Activity Report 2018

Section Application Domains

<p align="center" style="color:red">**ARIC Project-Team**</p>

4. Application Domains

4.1. Floating-point and Validated Numerics

Our expertise on validated numerics is useful to analyze and improve, and guarantee the quality of numerical results in a wide range of applications including:

- scientific simulation;
- global optimization;
- control theory.

Much of our work, in particular the development of correctly rounded elementary functions, is critical to the

- reproducibility of floating-point computations.

4.2. Cryptography, Cryptology, Communication Theory

Lattice reduction algorithms have direct applications in

- public-key cryptography;
- diophantine equations;
- communications theory.

4. Application Domains

4.1. Compute-intensive Loop Kernels

The CASH team targets HPC programs, at different levels. Small computation kernels (tens of lines of code) that can be analyzed and optimized aggressively, medium-size kernels (hundreds of lines of code) that require modular analysis, and assembly of compute kernels (either as classical imperative programs or written directly in a dataflow language).

The work on various application domains and categories of programs is driven by the same idea: exploring various topics is a way to converge on unifying representations and algorithms even for specific applications. All these applications share the same research challenge: find a way to integrate computations, data, mapping, and scheduling in a common analysis and compilation framework.

Typical HPC kernels include linear solvers, stencils, matrix factorizations, BLAS kernels, etc. Many kernels can be found in the Polybench/C benchmark suite [46]. The irregular versions can be found in [47]. Numerical kernels used in quantitative finance [57] are also good candidates, e.g., finite difference and Monte-Carlo simulation.

4.2. Medium-size HPC applications

The medium-size applications we target are streaming algorithms [19], scientific workflows [52], and also the now very rich domain of deep learning applications [40]. We explore the possibilities of writing (see Section 3.1) and compiling (see Section 3.3) applications using a dataflow language. As a first step, we will target dataflow programs written in SigmaC [22] for which the fine grain parallelism is not taken into account. In parallel, we will also study the problem of deriving relevant (with respect to safety or optimization) properties on dataflow programs with array iterators.

Obviously, large applications are not limited to assembly of compute kernels. Our languages and formalism definitions (3.1) and analyses (3.2) must also be able to deal with general programs. Our targets also include generalist programs with complex behaviors such as recursive programs operating on arrays, lists and trees; worklist algorithms (lists are not handled within the polyhedral domain). Analysis on these programs should be able to detect non licit memory accesses, memory consumption, hotspots, ..., and to prove functional properties.

The simulation activities (3.5) are both applied internally in CASH, to simulate intermediate representations, and for embedded systems. We are interested in Transaction-Level Models (TLM) of Systems-on-a-Chip (SoCs) including processors and hardware accelerators. TLM provides an abstract but executable model of the chip, with enough details to run the embedded software. We are particularly interested in models written in a loosely timed coding style. We plan to extend these to heterogeneous simulations including a SystemC/TLM part to model the numerical part of the chip, and other simulators to model physical parts of the system.

<p style="text-align:center"><strong style="color:red">CONVECS Project-Team</p>

4. Application Domains

4.1. Application Domains

The theoretical framework we use (automata, process algebras, bisimulations, temporal logics, etc.) and the software tools we develop are general enough to fit the needs of many application domains. They are applicable to virtually any system or protocol that consists of distributed agents communicating by asynchronous messages. The list of recent case studies performed with the CADP toolbox (see in particular § 6.5) illustrates the diversity of applications:

- *Bioinformatics:* genetic regulatory networks, nutritional stress response, metabolic pathways,
- *Component-based systems:* Web services, peer-to-peer networks,
- *Cloud computing:* self-deployment protocols, dynamic reconfiguration protocols,
- *Fog and IoT:* stateful IoT applications in the fog,
- *Databases:* transaction protocols, distributed knowledge bases, stock management,
- *Distributed systems:* virtual shared memory, dynamic reconfiguration algorithms, fault tolerance algorithms, cloud computing,
- *Embedded systems:* air traffic control, avionic systems, medical devices,
- *Hardware architectures:* multiprocessor architectures, systems on chip, cache coherency protocols, hardware/software codesign,
- *Human-machine interaction:* graphical interfaces, biomedical data visualization, plasticity,
- *Security protocols:* authentication, electronic transactions, cryptographic key distribution,
- *Telecommunications:* high-speed networks, network management, mobile telephony, feature interaction detection.

