  - MODL is a mathematical framework that turns the learning task into a model selection problem. It aims at finding the most probable model given the data. The MODL approach has been applied on numerous learning tasks. In all cases, this approach leads to a regularized optimization criterion. We formalize a new MODL criterion able to learn hybrid models on time series in order to: i) make a partition of time series; ii) learn local regression models. This approach formalizes these two steps in a unified way.
  - We are also developing an hybrid neural network structure that is able to learn automatically a soft partitioning of the data together with local models on each partition.

  In the next steps of this project, we will analyze the performance of this two strategies on KPI time series provided by Orange and compare them to classical ensemble methods.
- **#DigitAg: Digital Agriculture**
  Participants: A. Termier, V. Masson, C. Largouët, A.I. Graux
  #DigitAg is a "Convergence Institute" dedicated to the increasing importance of digital techniques in agriculture. Its goal is twofold: First, make innovative research on the use of digital techniques in agriculture in order to improve competitiveness, preserve the environment, and offer correct living conditions to farmers. Second, prepare future farmers and agricultural policy makers to successfully exploit such technologies. While #DigitAg is based on Montpellier, Rennes is a satellite of the institute focused on cattle farming.

LACODAM is involved in the "data mining" challenge of the institute, which A. Termier co-leads. He is also the representative of Inria in the steering comittee of the institute. The interest for the team is to design novel methods to analyze and represent agricultural data, which are challenging because they are both heterogeneous and multi-scale (both spatial and temporal).

9.1.1. ANR

- **FAbLe: Framework for Automatic Interpretability in Machine Learning**
  Participants: L. Galárraga (holder), C. Largouët
  How can we fully automatically choose the best explanation for a given use case in classification?. Answering this question is the raison d'être of the JCJC ANR project FAbLe. By "best explanation" we mean the explanation that yields the best trade-off between interpretability and fidelity among a universe of possible explanations. While fidelity is well-defined as the accuracy of the explanation w.r.t the answers of the black-box, interpretability is a subjective concept that has not been formalized yet. Hence, in order to answer our prime question we first need to answer the question: "How can we formalize and quantify interpretability across models?". Much like research in automatic machine learning has delegated the task of accurate model selection to computers [26], FAbLe aims at fully delegating the selection of interpretable explanations to computers. Our goal is to produce a suite of algorithms that will compute suitable explanations for ML algorithms based on our insights of what is interpretable. The algorithms will choose the best explanation method based on the data, the use case, and the user's background. We will implement our algorithms so that they are fully compatible with the body of available software for data science (e.g., Scikit-learn).

9.1.2. National Platforms

- **PEPS: Pharmaco-epidemiology for Health Products**
  Participants: J. Bakalara, Y. Dauxais, T. Guyet, V. Masson, R. Quinou, A. Samet
  The PEPS project (Pharmaco-epidemiology des Produits de Santé) is funded by the ANSM (National Agency for Health Security). The project leader is E. Oger from the clinical investigation center CIC-1414 INSERM/CHU Rennes. The other partners located in Rennes are the Institute of Research and Technology (IRT), B<>Com, EHESP and the LTSI. The project started in January 2015 and is funded for 4 years. The PEPS project consists of two parts: a set of clinical studies and a research program dedicated to the development of innovative tools for pharmaco-epidemiological studies with medico-administrative databases. Our contribution to this project will be to propose pattern mining algorithms and reasoning techniques to analyse the typical care pathways of specific groups of insured patients. Since last year we have been working on the design and development of algorithms [25], [24] to mine patterns on care pathways.

9.2. International Research Visitors

9.2.1. Internships

From September to December 2019 we hosted Vaishnavi Bhargava, a computer science student from the Birla Institute of Technology and Science in Pilani, who worked on "Automatic Neighborhood Design for Localized Model-interpretation". Her work aimed at finding a set of metrics and procedures to determine the best parameterization of the method LIME for local post-hoc interpretability of machine learning models. The goal of this effort is to inform users of the parameter values (if any) for which a LIME explanation should be trusted because it can faithfully reproduce the behavior of the black-box it tries to explain.

LINKMEDIA Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Computer vision for smart phones (MobilAI)

Participants: Yannis Avrithis, Mateusz Budnik.

Duration: 2 years, started in September 2018
Partners: Lamark, Quai des Apps, AriadNext

The ability of our mobile devices to process visual information is currently not limited by their camera or computing power but by the network. Many mobile apps suffer from long latency due to data transmitted over the network for visual search. MobilAI aims to provide fast visual recognition on mobile devices, offering quality user experience whatever the network conditions. The idea is to transfer efficient deep learning solutions for image classification and retrieval onto embedded platforms such as smart phones. The intention is to use such solutions in B2B and B2C application contexts, for instance recognizing products and ordering online, accessing information about artifacts in exhibitions, or identifying identity documents. In all cases, visual recognition is performed on the device, with minimal or no access to the network.

9.1.2. CominLabs Project BigCLIN

Participants: Vincent Claveau, Ewa Kijak, Clément Dalloux.

Duration: 3 years, started in September 2016
Partners: STL-CNRS, Inserm/CHU Rennes, Inria
URL: https://bigclin.cominlabs.u-bretagneloire.fr/fr

Data collected or produced during clinical care process can be exploited at different levels and across different domains. Yet, a well-known challenge for secondary use of health big data is that much of detailed patient information is embedded in narrative text, mostly stored as unstructured data. The project proposes to address the essential needs when reusing unstructured clinical data at a large scale. We propose to develop new clinical records representation relying on fine-grained semantic annotation thanks to new NLP tools dedicated to French clinical narratives. To efficiently map this added semantic information to existing structured data for further analysis at big scale, the project also addresses distributed systems issues: scalability, management of uncertain data and privacy, stream processing at runtime, etc.

9.2. National Initiatives

9.2.1. Inria Project Lab Knowledge-driven data and content collaborative analytics (iCODA)

Participants: Laurent Amsaleg, Cheikh Brahim El Vaigh, Guillaume Gravier, Cyrielle Mallart, Pascale Sébillot.

Duration: 4.5 years, started in April 2017
Partners: Inria project-teams Linkmedia, CEDAR, GraphIK and ILDA, with Ouest-France, Le Monde and AFP

One of today's major issues in data science is the design of algorithms that allow analysts to efficiently infer useful information and knowledge by collaboratively inspecting heterogeneous information sources, from structured data to unstructured content. Taking data journalism as an emblematic use-case, the goal of the project is to develop the scientific and technological foundations for knowledge- mediated user-in-the-loop collaborative data analytics on heterogeneous information sources, and to demonstrate the effectiveness of the approach in realistic, high-visibility use-cases. The project stands at the crossroad of multiple research fields—content analysis, data management, knowledge representation, visualization—that span multiple Inria themes, and counts on a club of major press partners to define usage scenarios, provide data and demonstrate achievements.

9.2.2. Inria-BNF: Classification d'images patrimoniales (CIP)

Participants: Florent Michel, Laurent Amsaleg, Guillaume Gravier, Ewa Kijak, Yannis Avrithis.

Duration: 1 year, started in Dec 2018

This project is within the context of the collaborations between Inria and the French Ministry of Culture. In that context, we have started a collaboration with the French National Library (BNF) which collects, preserves and makes known the national documentary heritage. This collaboration aims at facilitating the automatic classification of heritage images through the use of recent deep-learning techniques. Such images are quite specific: they are not at all similar with what deep-learning techniques are used to work with, that is, the classification of heritage images does not target modern categories such as planes, cars, cats and dogs because this is irrelevant and because heritage collections do not include images of contemporary objects. Furthermore, heritage images come in vast quantities, but they are little annotated and deep-learning techniques can hardly rely on massive annotations to easily learn. Last, the learning has to be continuous as curators may need to add or modify existing classes, without re-learning everything from scratch.

The techniques of choice to reach that goal include the semi-supervised learning, low-shot learning techniques, knowledge transfer, fine tuning existing models, etc.

9.2.3. ANR Archival: Multimodal machine comprehension of language for new intelligent interfaces of scientific and cultural mediation

Participants: Laurent Amsaleg, Guillaume Gravier, Pascale Sébillot.