<p style="text-align:center;color:red;font-weight:bold;">CORSE Project-Team</p>

4. Application Domains

4.1. Transfer

The main industrial sector related to the research activities of CORSE is the one of semi-conductor (programmable architectures spanning from embedded systems to servers). Obviously any computing application which has the objective of exploiting as much as possible the resources (in terms of high-performance but also low energy consumption) of the host architecture is intended to take advantage of advances in compiler and run-time technology. These applications are based over numerical kernels (linear algebra, FFT, convolution...) that can be adapted on a large spectrum of architectures. Members of CORSE already maintain fruitful and strong collaborations with several companies such as STMicroelectronics, Atos/Bull, Kalray.

<p style="text-align:center">**DATASPHERE Team**</p>

4. Application Domains

4.1. Governance

- City governance, local democracy and interaction with citizens.
- Local governance versus global norms and control.
- Strategy beyond public open data.
- Smart city governance.

4.2. CyberStrategy/CyberSecurity

- Cyber-strategy, defense and security in an evolving world shaped by the digital in particular China/Russia/US cyber-strategy.
- Data strategy for the digital economy, cross border intermediation, platform strategie.
- Strategy of Artificial Intelligence, transparency/acceptability/explainability of AI.
- Cartography of the cyberspace.
- Network, BGP security.

4.3. Anthropocene

- Adaptation to the conditions of the anthropocene, digital control of resources and homeostasis.
- Geopolitics of the environmental challenges, adaptation and mitigation.
- Contemporaneity of the digital revolution and global warming.

<div align="center">**PRIVATICS Project-Team**</div>

3. Application Domains

3.1. Domain 1: Privacy in smart environments

Privacy in smart environments. One illustrative example is our latest work on privacy-preserving smart-metering [2]. Several countries throughout the world are planning to deploy smart meters in house-holds in the very near future. Traditional electrical meters only measure total consumption on a given period of time (i.e., one month or one year). As such, they do not provide accurate information of when the energy was consumed. Smart meters, instead, monitor and report consumption in intervals of few minutes. They allow the utility provider to monitor, almost in real-time, consumption and possibly adjust generation and prices according to the demand. Billing customers by how much is consumed and at what time of day will probably change consumption habits to help matching energy consumption with production. In the longer term, with the advent of smart appliances, it is expected that the smart grid will remotely control selected appliances to reduce demand. Although smart metering might help improving energy management, it creates many new privacy problems. Smart-meters provide very accurate consumption data to electricity providers. As the interval of data collected by smart meters decreases, the ability to disaggregate low-resolution data increases. Analysing high-resolution consumption data, Non-intrusive Appliance Load Monitoring (NALM) can be used to identify a remarkable number of electric appliances (e.g., water heaters, well pumps, furnace blowers, refrigerators, and air conditioners) employing exhaustive appliance signature libraries. We developed DREAM, DiffeRentially privatE smArt Metering, a scheme that is private under the differential privacy model and therefore provides strong and provable guarantees. With our scheme, an (electricity) supplier can periodically collect data from smart-meters and derive aggregated statistics while learning only limited information about the activities of individual households. For example, a supplier cannot tell from a user's trace when he watched TV or turned on heating.

3.2. Domain 2: Big Data and Privacy

We believe that another important problem will be related to privacy issues in big data. Public datasets are used in a variety of applications spanning from genome and web usage analysis to location-based and recommendation systems. Publishing such datasets is important since they can help us analyzing and understanding interesting patterns. For example, mobility trajectories have become widely collected in recent years and have opened the possibility to improve our understanding of large-scale social networks by investigating how people exchange information, interact, and develop social interactions. With billion of handsets in use worldwide, the quantity of mobility data is gigantic. When aggregated, they can help understand complex processes, such as the spread of viruses, and build better transportation systems. While the benefits provided by these datasets are indisputable, they unfortunately pose a considerable threat to individual privacy. In fact, mobility trajectories might be used by a malicious attacker to discover potential sensitive information about a user, such as his habits, religion or relationships. Because privacy is so important to people, companies and researchers are reluctant to publish datasets by fear of being held responsible for potential privacy breaches. As a result, only very few of them are actually released and available. This limits our ability to analyze such data to derive information that could benefit the general public. It is now an urgent need to develop Privacy-Preserving Data Analytics (PPDA) systems that collect and transform raw data into a version that is immunized against privacy attacks but that still preserves useful information for data analysis. This is one of the objectives of Privatics. There exists two classes of PPDA according to whether the entity that is collecting and anonymizing the data is trusted or not. In the trusted model, that we refer to as Privacy-Preserving Data Publishing (PPDP), individuals trust the publisher to which they disclose their data. In the untrusted model, that we refer to as Privacy-Preserving Data Collection (PPDC), individuals do not trust the data publisher. They may add some noise to their data to protect sensitive information from the data publisher.

Privacy-Preserving Data Publishing: In the trusted model, individuals trust the data publisher and disclose all their data to it. For example, in a medical scenario, patients give their true information to hospitals to receive proper treatment. It is then the responsibility of the data publisher to protect privacy of the individuals' personal data. To prevent potential data leakage, datasets must be sanitized before possible release. Several proposals have been recently proposed to release private data under the Differential Privacy model [25, 56, 26, 57, 50]. However most of these schemes release a "snapshot" of the datasets at a given period of time. This release often consists of histograms. They can, for example, show the distributions of some pathologies (such as cancer, flu, HIV, hepatitis, etc.) in a given population. For many analytics applications, "snapshots" of data are not enough, and sequential data are required. Furthermore, current work focusses on rather simple data structures, such as numerical data. Release of more complex data, such as graphs, are often also very useful. For example, recommendation systems need the sequences of visited websites or bought items. They also need to analyse people connection graphs to identify the best products to recommend. Network trace analytics also rely on sequences of events to detect anomalies or intrusions. Similarly, traffic analytics applications typically need sequences of visited places of each user. In fact, it is often essential for these applications to know that user A moved from position 1 to position 2, or at least to learn the probability of a move from position 1 to position 2. Histograms would typically represent the number of users in position 1 and position 2, but would not provide the number of users that moved from position 1 to position 2. Due to the inherent sequentiality and high-dimensionality of sequential data, one major challenge of applying current data sanitization solutions on sequential data comes from the uniqueness of sequences (e.g., very few sequences are identical). This fact makes existing techniques result in poor utility. Schemes to privately release data with complex data structures, such as sequential, relational and graph data, are required. This is one the goals of Privatics. In our current work, we address this challenge by employing a variable-length n-gram model, which extracts the essential information of a sequential database in terms of a set of variable-length n - grams [15]. We then intend to extend this approach to more complex data structures.

Privacy-Preserving Data Collection: In the untrusted model, individuals do not trust their data publisher. For example, websites commonly use third party web analytics services, such as Google Analytics to obtain aggregate traffic statistics such as most visited pages, visitors' countries, etc. Similarly, other applications, such as smart metering or targeted advertising applications, are also tracking users in order to derive aggregated information about a particular class of users. Unfortunately, to obtain this aggregate information, services need to track users, resulting in a violation of user privacy. One of our goals is to develop Privacy-Preserving Data Collection solutions. We propose to study whether it is possible to provide efficient collection/aggregation solutions without tracking users, i.e. without getting or learning individual contributions.

<p style="text-align:center">**SPADES Project-Team**</p>

4. Application Domains

4.1. Industrial Applications

Our applications are in the embedded system area, typically: transportation, energy production, robotics, telecommunications, the Internet of things (IoT), systems on chip (SoC). In some areas, safety is critical, and motivates the investment in formal methods and techniques for design. But even in less critical contexts, like telecommunications and multimedia, these techniques can be beneficial in improving the efficiency and the quality of designs, as well as the cost of the programming and the validation processes.

Industrial acceptance of formal techniques, as well as their deployment, goes necessarily through their usability by specialists of the application domain, rather than of the formal techniques themselves. Hence, we are looking to propose domain-specific (but generic) realistic models, validated through experience (*e.g.*, control tasks systems), based on formal techniques with a high degree of automation (*e.g.*, synchronous models), and tailored for concrete functionalities (*e.g.*, code generation).