Duration: 3.5 year, started in Dec. 2019

The multidisciplinary and multi-actor ARCHIVAL project aims at yielding collaborations between researchers from the fields of Information and Communication Sciences as well as Computer Sciences around archive value enhancing and knowledge sharing for arts, culture and heritage. The project is structured around the following questionings: What part can machine comprehension methods play towards the reinterpretation of thematic archive collections? How can content mediation interfaces exploit results generated by current AI approaches?

ARCHIVAL teams will explore heterogeneous document collection structuration in order to explicitly reveal implicit links, to explain the nature of these links and to promote them in an intelligible way towards ergonomic mediation interfaces that will guarantee a successful appropriation of contents. A corpus has been delimited from the FMSH "self-management" collection, recently awarded as Collex, which will be completed from the large Canal-U academic audiovisual portal. The analysis and enhancement of this collection is of particular interest for Humanities and Social Sciences in a context where it becomes a necessity to structurally reconsider new models of socioeconomic development (democratic autonomy, social and solidarity-based economy, alternative development,...).

9.3. European Initiatives

9.3.1. EIT Digital CREEP2

Program: EIT Digital

Project acronym: CREEP 2

Project title: Cyberbullying effects prevention

Duration: 01/2019 - 12/2019

Coordinator: FBK, Italy

Other partners: Expert Systems (IT), Inria (FR), Engineering (IT)

Abstract: Project CREEP (Cyberbulling Effects Prevention) aims at identifying and preventing the possible negative impacts of cyberbullying on young people. It seeks to realise advanced technologies for the early detection of cyberbullying phenomena through the monitoring of social media and the communication of preventive advices and personalized recommendations tailored to adolescents' needs through a virtual coaching system (chatbot).

9.3.2. JPI CH READ-IT

Program: Joint Programming Initiative on Cultural Heritage

Project acronym: READ-IT

Project title: Reading Europe Advanced Data Investigation Tool

Duration: 05/2018 - 04/2021

Coordinator: Université Le Mans (FR)

Other partners: CNRS-IRISA (FR), Open University (UK), Universiteit Utrecht (NL), Institute of Czech Litterature (CZ)

Abstract: READ-IT is a transnational, interdisciplinary R&D project that will build a unique large-scale, user- friendly, open access, semantically-enriched investigation tool to identify and share groundbreaking evidence about 18th-21st century Cultural Heritage of reading in Europe. READ-IT will ensure the sustainable and reusable aggregation of qualitative data allowing an in-depth analysis of the Cultural Heritage of reading. State-of-the art technology in Semantic Web and information systems will provide a versatile, end-users oriented environment enabling scholars and ordinary readers to retrieve information from a vast amount of community-generated digital data leading to new understanding about the circumstances and effects of reading in Europe.

9.3.3. CHIST-ERA ID_IOT

Program: CHIST ERA

Project acronym: ID_IOT

Project title: Identification for the Internet of things

Duration: 3 years, started in Oct 2016.

Coordinator: Boris Skoric (Eindhoven Univ. of Technology (NL))

Other partners: Inria-RBA (Teddy Furon, Marzieh Gheisari Khorasgani), Univ. of Geneva (CH)

Abstract: The IoT will contain a huge number of devices and objects that have very low or nonexistent processing and communication resources, coupled to a small number of high-power devices. The weakest devices, which are most ubiquitous, will not be able to authenticate themselves using cryptographic methods. This project addresses these issues using physical unclonable functions (PUFs). PUFs, and especially quantum readout PUFs, are ideally suited to the IoT setting because they allow for the authentication and identification of physical objects without requiring any crypto or storage of secret information.

Furthermore, we foresee that back-end systems will not be able to provide security and privacy via cryptographic primitives due to the sheer number of IoT devices. Our plan is to address these problems using privacy preserving database structures and algorithms with good scaling behaviour. Approximate nearest neighbour (ANN) search algorithms, which have remarkably good scaling behaviour, have recently become highly efficient, but do not yet have the right security properties and have not yet been applied to PUF data. Summarised in a nutshell, the project aims to improve the theory and practice of technologies such as PUFs and ANN search in the context of generic IoT authentication and identification scenarios.

9.3.4. Collaborations with Major European Organizations

Program: ConFAP-CNRS Project

Project acronym: FIGTEM

Project title: FIne-Grain TExt Mining for clinical data

Duration: 01/2016 - 05/2019

Coordinator: CNRS-IRISA

Other partners: PUCPR, Curitiba, Brasil; CNRS-STL Lille; Inserm LTSI/CHU Rennes

Abstract: FIGTEM is a research project that involves STL-CNRS, CHU Rennes, PUC Parana, Curitiba and led by LINKMEDIAThis project aimed at developing natural language processing methods, including information extraction and indexing, dedicated to the clinical trial domain. The goal was to populate a formal representation of patients (via their electronic patient records) and clinical trial data in different languages (French, English, Portuguese). The main outcomes of the project was NLP tools for these 3 languages and annotated datasets made available for research purposes. It ended in May 2019.

9.4. International Initiatives

9.4.1. Inria International Partners

9.4.1.1. Informal International Partners

- Michael Houle, NII, Japan
- Marcel Worring, UvA, Netherlands
- Martha Larson, Radboud U., Netherlands

9.4.2. Participation in Other International Programs

9.4.2.1. STIC AmSud TRANSFORM

Program: STIC AmSud

Project acronym: TRANSFORM

Project title: Transforming multimedia data for indexing and retrieval purposes

Duration: 01/2018 - 31/2019

Partners: CNRS-IRISA (FR), PUC Minas (BR), UChile (CL)

9.4.2.2. CAPES/COFECUB HIMMD

Program: CAPES/COFECUB

Project acronym: HIMMD

Project title: Hierarchical graph-based analysis of image, video, and multimedia data

Duration: 01/2019 - 31/2022

Partners: LIGM (FR), IRISA (FR), INPG (FR), PUC Minas (BR), UNICamp (BR), UFMG (BR)

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Silvio Guimaraes (PUC Minas, Brazil) visited the team in July (1 week). His visit was related to the Stic-Amsud project.
- Benjamin Bustos (Univ. Chile, Chile) visited the team in July (1 week). His visit was related to the Stic-Amsud project.

9.5.2. Visits to International Teams

9.5.2.1. Research Stays Abroad

- Yannis Avrithis, National and Kapodistrian University of Athens, 3 visits on April (1 week), June (1 week) and September-October 2019 (3 weeks).

MIMETIC Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. Liv-Lab Breizh Digital Sport

Participants: Richard Kulpa [contact], Benoit Bideau, Franck Multon.

Our project aims, through new virtual reality and augmented reality technologies, to bring people who do not practice physical activity back into sport, whether for economic reasons, or for issues related to social and/or geographical isolation. To achieve this, the Brittany Region, accompanied by identified partners with complementary skills, proposes the development and networking of dedicated rooms at regional level. These existing rooms are chosen to be as close as possible to the target population, i.e. in priority areas: in the City Political District (QPV) for Rennes and Brest, and in the Rural Area to be Revitalized (ZRR) for Auray and Rostrenen. They will be redesigned to integrate these new technologies and attract target populations through the development of remote entertainment and collaborative applications. Indeed, the rooms will be connected to each other allowing participants to train together and create a community of practitioners. They will be equipped with simple sensors to evaluate their practices using a multidisciplinary cross-disciplinary approach, with biomechanical, physiological and psychological analyses (M2S/MimeTIC, CREAD and VIPS^2 laboratories). These evaluations will be used to propose physical activities that are progressive and adapted to the level of the practitioner. Access to objective data on their performance will be an additional motivating factor to keep these target audiences active. Support to local structures will allow them to extend their sporting experience after leaving Liv-Lab. Finally, subjects suffering from pathologies that are too disabling will be redirected to a health network, such as Rennes in the Living Lab ISAR (Innovation Santé Autonomie Rennes).