4.2. Industrial Design Tools

The commercially available design tools (such as UML with real-time extensions, MATLAB/ SIMULINK/ dSPACE[0]) and execution platforms (OS such as VXWORKS, QNX, real-time versions of LINUX ...) start now to provide, besides their core functionalities, design or verification methods. Some of them, founded on models of reactive systems, come close to tools with a formal basis, such as for example STATEMATE by iLOGIX.

Regarding the synchronous approach, commercial tools are available: SCADE[0] (based on LUSTRE), CONTROLBUILD and RT-BUILDER (based on SIGNAL) from GEENSYS[0] (part of DASSAULTSYSTEMES), specialized environments like CELLCONTROL for industrial automatism (by the Inria spin-off ATHYS– now part of DASSAULTSYSTEMES). One can observe that behind the variety of actors, there is a real consistency of the synchronous technology, which makes sure that the results of our work related to the synchronous approach are not restricted to some language due to compatibility issues.

4.3. Current Industrial Cooperations

Regarding applications and case studies with industrial end-users of our techniques, we cooperate with Thales on schedulability analysis for evolving or underspecified real-time embedded systems, with Orange Labs on software architecture for cloud services and with Daimler on reduction of nondeterminism and analysis of deadline miss models for the design of automotive systems.

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[0] http://www.dspaceinc.com
[0] http://www.esterel-technologies.com
[0] http://www.geensoft.com

4. Application Domains

4.1. Mechanical Engineering

Many physicists and mathematicians have strived for centuries to understand the principles governing those complex mechanical phenomena, providing a number of continuous models for slender structures, granular matter, and frictional contact. In the XX$^\text{th}$ century, industrial applications such as process automatization and new ways of transportation have boosted the fields of Mechanical Engineering and Computer-Aided Design, where material strength, reliability of mechanisms, and safety, standed for the main priorities. Instead, large displacements of structures, buckling, tearing, or entanglement, and even dynamics, were long considered as undesirable behaviors, thus restraining the search for corresponding numerical models.

Only recently, the engineering industry has shown some new and growing interest into the modeling of dynamic phenomena prone to large displacements, contact and friction. For instance, the cosmetology industry is more and more interested in understanding the nonlinear deformation of hair and skin, with the help of simulation. Likewise, auto and aircraft manufacturers are facing new challenges involving buckling or entanglement of thin structures such as carbon or optical fibers; they clearly lack predictive, robust and efficient numerical tools for simulating and optimizing their new manufacturing process, which share many common features with the large-scale simulation scenarii traditionally studied in Computer Graphics applications.

4.2. Computer Graphics

In contrast, Computer Graphics, which has emerged in the 60's with the advent of modern computers, was from the very beginning eager to capture such peculiar phenomena, with the sole aim to produce spectacular images and create astonishing stories. At the origin, Computer Graphics thus drastically departed from other scientific fields. Everyday-life phenomena such as cloth buckling, paper tearing, or hair fluttering in the wind, mostly ignored by other scientists at that time, became actual topics of interest, involving a large set of new research directions to be explored, both in terms of modelling and simulation. Nowadays, although the image production still remains the core activity of the Computer Graphics community, more and more research studies are directed through the virtual and real prototyping of mechanical systems, notably driven by a myriad of new applications in the virtual try on industry (e.g., hairstyling and garment fitting). Furthermore, the advent of additive fabrication is currently boosting research in the free design of new mechanisms or systems for various applications, from architecture design and fabrication of metamaterials to the creation of new locomotion modes in robotics. Some obvious common interests and approaches are thus emerging between Computer Graphics and Mechanical Engineering, yet the two communities remain desperately compartmentalized.

4.3. Soft Matter Physics

From the physics-based viewpoint, since a few decades a new generation of physicists became interested again in the understanding of such visually fascinating phenomena, and started investigating the tight links between geometry and elasticity [0]. Common objects such as folded or torn paper, twined plants, coiled honey threads, or human hair have thus regained some popularity among the community in Nonlinear Physics [0]. In consequence, phenomena of interest have become remarkably close to those of Computer Graphics, since scientists in both places share the common goal to model complex and integrated mechanical phenomena at the macroscopic

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[0]In France this new trend was particularly stimulated by the work of Yves Pomeau, who convinced many young scientists to study the nonlinear physics of common objects such as paper, plants, or hair [24].