9.2. National Initiatives

9.2.1. ANR

9.2.1.1. ANR PRCE Cineviz

Participants: Marc Christie [contact], Quentin Galvane.

Cineviz is a 3-year ANR LabCom project (2016-2019). Amount: 300kE. Parnters: SolidAnim, UR1.

The project is a bilateral collaboration with the SolidAnim company. The objective is to jointly progress on the design and implementation of novel tools for the preproduction in the film industry. The project will address the challenges related to (i) proposing expressive framing tools, (ii) integrating the technical aspects of shooting (how to place the cameras, lights, green sets) directly at the design stage), and (iii) novel interaction metaphors for designing and controlling the staging of lights in preproduction, using an example-based approach.

9.2.1.2. ANR PRC Capacities

Participants: Charles Pontonnier [contact], Georges Dumont, Pierre Puchaud, Claire Livet, Anthony Sorel.

This project is leaded by Christophe Sauret, from INI/CERAH. The project objective is to build a series of biomechanical indices characterizing the biomechanical difficulty for a wide range of urban environmental situations. These indices will rely on different biomechanical parameters such as proximity to joint limits, forces applied on the handrims, mechanical work, muscle and articular stresses, etc. The definition of a more comprehensive index, called Comprehensive BioMechanical (CBM) cost, including several of the previous indices, will also be a challenging objective. The results of this project would then be used in the first place in VALMOBILE application to assist MWC users in selecting optimal route in Valenciennes agglomeration (project founded by the French National Agency for Urban Renewal and the North Department of France). The MimeTIC team is involved on the musculoskeletal simulation issues and the biomechanical costs definition.

9.2.1.3. ANR JCJC Per2

Participants: Ludovic Hoyet [contact], Benjamin Niay, Anne-Hélène Olivier, Richard Kulpa, Franck Multon.

Per2 is a 42-month ANR JCJC project (2018-2022) entitled *Perception-based Human Motion Personalisation* (Budget: 280kE; website: https://project.inria.fr/per2/)

The objective of this project is to focus on how viewers perceive motion variations to automatically produce natural motion personalisation accounting for inter-individual variations. In short, our goal is to automate the creation of motion variations to represent given individuals according to their own characteristics, and to produce natural variations that are perceived and identified as such by users. Challenges addressed in this project consist in (i) understanding and quantifying what makes motions of individuals perceptually different, (ii) synthesising motion variations based on these identified relevant perceptual features, according to given individual characteristics, and (iii) leveraging even further the synthesis of motion variations and to explore their creation for interactive large-scale scenarios where both performance and realism are critical.

This work is performed in collaboration with Julien Pettré from Rainbow team.

9.2.1.4. ANR PRCI HoBis

Participants: Franck Multon [contact], Armel Crétual, Georges Dumont, Charles Pontonnier, Anthony Sorel.

Hobis is a 42-month ANR collaborative (PRCI) project (2018-2022) entitled *Hominin BipedalismS: Exploration of bipedal gaits in Hominins thanks to Specimen-Specific Functional Morphology*. HoBis is leaded by the Museum Nationale d'Histoires Naturelles (CNRS), with CNRS/LAAS, and Antwerpen University (Belgium), with a total of 541KE budget (140KE for MimeTIC).

HoBiS (Hominin BipedalismS) is a pluridisciplinary research project, fundamental in nature and centred on palaeoanthropological questions related to habitual bipedalism, one of the most striking features of the human lineage. Recent discoveries (up to 7 My) highlight an unexpected diversity of locomotor anatomies in Hominins that lead palaeoanthropologists to hypothesize that habitual bipedal locomotion took distinct shapes through our phylogenetic history. In early Hominins, this diversity could reveal a high degree of locomotor plasticity which favoured their evolutionary success in the changing environments of the late Miocene and Pliocene. Furthermore, one can hypothesize based on biomechanical theory that differences in gait characteristics, even slight, have impacted the energy balance of hominin species and thus their evolutionary success. However, given the fragmented nature of fossil specimens , previous morphometric and anatomo-functional approaches developed by biologists and palaeoanthropologists, do not allow the assessment of the biomechanical and energetic impacts of such subtle morphological differences, and the manners in which hominin species walked still remains unknown. To tackle this problem, HoBiS proposes as main objective a totally new specimen-specific approach in evolutionary anthropology named Specimen-Specific Functional Morphology: inferring plausible complete locomotor anatomies based on fossil remains, to link these reconstructed anatomies and corresponding musculoskeletal models (MSM) with plausible gaits using simulations. Both sub-objectives will make use of an extensive comparative anatomical and gait biomechanical data bases (challenges). To this end, we will integrate anatomical and functional studies, tools for anatomical modelling, optimization and simulation rooted in informatics, biomechanics, and robotics, to build an in-silico decision-support system (DSS). This DSS will provide biomechanical simulations and energetic estimations of the most plausible bipedal gaits for a variety of hominin species based on available remains, from partial to well-preserved specimens. To achieve this main objective, the project will address the following sub-objectives and challenges

MimeTIC is Leader of WP3 "Biomechanical simulation", aiming at predicting plausible bipedal locomotion based on paleoanthropological heuristics and a given MSM.

9.2.1.5. Labex CominLabs : Moonlight

Participants: Guillaume Nicolas [contact], Nicolas Bideau.

Moonlight is a 2-year Labex Cominlabs project (2018-2019). Amount: 55kE (including a one-year postdoctoral fellowship). Partners: Granit Team IRISA (http://www-granit.irisa.fr/fr/), M2S Lab.

The Moonlight project is part of an effort to transpose the tools and methodologies used in motion capture from optoelectronic equipment to inertial unit devices. More specifically, the overall objective of Moonlight project is to design a new embedded system in order to analyze cyclists' movements in real conditions, i.e. outside of the laboratory. This requires to estimate reliable 3D joint angles, lower limb kinematics and pedals orientation. IMUs are used as an alternative to optoelectronical motion capture but some challenges have to be addressed as regards to sensor-to-segment misalignment and drift. Indeed, a real time accurate orientation of the crank is necessary to get limb position. To achieve this goal, data fusion algorithms between IMU data and pedal orientation are implemented. A wireless sensor network with accurate time synchronization mechanism is needed to process data fusion from all sensor's nodes on a tablet. Finally, the system deals with size, energy consumption and ease-to-use constraints.

9.2.2. National scientific collaborations

9.2.2.1. Cavaletic

Participant: Franck Multon [contact].

The Cavaletic collaborative project is leaded by University Bretagne Sud and also involves University Rennes2 (CREAD Lab.). It has been funded by the National IFCE (Institut Français du Cheval et de l'Equitation) in order to develop and evaluate technological assistance in horse riding learning, thanks to a user-centered approach. MimeTIC is involved in measuring expert and non-expert horse riders' motions in standardized situations in order to develop metrics to measure riders' performance. It will be used to develop a technological system embedded on users to evaluate their performance and provide them with real-time feedback to correct potential errors.

The project funded by IFCE ended in 2018 but we got a 30K€ budget from SATT Ouest Valorisation in order to finish the development of the technological prototype, and to evaluate the possibility to patent the process, and transfer it to private companies. This project is in collaboration with LEGO lab. in University Bretagne Sud, and CAIRN Inria team.

9.2.2.2. French Federation of Tennis

Participants: Richard Kulpa [contact], Benoit Bideau, Pierre Touzard.

An exclusive contract has been signed between the M2S laboratory and the French Federation of Tennis for three years. The goal is to perform biomechanical analyses of 3D tennis serves on a population of 40 players of the Pôle France. The objective is to determine the link between injuries and biomechanical constraints on joints and muscles depending on the age and gender of the players. At the end, the goal is to evaluate their training load.

9.2.3. Chaire Safran-Saint-Cyr "the enhanced soldier in the digital battlefield"

Participants: Charles Pontonnier [contact], Pierre Puchaud.

The chaire has the goal to answer to scientific questions accompanying the evolution of the technologies equipping the soldiers in mission. In this scheme, the MimeTIC team is involved in generic and specific musculoskeletal models for the prototyping of load carriage assistive devices (exoskeletons). Chair sponsored by SAFRAN group, led by Yvon Erhel (Professor, Ecoles de Sainr-Cyr Coëtquidan).