[0]It is however amusing to observe that research in these areas is quite successful in obtaining the IG Nobel prize [5], [27], thus still being considered as an exotic research topic by physicists.

scale. Of course, the goals and employed methodologies differ substantially from one community to the other, but showcase some evident complementarity: while computer scientists are eager to learn and understand new physical models, physicists get more and more interested in the numerical tools, in which they perceive not only a means to confirm predictions afterwards, but also a support for testing new hypothesis and exploring scenarios that would be too cumbersome or even impossible to investigate experimentally. Besides, numerical exploration starts becoming a valuable tool for getting insights into the search for analytic solutions, thus fully participating to the modeling stage and physical understanding. However, physicists may be limited to a blind usage of numerical black boxes, which may furthermore not be dedicated to their specific needs. According to us, promoting a science of modeling in numerical physics would thus be a promising and rich avenue for the two research fields. Unfortunately, very scarce cooperation currently exists between the two communities, and large networks of collaboration still need to be set up.

MISTIS Project-Team

4. Application Domains

4.1. Image Analysis

Participants: Alexis Arnaud, Veronica Munoz Ramirez, Florence Forbes, Stéphane Girard, Jaime Eduardo Arias Almeida, Pierre-Antoine Rodesch, Hongliang Lu, Fabien Boux, Benoit Kugler, Alexandre Constantin.

As regards applications, several areas of image analysis can be covered using the tools developed in the team. More specifically, in collaboration with team PERCEPTION, we address various issues in computer vision involving Bayesian modelling and probabilistic clustering techniques. Other applications in medical imaging are natural. We work more specifically on MRI and functional MRI data, in collaboration with the Grenoble Institute of Neuroscience (GIN) and the NeuroSpin center of CEA Saclay. We also consider other statistical 2D fields coming from other domains such as remote sensing, in collaboration with the Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) and the Centre National d'Etudes Spatiales (CNES). In this context, we worked on hyperspectral and/or multitemporal images. In the context of the "pole de competivité" project I-VP, we worked of images of PC Boards. We also address reconstruction problems in tomography with CEA Grenoble.

4.2. Multi sensor Data Analysis

Participants: Jean-Michel Bécu, Florence Forbes, Thibaud Rahier, Hongliang Lu, Fatima Fofana.

A number of our methods are at the the intersection of data fusion, statistics, machine learning and acoustic signal processing. The context can be the surveillance and monitoring of a zone acoustic state from data acquired at a continuous rate by a set of sensors that are potentially mobile and of different nature (eg WIFUZ project with the ACOEM company in the context of a DGA-rapid initiative). Typical objectives include the development of prototypes for surveillance and monitoring that are able to combine multi sensor data coming from acoustic sensors (microphones and antennas) and optical sensors (infrared cameras) and to distribute the processing to multiple algorithmic blocs. Our interest in acoustic data analysis mainly started from past European projects, POP and Humavips, in collaboration with the PERCEPTION team (PhD theses of Vassil Khalidov, Ramya Narasimha, Antoine Deleforge, Xavier Alameda, and Israel Gebru).

4.3. Biology, Environment and Medicine

Participants: Jaime Eduardo Arias Almeida, Alexis Arnaud, Florence Forbes, Stéphane Girard, Jean-Baptiste Durand, Clément Albert, Julyan Arbel, Jean-Michel Bécu, Thibaud Rahier, Brice Olivier, Karina Ashurbekova, Fabien Boux, Veronica Munoz Ramirez, Fei Zheng.

A third domain of applications concerns biology and medicine. We considered the use of mixture models to identify biomakers. We also investigated statistical tools for the analysis of fluorescence signals in molecular biology. Applications in neurosciences are also considered. In the environmental domain, we considered the modelling of high-impact weather events and the use of hyperspectral data as a new tool for quantitative ecology.

NANO-D Project-Team (section vide)

<p style="text-align:center">**NECS Project-Team**</p>

4. Application Domains

4.1. A large variety of application domains

Sensor and actuator networks are ubiquitous in modern world, thanks to the advent of cheap small devices endowed with communication and computation capabilities. Potential application domains for research in networked control and in distributed estimation are extremely various, and include the following examples.