9.2.4. AUTOMA-PIED

Participants: Anne-Hélène Olivier [contact], Armel Crétual, Anthony Sorel.

The AUTOMA-PIED project is driven by IFSTTAR. Using a set-up in virtual reality, the first objective of the project aims at comparing pedestrian behaviour (young and older adults) when interacting with traditional or autonomous vehicles in a street crossing scenario. The second objective is to identify postural cues that can predict whether or not the pedestrian is about to cross the street.

9.2.5. IPL Avatar

Participants: Ludovic Hoyet [contact], Franck Multon.

This project aims at design avatars (i.e., the user's representation in virtual environments) that are better embodied, more interactive and more social, through improving all the pipeline related to avatars, from acquisition and simulation, to designing novel interaction paradigms and multi-sensory feedback. It involves 6 Inria teams (GraphDeco, Hybrid, Loki, MimeTIC, Morpheo, Potioc), Prof. Mel Slater (Uni. Barcelona), and 2 industrial partners (InterDigitak and Faurecia).

Website: http://avatar.inria.fr

9.3. European Initiatives

9.3.1. FP7 & H2020 Projects

9.3.1.1. H2020 ICT-25 PRESENT

Participants: Marc Christie, Ludovic Hoyet [contact], Anne-Hélène Olivier, Alberto Jovane, Adèle Colas.

This European project aims at creating virtual characters that are realistic in looks and behaviour, and who can act as trustworthy guardians and guides in the interfaces for AR, VR and more traditional forms of media. It is conducted in collaboration with industrial partners The Framestore Ltd, Cubic Motion Ltd, InfoCert Spa, Brainstorm Multimedia S.L., Creative Workers - Creatieve Werkers VZW, and academic partners Universidad Pompeu Fabra and Universität Augsburg.

9.3.1.2. JPI-CH SCHEDAR

Participants: Franck Multon [contact], Richard Kulpa.

SCHEDAR (Safeguarding the Cultural HEritage of Dance through Augmented Reality) is a Joint Program Initiative for preserving immaterial cultural heritage. The project started in June 2018 and will finish December 2021. It is coordinated by University of Cyprus, in collaboration with Algolysis LTD (Cyprus), University of Warwick (UK), University of Reims Champagne Ardennes (France).

Dance is an integral part of any culture. Through its choreography and costumes dance imparts richness and uniqueness to that culture. Over the last decade, technological developments have been exploited to record, curate, remediate, provide access, preserve and protect tangible CH. However, intangible assets, such as dance, has largely been excluded from this previous work. Recent computing advances have enabled the accurate 3D digitization of human motion. Such systems provide a new means for capturing, preserving and subsequently re-creating ICH which goes far beyond traditional written or imaging approaches. However, 3D motion data is expensive to create and maintain, encompassed semantic information is difficult to extract and formulate, and current software tools to search and visualize this data are too complex for most end-users. SCHEDAR will provide novel solutions to the three key challenges of archiving, re-using and re-purposing, and ultimately disseminating ICH motion data. In addition, we will devise a comprehensive set of new guidelines, a framework and software tools for leveraging existing ICH motion databases. Data acquisition will be undertaken holistically; encompassing data related to the performance, the performer, the kind of the dance, the hidden/untold story, etc. Innovative use of state-of-the-art multisensory Augmented Reality technology will enable direct interaction with the dance, providing new experiences and training in traditional dance which is key to ensure this rich culture asset is preserved for future generations. MimeTIC is responsible for WP3 "Dance Data Enhancement".

9.4. International Initiatives

9.4.1. Inria Associate Teams Not Involved in an Inria International Labs

9.4.1.1. BEAR

Title: from BEhavioral Analysis to modeling and simulation of interactions between walkeRs

International Partner: Michael Cinelli (Wilfrid Laurier University, Canada) and Michael Barnett Cowann (University of Waterloo, Canada)

Start year: 2019

See also: https://sites.google.com/view/inriabearproject/home

Interactions between individuals are by definition at the very core of our society since they represent the basic synergies of our daily life. When walking in the street or in more dynamical and strategic situations such as sports motion, we take in information about our surrounding environment in order to interact with people, move without collision, alone or in a group, intercept, meet or escape other people. In this context, the BEAR project is a collaboration between researchers from Inria Rennes (Computer Sciences) and Waterloo universities (Kinesiology-Neuroscience). The project aims at providing more realistic models and simulations of interactions between pedestrians, for various applications such as rehabilitation, computer graphics, or robotics. The originality of the project is to investigate the complexity of human interactions from a human motor control perspective, considering the strong coupling between pedestrians' visual perception and their locomotor adaptations. We will investigate how people gather the relevant information to control their motion. To provide generic models considering the inter-individual variability of humans, we will consider both normal populations and specific populations (children, older adults, injured, diseased ...) for whom an altered perception can modify their motion. The strength of this project is the complementarity of theinvolved teams. While all researchers will equally perform experiments on interactions between pedestrians, the researchers from Waterloo will take the lead to identify the relevant behavioral variables that will be used mainly by the researchers from Rennes to design the new models and simulations.

9.4.2. International Mobility Grant

- Mitacs Globalink grant: Perception-Action Integration in Collision Avoidance in Older Adults, Robyn Grundberg, University Wilfrid Laurier, Canada (April-July 2019)
- Mitacs Globalink grant: Influence of walking speed and trunk sway on collision avoidance with a virtual human, Sheryl Bourgaize, University Wilfrid Laurier, Canada (April-July 2019).

9.4.3. Inria International Partners

9.4.3.1. Informal International Partners

- Dr. Rachel McDonnell, Trinity College Dublin, Ireland (on-going collaboration with Ludovic Hoyet)
- Prof. Carol O Sullivan, Trinity College Dublin, Ireland (on-going collaboration with Ludovic Hoyet)
- Prof Michael Cinelli, University Wilfrid Laurier, Waterloo, Canada (on-going collaboration with Anne-Hélène Olivier)
- Prof Michael Barnet-Cowann, University of Waterloo, Waterloo, Canada (on-going collaboration with Anne-Hélène Olivier)
- Prof. Hui Huang, Shenzhen University (on-going collaboration with Marc Christie)
- Prof. Baoquan Chen, Pekin University (on-going collaboration with Marc Christie)
- Dr. Bin Wang, Beijing Film Academy University (on-going collaboration with Marc Christie)

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Michael Barnett-Cowan (from Waterloo University, Canada): Visiting Professor, Research Chair of America, Rennes 2 (September 2019): multisensory integration of perceptual information.
- Kristoffer Larsen Norheim (from Aalborg University, Denmark): Doctoral stay (September-November 2019): biomechanical analysis of virtual hammering tasks.

9.5.1.1. Internships

- Sheryl Bourgaize, PhD Student, Wilfrid Laurier University, Canada (April-July 2019)
- Robyn Grunberg, Master Student, Wilfrid Laurier University, Canada (April-July 2019)

9.5.2. Visits to International Teams

9.5.2.1. Research Stays Abroad

- Simon Hilt: doctoral stay at Aalborg University Denmark (May-July 2019): biomechanical analysis of hammering tasks.

PANAMA Project-Team

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. Labex Comin Labs projects

ComInLabs is a Laboratoire d'Excellence funded by the PIA (Programme Investissements d'Avenir) in the broad area of telecommunications.

- **HEMISFER (2014-2017) and HEMISFER-CLINICAL (2018-2019)**
  Participant: Rémi Gribonval.

  Acronym: HYBRID (Hybrid Eeg-MrI and Simultaneous neuro-feedback for brain Rehabilitation)

  http://hemisfer.cominlabs.u-bretagneloire.fr/

  Research axis: 3.1

  ComInLabs partners : EMPENN, HYBRID and PANAMA Inria project-teams;

  External partners : EA 4712 team from University of Rennes I; ATHENA Inria project-team, Sophia-Antipolis;

  Coordinator: Christian Barillot, EMPENN Inria project-team

  Description: The goal of HEMISFER is to make full use of neurofeedback paradigm in the context of rehabilitation and psychiatric disorders. The major breakthrough will come from the use of a coupling model associating functional and metabolic information from Magnetic Resonance Imaging (fMRI) to Electro-encephalography (EEG) to "enhance" the neurofeedback protocol. We propose to combine advanced instrumental devices (Hybrid EEG and MRI platforms), with new man-machine interface paradigms (Brain computer interface and serious gaming) and new computational models (source separation, sparse representations and machine learning) to provide novel therapeutic and neuro-rehabilitation paradigms in some of the major neurological and psychiatric disorders of the developmental and the aging brain (stroke, attention-deficit disorder, language disorders, treatment-resistant mood disorders, ...).

  Contribution of PANAMA: PANAMA, in close cooperation with the EMPENN team, contributes to a coupling model between EEG and fMRI considered as a joint inverse problem addressed with sparse regularization. By combining both modalities, one expects to achieve a good reconstruction both in time and space. This new imaging technique will then be used for improving neurofeedback paradigms in the context of rehabilitation and psychiatric disorders, which is the final purpose of the HEMISFER project.

- **TEPN**
  Participant: Rémi Gribonval.

  Acronym: TEPN (Toward Energy Proportional Networks)

  http://tepn.cominlabs.u-bretagneloire.fr/

  Research axis: 3.1

  ComInLabs partners : IRISA OCIF - Telecom Bretagne; IETR SCN; IETR SCEE; PANAMA Inria project-team

  Coordinator: Nicolas Montavont, IRISA OCIF - Telecom Bretagne

Description: As in almost all areas of engineering in the past several decades, the design of computer and network systems has been aimed at delivering maximal performance without regarding to the energy efficiency or the percentage of resource utilization. The only places where this tendency was questioned were battery-operated devices (such as laptops and smartphones) for which the users accept limited (but reasonable) performance in exchange for longer use periods. Even though the end users make such decisions on a daily basis by checking their own devices, they have no way of minimizing their energy footprint (or conversely, optimize the network resource usage) in the supporting infrastructure. Thus, the current way of dimensioning and operating the infrastructure supporting the user services, such as cellular networks and data centers, is to dimension for peak usage. The problem with this approach is that usage is rarely at its peak. The overprovisioned systems are also aimed at delivering maximal performance, with energy efficiency being considered as something desired, but non-essential. This project aims at making the network energy consumption proportional to the actual charge of this network (in terms of number of served users, or requested bandwidth). An energy proportional network can be designed by taking intelligent decisions (based on various constraints and metrics) into the network such as switching on and off network components in order to adapt the energy consumption to the user needs. This concept can be summarized under the general term of Green Cognitive Network Approach.

Contribution of PANAMA: PANAMA, in close cooperation with the SCEE team at IETR (thesis of Marwa Chafii, 2016), focuses on the design of new waveforms for multi carrier systems with reduced Peak to Average Power Ratio (PAPR).

- **FAWI** (2019-2020)
  Fourier Adaptive Waveform Implementation
  Participant: Rémi Gribonval.
  - This project is a follow-up to TEPN. Its main goal is to implement a prototype demonstrating concretely the feasibility of the new Fourier Adaptive Waveform modulation which has been patented [62].
  - Contribution of PANAMA: to provide initial training to the recruited engineer in charge of the implementation.
  - *Partners: PANAMA, IETR.*
  - Funding: 18 months of engineer, hosted by IETR.
- **SPARSE** (2019)
  Sparse representations in continuous dictionaries
  Participants: Rémi Gribonval, Clément Elvira, Clément Merdrignac.
  - This short exploratory action aims to explore the new paradigm of sparse representations in "continuous" dictionaries.
  - Contribution of PANAMA: to design algorithms for the sparse representation problem in continuous dictionaries with theoretical success guarantees.
  - *Partners: PANAMA, SIMSMART (Inria-Rennes), ENSTA Bretagne, IMT Atlantique.*
  - Funding: 5.6kEuros (internship + travel)

8.1.2. ANR INVATE project with IRT b-com, Rennes

Participants: Rémi Gribonval, Nancy Bertin, Mohammed Hafsati.

Thesis on 3D audio scene decomposition for interactive navigation

Duration: 3 years (2016-2019)

Research axis: 3.2.2

Partners: IRT b<>com; Inria-Rennes; IRISA

Funding: ANR INVATE project (PIA)

The objective of this thesis is to develop tools to analyze audio scenes in order to identify, locate, and extract the sources present in the scene to re-spatialize them according to the user head orientation and the movement of the user in the targeted virtual scene.

8.1.3. ANR OATMIL project

Participants: Rémi Gribonval, Antoine Chatalic, Nicolas Courty.

Duration: 4 years (2017-2021)

Acronym: OATMIL (Bringing Optimal Transport and Machine Learning Together)

http://people.irisa.fr/Nicolas.Courty/OATMIL/

Research Axis 3.1

Partners: Obelix team and PANAMA Inria project-team, IRISA; LITIS, Rouen; Lagrange Laboratory, Nice; Technicolor R&I France, Rennes.

Coordinator: Nicolas Courty (Obelix team)

Description: The OATMIL project will propose novel concepts, methodologies, and new tools for exploiting large data collections. This will result from a cross-fertilization of fundamental tools and ideas from optimal transport (OT) and machine learning (ML). The main objective of OATMIL is to develop new techniques for large-scale machine learning, encompassing adaptability, scalability, and robustness, by a cross-fertilization of ideas coming from OT and ML. This cross-fertilization leads to two complementary scientific challenges : bringing OT to ML and bringing ML to OT.

Contribution of PANAMA: PANAMA will explore the use of dimension-reduction with sketching strategies in the context compressive optimal transport.

Funding: ANR

8.1.4. Collaboration with 5th dimension – dynamic separation of localized sound sources

Participants: Nancy Bertin, Ewen Camberlein, Romain Lebarbenchon.

Duration: 1 year (2018-2019)

Research axis: 3.2

Partner: 5^{th} dimension (https://5dimo.com/)

Funding: LABEX AMIEX (https://www.agence-maths-entreprises.fr/a/)

After a first phase of this contract which involved porting in C++ a subset of our source localization library Multichannel BSS Locate (Oct.-Nov. 2018, in collaboration with InriaTech), a second phase was realized in 2019 with support from LABEX AMIES. We specified and recorded new data adapted to the partner's use case (microphones on glasses temples) and investigated the interplay between localization and separation, using the FASST library, on simulated and real data recorded with a prototype.

8.2. International Initiatives

8.2.1. Inria International Partners

8.2.1.1. Informal International Partners

Nancy Bertin is "external collaborator" of the MERLIN project (project between the Acoustics Research Institute of the Austrian Academy of Sciences and the Signal Processing Laboratory at Brno University of Technology.)

8.3. International Research Visitors

8.3.1. Visits of International Scientists

8.3.1.1. Internships

- Pavel Záviška and Ondřej Mokrý, visiting students from Brno University of Technology, in December 2018 (within the MERLIN collaboration).
- Andersen Man Shun Ang, visiting student from University of Mons, in February 2019.

RAINBOW Project-Team

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. SAD WH-DRONE

Participants: Marco Aggravi, Claudio Pacchierotti.

no CNRS Rennes 181089, duration: 24 months.

This project funded by the Brittany council started in January 2019. It supports in part Marco Aggravi's research on using wearable interfaces for flying swarms of drones.

8.1.2. Allocation d'installation scientifique

Participant: Claudio Pacchierotti.

no CNRS Rennes 17C0487, duration: 36 months.

This grant from "Rennes Métropole" has been obtained in July 2017 and supports the activities related to the teleoperation of drones (quadrotor UAVs) using wearable haptics interfaces.

8.1.3. IRT Jules Verne Happy

Participant: François Chaumette.

no Inria Rennes 13521, duration: 36 months.

This project started in June 2018. It is managed by IRT Jules Verne in Nantes and achieved in cooperation with LS2N and Airbus. Its goal is to develop local sensor-based control methods for the assembly of large parts of aircrafts.