- Intelligent buildings, where sensor information on CO_2 concentration, temperature, room occupancy, etc. can be used to control the heating, ventilation and air conditioning (HVAC) system under multi-objective considerations of comfort, air quality, and energy consumption.
- Smart grids: the operation of electrical networks is changing from a centralized optimization framework towards more distributed and adaptive protocols, due to the high number of small local energy producers (e.g., solar panels on house roofs) that now interact with the classic large power-plants.
- Disaster relief operations, where data collected by sensor networks can be used to guide the actions of human operators and/or to operate automated rescue equipment.
- Surveillance using swarms of Unmanned Aerial Vehicles (UAVs), where sensor information (from sensors on the ground and/or on-board) can be used to guide the UAVs to accomplish their mission.
- Environmental monitoring and exploration using self-organized fleets of Autonomous Underwater Vehicles (AUVs), collaborating in order to reach a goal such as finding a pollutant source or tracing a seabed map.
- Infrastructure security and protection using smart camera networks, where the images collected are shared among the cameras and used to control the cameras themselves (pan-tilt-zoom) and ensure tracking of potential threats.

In particular, NECS team is currently focusing in the areas described in detail below.

4.2. Intelligent transportation systems

Throughout the world, roadways are notorious for their congestion, from dense urban network to large freeway systems. This situation tends to get worse over time due to the continuous increase of transportation demand whereas public investments are decreasing and space is lacking to build new infrastructures. The most obvious impact of traffic congestion for citizens is the increase of travel times and fuel consumption. Another critical effect is that infrastructures are not operated at their capacity during congestion, implying that fewer vehicles are served than the amount they were designed for. Using macroscopic fluid-like models, the NECS team has initiated new researches to develop innovative traffic management policies able to improve the infrastructure operations. The research activity is on two main challenges: (1) modeling and forecasting, so as to provide accurate information to users, e.g., travel times; and (2) control, via ramp-metering and/or variable speed limits. The Grenoble Traffic Lab (see http://necs.inrialpes.fr/pages/grenoble-traffic-lab.php) is an experimental platform, collecting traffic infrastructure information in real time from Grenoble South Ring, together with innovative software e.g. for travel-time prediciton, and a show-case where to graphically illustrate results to the end-user. This activity is done in close collaboration with local traffic authorities (DIR-CE, CG38, La Metro), and with the start-up company Karrus (http://www.karrus-its.com/)

4.3. Inertial navigation

The team is exploring techniques and approaches from estimation, filtering and machine learning, in order to use inertial sensor units in pedestrian navigation, attitude estimation, augmented reality and human activities recognition. These units are composed of accelerometers, magnetometers and gyroscopes, sensors that we find usually in smartphones. This area of research in the team will evolve towards multimodal navigation, cooperative and collaborative navigation in indoor and outdoor environments.