8.1.4. Prisme

Participants: Solenne Fortun, François Pasteau, Marie Babel.

no Insa Rennes 2017-0004, duration: 36 months.

This project started in January 2017 and is supported by Brittany region/BPI. This project aims at designing a fall prevention strategy based on the sensing collaboration of a smart wheelchair and a smart medical bed. Fall detection and automatic positioning of the wheelchair next to the bed issues are addressed (see Section 6.2.14).

8.1.5. Silver Connect

Participant: Marie Babel.

no Insa Rennes 2018-0076, duration: 34 months.

This project started in November 2018 and is supported by Brittany region/BPI as well as FEDER. This project aims at designing a fall detection framework by means of vision-based algorithms coupled with deep learning solutions.

8.1.6. Cartam

Participants: Noura Neji, Fabien Spindler, François Chaumette.

no Inria 13954 and 14041, duration: 36 months.

This project started in January 2019 and is supported by Brittany region and FEDER. It is managed by Triskalia with Unilet, Copeeks, Neotec Vision, Rainbow group, and our start-up Dilepix. It aims at designing a vision system able to detect adventices in a field. We are in charge of tracking the adventices once they are detected and of building a mosaic of the field for locating them.

8.2. National Initiatives

8.2.1. ANR PLaTINUM

Participant: Vincent Drevelle.

no Inria Sophia 10204, duration: 42 months.

This project started in November 2015. It involves a consortium managed by Litis in Rouen with IGN Matis (Paris), Le2i (Le Creusot) and Inria (Chorale group in Sophia-Antipolis and Rainbow). The project is focused on robust long-term mapping of urban environments. Map building consists in the acquisition of a textured 3-D model of urban environment, and automatic semantic labelling of the environment features (roads, buildings, cars, etc.). From this model, an optimal representation is generated and made available in the cloud, in the form of a network of RGB-D-L spheres storing photometry, geometry (depth) and object labels. Mobile agents are able to determine their position and navigate in the sphere graph using dense matching. Agents upload significant environment changes to the sphere server in cloud, for map update purposes.

8.2.2. ANR Sesame

Participant: François Chaumette.

no Inria 13722, duration: 48 months.

This project started in January 2019. It involves a consortium managed by LS2N (Nantes) with LIP6 (Paris) and Rainbow group. It aims at analysing singularity and stability issues in visual servoing.

8.2.3. Equipex Robotex

Participants: Fabien Spindler, François Chaumette.

no Inria Rennes 6388, duration: 9 years.

Rainbow is one of the 15 French academic partners involved in the Equipex Robotex network that started in February 2011. It is devoted to get and manage significant equipment in the main robotics labs in France. In the scope of this project, we have obtained the humanoid robot Romeo in 2015.

8.3. European Initiatives

FP7 & H2020 Projects

8.3.1. FP7 Space RemoveDEBRIS

Participants: Eric Marchand, François Chaumette.

Instrument: Specific Targeted Research Project

Duration: October 2013 - March 2019

Coordinator: University of Surrey (United Kingdom)

Partners: Surrey Satellite Technology (United Kingdom), Airbus (Toulouse, France and Bremen, Germany), Isis (Delft, The Netherlands), CSEM (Neuchâtel, Switzerland), Stellenbosch University (South Africa).

Inria contact: François Chaumette

Abstract: A huge amount of debris have progressively been generated since the beginning of the space era. Most of the objects launched into space are still orbiting the Earth and today these objects and their by-products represent a threat both in space and on Earth. In Space, debris lead to collisions and therefore to damages to operational satellites. For both issues, a credible solution has emerged over the recent years: actively removing heavy debris objects by capturing them and then either disposing them by destructive re-entry in Earth atmosphere or disposing them in graveyard orbits. The RemoveDEBRIS project aimed to demonstrate key technologies for ADR in three main domains by performing in-orbit demonstrations representative of an ADR mission. The specific key technologies that have been demonstrated as part of this project are: (i) Capture technologies such as nets and harpoons (ii) De-orbiting technologies such as electric propulsion and drag augmentation (iii) Proximity Rendezvous operations technologies based on vision-based navigation. The technology demonstrations has been carried in orbit using a micro satellite test-bed, a world's first. The micro satellite has carried the ADR payloads together with two deployable nanosatellites (CubeSats). Through a series of operations, the nanosatellites have been ejected, re-captured, inspected and de-orbited, thereby demonstrating the ADR key technologies [16], [8], [7]. Our goal in this long project was to develop and validate model-based tracking algorithms on images acquired during the actual space debris removal mission [47].

8.3.2. H2020 ICT Comanoid

Participants: Fabien Spindler, François Chaumette.

Title: Multi-contact Collaborative Humanoids in Aircraft Manufacturing

Programme: H2020

Duration: January 2015 - February 2019

Coordinator: CNRS (Lirmm)

Partners: Airbus Group (France), DLR (Germany), Università Degli Studi di Roma La Sapienza (Italy), CNRS (I3S)

Inria contact: François Chaumette

Abstract: Comanoid investigated the deployment of robotic solutions in well-identified Airbus airliner assembly operations that are laborious or tedious for human workers and for which access is impossible for wheeled or rail-ported robotic platforms. As a solution to these constraints a humanoid robot was proposed to achieve the described tasks in real-use cases provided by Airbus Group. At a first glance, a humanoid robotic solution appears extremely risky, since the operations to be conducted are in highly constrained aircraft cavities with non-uniform (cargo) structures. Furthermore, these tight spaces are to be shared with human workers. Recent developments, however, in multi-contact planning and control suggested that this is a much more plausible solution than current alternatives such as a manipulator mounted on multi-legged base. Indeed, if humanoid robots can efficiently exploit their surroundings in order to support themselves during motion and manipulation, they can ensure balance and stability, move in non-gaited (acyclic) ways through narrow passages, and also increase operational forces by creating closed-kinematic chains. Bipedal robots are well suited to narrow environments specifically because they are able to perform manipulation using only small support areas. Moreover, the stability benefits of multi-legged robots that have larger support areas are largely lost when the manipulator must be brought close, or even beyond, the support borders. COMANOID aimed at assessing clearly how far the state-of-the-art stands from such novel technologies. In particular the project focused on implementing a real-world humanoid robotics solution using the best of research and innovation. The main challenge was to integrate current scientific and technological advances including multi-contact planning and control; advanced visual-haptic servoing; perception and localization; human-robot safety, and the operational efficiency of cobotics solutions in airliner manufacturing [21].

8.3.3. H2020 ICT CrowdBot

Participants: Javad Amirian, Fabien Grzeskowiak, Solenne Fortun, Marie Babel, Julien Pettré, Fabien Spindler.

Title: Robot navigation in dense crowds

Programme: H2020

Duration: Jan 2018 - Jun 2021

Coordinator: Inria

Partners: UCL (UK), SoftBank Robotics (France), Univ. Aachen (Germany), EPFL (Switzerland), ETHZ (Switzerland), Locomotec (Germany)

Inria contact: Julien Pettré

Abstract: CROWDBOT will enable mobile robots to navigate autonomously and assist humans in crowded areas. Today's robots are programmed to stop when a human, or any obstacle is too close, to avoid coming into contact while moving. This prevents robots from entering densely frequented areas and performing effectively in these high dynamic environments. CROWDBOT aims to fill in the gap in knowledge on close interactions between robots and humans during navigation tasks. The project considers three realistic scenarios: 1) a semi-autonomous wheelchair that must adapt its trajectory to unexpected movements of people in its vicinity to ensure neither its user nor the pedestrians around it are injured; 2) the commercially available Pepper robot that must navigate in a dense crowd while actively approaching people to assist them; 3) the under development robot cuyBot will adapt to compact crowd, being touched and pushed by people. These scenarios generate numerous ethical and safety concerns which this project addresses through a dedicated Ethical and Safety Advisory Board that will design guidelines for robots engaging in interaction in crowded environments. CROWDBOT gathers the required expertise to develop new robot capabilities to allow robots to move in a safe and socially acceptable manner. This requires achieving step changes in a) sensing abilities to estimate the crowd motion around the robot, b) cognitive abilities for the robot to predict the short term evolution of the crowd state and c) navigation abilities to perform safe motion at close range from people. Through demonstrators and open software components, CROWDBOT will show that safe navigation tasks can be achieved within crowds and will facilitate incorporating its results into mobile robots, with significant scientific and industrial impact. By extending the robot operation field toward crowded environments, we enable possibilities for new applications, such as robot-assisted crowd traffic management.