4. Application Domains

4.1. Applications Domains

Nonsmooth dynamical systems arise in a lot of application fields. *We briefly expose here some applications that have been treated in the BIPOP team and that we will continue in the TRIPOP team, as a validation for the research axes and also in terms of transfer (Sect. 7.1).* In mechanics, the main instances of nonsmooth dynamical systems are multibody systems with Signorini's unilateral contact, set-valued (Coulomb-like) friction and impacts, or in continuum mechanics, ideal plasticity, fracture or damage. Some illustrations are given in Figure 4 (a-f). Other instances of nonsmooth dynamical systems can also be found in electrical circuits with ideal components (see Figure 4 (g)) and in control theory, mainly with sliding mode control and variable structure systems (see Figure 4 (h)). More generally, every time a piecewise, possibly set–valued, model of systems is invoked, we end up with a nonsmooth system. This is the case, for instance, for hybrid systems in nonlinear control or for piecewise linear modeling of gene regulatory networks in mathematical biology (see Figure 4 (i)). Another common example of nonsmooth dynamics is also found when the vector field of a dynamical system is defined as a solution of an optimization problem under constraints, or a variational inequality. Examples of this kind are found in the optimal control theory, in dynamic Nash equilibrium or in the theory of dynamic flows over networks.
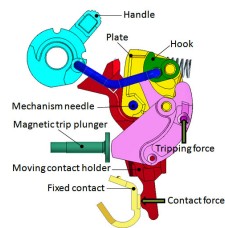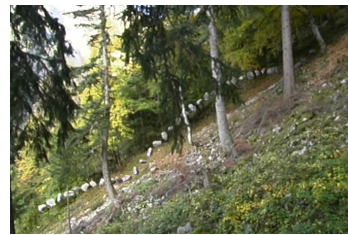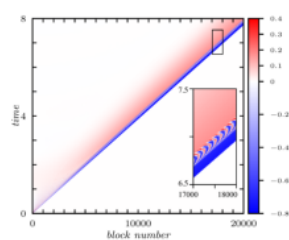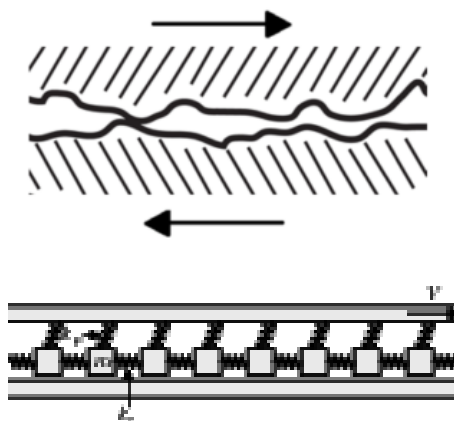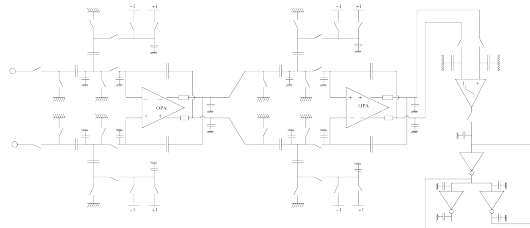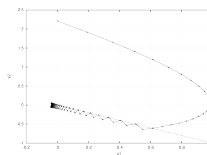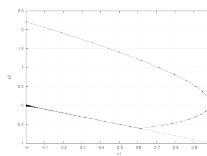
(a) Circuit breakers mechanisms [40]

(b) Granular flows
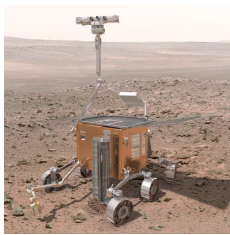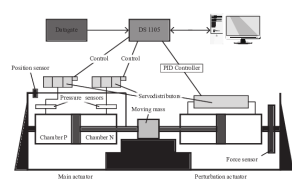

(c) Robots (ESA ExoMars Rover [35])
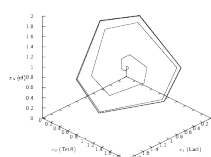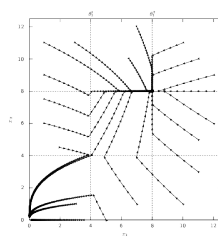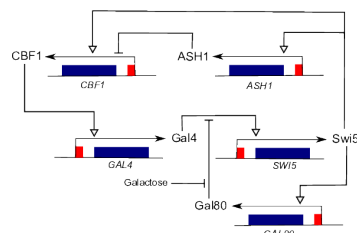

(d) Rockfall [47], [46], [59]

(e) Frictional interface and solitary waves in the Burridge-Knopoff model [81]

(a) Switched electrical circuits (delta-sigma converter) [29]

(b) Sliding mode control [32], [34], [70], [71], [80]

AIRSEA Project-Team

4. Application Domains

4.1. The Ocean-Atmosphere System

The evolution of natural systems, in the short, mid, or long term, has extremely important consequences for both the global Earth system and humanity. Forecasting this evolution is thus a major challenge from the scientific, economic, and human viewpoints.

Humanity has to face the problem of **global warming**, brought on by the emission of greenhouse gases from human activities. This warming will probably cause huge changes at global and regional scales, in terms of climate, vegetation and biodiversity, with major consequences for local populations. Research has therefore been conducted over the past 15 to 20 years in an effort to model the Earth's climate and forecast its evolution in the 21st century in response to anthropic action.

With regard to short-term forecasts, the best and oldest example is of course **weather forecasting**. Meteorological services have been providing daily short-term forecasts for several decades which are of crucial importance for numerous human activities.