8.3.4. H2020 ICT PRESENT

Participants: Adèle Colas, Alberto Jovane, Claudio Pacchierotti, Julien Pettré.

Title: Photoreal REaltime Sentient ENTity

Programme: H2020

Duration: Sep 2019 - Aug 2022

Coordinator: Univ Pompeu Fabra (Spain)

Partners: The Framestore Ltd (UK), Cubic Motion Ltd (UK), InfoCert Spa (Italy), Brainstorm Multimedia S.L. (ES), Creative Workers - Creatieve Werkers VZW (Belgium), Universitaet Augsburg (Germany), Inria (France)

Inria contact: Julien Pettré

Abstract: PRESENT is a three-year Research and Innovation project to create virtual digital companions—embodied agents—that look entirely naturalistic, demonstrate emotional sensitivity, can establish meaningful dialogue, add sense to the experience, and act as trustworthy guardians and guides in the interfaces for AR, VR and more traditional forms of media.

There is no higher quality interaction than the human experience when we use all our senses together with language and cognition to understand our surroundings and—above all—to interact with other people. We interact with today's Ïntelligent Personal Assistantsprimarily by voice; communication is episodic, based on a request-response model. The user does not see the assistant, which does not take advantage of visual and emotional clues or evolve over time. However, advances in the real-time creation of photorealistic computer generated characters, coupled with emotion recognition and behaviour, and natural language technologies, allow us to envisage virtual agents that are realistic in both looks and behaviour; that can interact with users through vision, sound, touch and movement as they navigate rich and complex environments; converse in a natural manner; respond to moods and emotional states; and evolve in response to user behaviour.

PRESENT will create and demonstrate a set of practical tools, a pipeline and APIs for creating realistic embodied agents and incorporating them in interfaces for a wide range of applications in entertainment, media and advertising.

8.3.5. H2020 FET-OPEN H-Reality

Participants: Claudio Pacchierotti, Paolo Robuffo Giordano, François Chaumette.

Title: Mixed Haptic Feedback for Mid-Air Interactions in Virtual and Augmented Realities

Programme: H2020

Duration: October 2018 - September 2021

Coordinator: Univ. Birmingham (UK)

Partners: Univ. Birmingham (UK, coordinator), CNRS (France), TU Delft (NL), Ultrahaptics (UK) and Actronika SAS (France)

CNRS contact: Claudio Pacchierotti

Abstract: Digital content today remains focused on visual and auditory stimulation. Even in the realm of VR and AR, sight and sound remain paramount. In contrast, methods for delivering haptic (sense of touch) feedback in commercial media are significantly less advanced than graphical and auditory feedback. Yet without a sense of touch, experiences ultimately feel hollow, virtual realities feel false, and Human-Computer Interfaces become unintuitive. Our vision is to be the first to imbue virtual objects with a physical presence, providing a revolutionary, untethered, virtual-haptic reality: H-Reality. The ambition of H-Reality will be achieved by integrating the commercial pioneers of ultrasonic "non-contact" haptics, state-of-the-art vibrotactile actuators, novel mathematical and tribological modelling of the skin and mechanics of touch, and experts in the psychophysical rendering of sensation. The result will be a sensory experience where digital 3D shapes and textures are made manifest in real space via modulated, focused, ultrasound, ready for the untethered hand to feel, where next-generation wearable haptic rings provide directional vibrotactile stimulation, informing users of an object's dynamics, and where computational renderings of specific materials can be distinguished via their surface properties. The implications of this technology will be far-reaching. The computer touch-screen will be brought into the third dimension so that swipe gestures will be augmented with instinctive rotational gestures, allowing intuitive manipulation of 3D data sets and strolling about the desktop as a virtual landscape of icons, apps and files. H-Reality will transform online interactions; dangerous machinery will be operated virtually from the safety of the home, and surgeons will hone their skills on thin air. Rainbow is involved in H-Reality in cooperation with Anatole Lécuyer and Maud Marchal from the Hybrid group.

Collaborations in European Programs, Except FP7 & H2020

8.3.6. Interreg Adapt

Participants: Nicolas Le Borgne, Marie Babel.

Programme: Interreg VA France (Channel) England

Project acronym: Adapt

Project title: Assistive Devices for empowering disAbled People through robotic Technologies

Duration: Jan 2017 - Jun 2021

Coordinator: ESIGELEC/IRSEEM Rouen

Other partners: INSA Rennes - IRISA, LGCGM, IETR (France), Université de Picardie Jules Verne - MIS (France), Pôle Saint Hélier (France), CHU Rouen (France), Réseau Breizh PC (France), Pôle TES (France), University College of London - Aspire CREATE (UK), University of Kent (UK), East Kent Hospitals Univ NHS Found. Trust (UK), Health and Europe Centre (UK), Plymouth Hospitals NHS Trust (UK), Canterbury Christ Church University (UK), Kent Surrey Sussex Academic Health Science Network (UK), Cornwall Mobility Center (UK).

Abstract: This project aims to develop innovative assistive technologies in order to support the autonomy and to enhance the mobility of power wheelchair users with severe physical/cognitive disabilities. In particular, the objective is to design and evaluate a power wheelchair simulator as well as to design a multi-layer driving assistance system.

Collaborations with Major European Organizations

8.3.7. ANR Opmops

Participants: Florian Berton, Julen Bruneau, Julien Pettré.

Programme: ANR

Project acronym: Opmops

Project title: Organized Pedestrian Movement in Public Spaces: Preparation and Crisis Management of Urban Parades and Demonstration Marches with High Conflict Potential

Duration: June 2017 - June 2020

Coordinator: Université de Haute Alsace (for France), Technische Universität Kaiserslautern (for Germany)

Other partners: Gendarmerie Nationale, Hochschule München, ONHYS S.A.S, Polizei Rheinland-Pfalz, Universität Koblenz-Landau, VdS GmbH

Abstract: This project is about parades of highly controversial groups or of political demonstration marches that are considered as a major threat to urban security. Due to the movement of the urban parades and demonstration marches (in the following abbreviated by UPM) through large parts of cities and the resulting space and time dynamics, it is particularly difficult for forces of civil security (abbreviated in the following by FCS) to guarantee safety at these types of urban events without endangering one of the most important indicators of a free society. In this proposal, partners representing the FCS (police and industry) will cooperate with researchers from academic institutions to develop a decision support tool which can help them both in the preparation phase and crisis management situations of UPMs. Specific technical issues which the French-German consortium will have to tackle include the following: Optimization methods to plan UPM routes, transportation to and from the UPM, location and personnel planning of FCS, control of UPMs using stationary and moving cameras, and simulation methods, including their visualization, with specific emphasis on social behavior.

8.3.8. iProcess

Participants: Agniva Sengupta, François Chaumette, Alexandre Krupa, Eric Marchand, Fabien Spindler.

Project acronym: i-Process

Project title: Innovative and Flexible Food Processing Technology in Norway

Duration: January 2016 - December 2019

Coordinator: Sintef Ocean (Norway)

Other partners: Nofima, Univ. of Stavanger, NMBU, NTNU (Norway), DTU (Denmark), KU Leuven (Belgium), and about 10 Norwegian companies.

Abstract: This project was granted by the Norwegian Government. Its main objective was to develop novel concepts and methods for flexible and sustainable food processing in Norway. In the scope of this project, the Rainbow group was involved for visual tracking and visual servoing of generic and potentially deformable objects (see Section 6.1.1 and Section 6.1.2). This year, we published [52], [53] in the scope of this project.

8.3.9. GentleMAN

Participants: Alexandre Krupa, Eric Marchand, François Chaumette, Fabien Spindler.

Project acronym: GentleMAN

Project title: Gentle and Advanced Robotic Manipulation of 3D Compliant Objects

Duration: August 2019 - December 2023

Coordinator: Sintef Ocean (Norway)

Other partners: NTNU (Norway), NMBU (Norway), MIT (USA) and QUT (Australia).

Abstract: This project is funded by the Norwegian Government. Its main objective is to develop a novel learning framework that uses visual, force and tactile sensing to develop new multi-modal learning models, interfaced with underlying robot control, for enabling robots to learn new and advanced skills for the manipulation of 3D compliant objects. In the scope of this project, the Rainbow group is involved in the elaboration of new approaches for visual tracking of deformable objects, active vision and visual servoing for deforming soft objects into desired shapes.

8.4. International Initiatives

8.4.1. Inria Associate Teams Not Involved in an Inria International Labs

8.4.1.1. ISI4NAVE

Title: Innovative Sensors and adapted Interfaces for assistive NAVigation and pathology Evaluation

International Partner (Institution - Laboratory - Researcher):

University College London (United Kingdom) - Aspire CREATe - Tom Carlson

Start year: 2019

See also: https://team.inria.fr/isi4nave/

Using a wheelchair allows people with disability to compensate a loss of mobility. However only 5 to 15% of the 70 million people worldwide who require a wheelchair have access to this type of technical aid. In particular, visual, visuo-spatial and/or cognitive impairments can alter the ability of an individual to independently operate a wheelchair safely.

This project focuses then on two main complementary objectives:

1. to compensate both sensorimotor disabilities and cognitive impairments by designing adapted interfaces,
2. to enhance the driving experience and to bring a new tool for rehabilitation purposes by defining efficient physical Human-Robot Interaction.

In order to ensure a widespread use of robotic systems, innovative interfaces, enabling relevant feedback (medically validated), constitute a major challenge. Trajectory corrections, obtained thanks to an assistance module, will have to be perceived by the user by means of sensitive (visual, tactile...) feedback that will have to be easily adapted to the pathology. Conversely, user interaction with the robotic system can be interpreted to control the wheelchair. Designing such systems require a multidisciplinary study, including medical data collection and analysis.

In our preliminary works, we demonstrated the relevance of share control frameworks. The scope of this new ISI4NAVE Associate Team is then to provide advanced and innovative solutions for controlling wheelchair as well as providing appropriate and relevant feedback to users.

8.4.2. Participation in Other International Programs

8.4.2.1. ACRV

François Chaumette is one of the five external experts of the Australian Center for Robotic Vision (see http://roboticvision.org). This center groups QUT in Brisbane, ANU in Canberra, Monash University and Adelaide University. In the scope of this project, Alexander Oliva received a grant to participate to the 2019 Robotic Vision Summer School in Kioloa (New South Wales) and spent a 1-week visit at QUT in March 2019.

SIROCCO Project-Team

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. CominLabs InterCom project

Participants: Aline Roumy, Thomas Maugey.

- Title : Interactive Communication (INTERCOM): Massive random access to subsets of compressed correlated data .
- Research axis : 7.4.1
- Partners : Inria-Rennes (Sirocco team and i4S team); LabSTICC, IMT Atlantique, Signal & Communications Department; External partners: L2S, CentraleSupelec, Univ. Paris Sud; EPFL, Signal Processing Laboratory (LTS4).
- Funding : Labex CominLabs.
- Period : Oct. 2016 - Dec. 2020.

This project aims to develop novel compression techniques allowing massive random access to large databases. Indeed, we consider a database that is so large that, to be stored on a single server, the data have to be compressed efficiently, meaning that the redundancy/correlation between the data have to be exploited. The dataset is then stored on a server and made available to users that may want to access only a subset of the data. Such a request for a subset of the data is indeed random, since the choice of the subset is user-dependent. Finally, massive requests are made, meaning that, upon request, the server can only perform low complexity operations (such as bit extraction but no decompression/compression). Algorithms for two emerging applications of this problem are being developed: Free-viewpoint Television (FTV) and massive requests to a database collecting data from a large-scale sensor network (such as Smart Cities).

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

9.2.1.1. ERC-CLIM

Participants: Pierre Allain, Pierre David, Elian Dib, Simon Evain, Christian Galea, Christine Guillemot, Laurent Guillo, Fatma Hawary, Xiaoran Jiang, Maja Krivokuca, Ehsan Miandji, Hoai Nam Nguyen, Mira Rizkallah, Alexander Sagel, Jinglei Shi.

- Title : Computational Light field Imaging.
- Research axis : 7.1.1 , 7.1.2 , 7.1.4 , 7.2.1 , 7.2.3 , 7.2.4 , 7.2.2 , 7.3.1 , 7.3.2 , 7.3.3 , 7.3.4
- Partners : Inria-Rennes
- Funding : European Research Council (ERC) advanced grant
- Period : Sept. 2016 - Aug. 2021.

All imaging systems, when capturing a view, record different combinations of light rays emitted by the environment. In a conventional camera, each sensor element sums all the light rays emitted by one point over the lens aperture. Light field cameras instead measure the light along each ray reaching the camera sensors and not only the sum of rays striking each point in the image. In one single exposure, they capture the geometric distribution of light passing through the lens. This process can be seen as sampling the plenoptic function that describes the intensity of the light rays interacting with the scene and received by an observer at every point in space, along any direction of gaze, for all times and every wavelength.

The recorded flow of rays (the light field) is in the form of high-dimensional data (4D or 5D for static and dynamic light fields). The 4D/5D light field yields a very rich description of the scene enabling advanced creation of novel images from a single capture, e.g. for computational photography by simulating a capture with a different focus and a different depth of field, by simulating lenses with different apertures, by creating images with different artistic intents. It also enables advanced scene analysis with depth and scene flow estimation and 3D modeling. The goal of the ERC-CLIM project is to develop algorithms for the entire static and video light fields processing chain. The planned research includes the development of:

- novel low-rank or graph-based models for dimensionality reduction and compression
- deep learning methods for scene analysis (e.g. scene depth and scene flow estimation)
- learning methods for solving a range of inverse problems: denoising, super-resolution, axial super-resolution, view synthesis.

9.3. International Initiatives

9.3.1. Inria International Labs

EPFL-Inria: Associate Team involved in the International Lab: Graph-based Omnidirectional video Processing (GOP)

- Participant: Thomas Maugey
- International Partner (Institution - Laboratory - Researcher): Ecole Polytechnique Fédérale de Lausanne (Switzerland) - LTS4 - Pascal Frossard
- period: 2017-2019

Due to new camera types, the format of the video data has become more complex than simple 2D images or videos as it was the case a few years ago. In particular, the omnidirectional cameras provide pixels on a whole sphere around a center point and enable a vision in 360°. In addition to the fact that the data size explodes with such cameras, the inherent structure of the acquired signal fundamentally differs from the 2D images, which makes the traditional video codec obsolete. In parallel of that, an important effort of research has been led recently, especially at EPFL, to develop new processing tools for signals lying on irregular structures (graphs). It enables in particular to build efficient coding tools for new types of signals. During this project, we study how graphs can be built for defining a suitable structure on one or several 360 videos and then used for compression.

9.3.2. Inria International Partners

9.3.2.1. Informal International Partners

We have international collaborations with:

- Reuben Farrugia, Prof. at the University of Malta, with whom we continue collaborating on light field super-resolution.The collaboration started during the sabbatical year (Sept. 2015-Aug. 2016) he spent within the team.
- Ehsan Miandji and Prof. Jonas Unger from Linkoping Univ. with whom we collaborate on compressive sampling of light fields.
- Mikael Le Pendu and Prof. Aljosa Smolic from Trinity College Dublin on HDR light field recovery from multiple exposures.
- Pascal Frossard, Prof. at EPFL, in the context of the Comin Lab/Intercom project and in the context of the EPFL-Inria associated team.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

9.4.1.1. Internships

- Zhaolin Xiao, Prof. Xian University, Dec. 2018-Nov. 2019.