Numerous other problems can also be mentioned, like **seasonal weather forecasting** (to enable powerful phenomena like an El Niño event or a drought period to be anticipated a few months in advance), **operational oceanography** (short-term forecasts of the evolution of the ocean system to provide services for the fishing industry, ship routing, defense, or the fight against marine pollution) or the prediction of **floods**.

As mentioned previously, mathematical and numerical tools are omnipresent and play a fundamental role in these areas of research. In this context, the vocation of AIRSEA is not to carry out numerical prediction, but to address mathematical issues raised by the development of prediction systems for these application fields, in close collaboration with geophysicists.

BEAGLE Project-Team

4. Application Domains

4.1. Domain 1

Applications concern Functional and Evolutionary Biology, plant, animal and human health. They are not detailed here because the project itself is oriented by its applications, so the description of applications is described along the project in the previous sections.

DRACULA Project-Team (section vide)

ERABLE Project-Team

4. Application Domains

4.1. Biology and Health

The main areas of application of ERABLE are: (1) biology understood in its more general sense, with a special focus on symbiosis and on intracellular interactions, and (2) health with a special emphasis for now on infectious diseases, rare diseases, and cancer.

IBIS Project-Team (section vide)

MOSAIC Team (section vide)

NUMED Project-Team (section vide)

STEEP Project-Team (section vide)

<p style="text-align:center">**AGORA Project-Team**</p>

4. Application Domains

4.1. Smart Cities

One major characteristic of modern societies is that they are prevalently urban. In coherence, the contributions of the Agora team are in particular applied to provide solutions tailored to the emergence of the Internet of Things (IoT) and to Smart Cities applications. A major motivation of the team is the forthcoming explosion of the number of connected devices. In particular, low cost - small data devices are supposed to be densely deployed in our environment, fostering the interest for a convergence of the traditional wireless networking paradigms.

Smart City is a constantly reshaped concept, embracing the future of dense metropolitan areas, with references to efficient and sustainable infrastructure, improving citizens' quality of life and protecting the environment. A consensus on the Smart City philosophy is however that it will be primarily achieved by leveraging a clever integration of Information and Communication Technologies (ICT) in the urban tissue. Indeed, ICTs are enabling an evolution from the current duality between the real world and its digitized counterpart to a continuum in which digital contents and applications are seamlessly interacting with classical infrastructures and services. Smart Cities are often described by the digital services that should be provided which are inherently dependent on dense measurements of the city environment and activities, the collection of these data, their processing into information, and their redistribution. The networking infrastructure plays therefore a critical role in enabling advanced services, in particular the wireless infrastructure supporting density and mobility.

From a wireless networking viewpoint, the digitization of cities can be seen as a paradigm shift extending the Internet of Things (IoT) to a citizen-centric model in order to leverage the massive data collected by pervasive sensors, connected mobiles or fixed devices, and social applications.

<div align="center">

AVALON Project-Team

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4. Application Domains

4.1. Overview

The AVALON team targets applications with large computing and/or data storage needs, which are still difficult to program, maintain, and deploy. Those applications can be parallel and/or distributed applications, such as large scale simulation applications or code coupling applications. Applications can also be workflow-based as commonly found in distributed systems such as grids or clouds.

The team aims at not being restricted to a particular application field, thus avoiding any spotlight. The team targets different HPC and distributed application fields, which brings use cases with different issues. This will be eased by our various collaborations: the team participates to the INRIA-Illinois Joint Laboratory for Petascale Computing, the Physics, Radiobiology, Medical Imaging, and Simulation French laboratory of excellence, the E-Biothon project, the INRIA large scale initiative Computer and Computational Sciences at Exascale (C2S@Exa), and to BioSyL, a federative research structure about Systems Biology of the University of Lyon. Moreover, the team members have a long tradition of cooperation with application developers such as CERFACS and EDF R&D. Last but not least, the team has a privileged connection with CC IN2P3 that opens up collaborations, in particular in the astrophysics field.

In the following, some examples of representative applications we are targeting are presented. In addition to highlighting some application needs, they also constitute some of the use cases we will use to valide our theoretical results.

4.2. Climatology

The world's climate is currently changing due to the increase of the greenhouse gases in the atmosphere. Climate fluctuations are forecasted for the years to come. For a proper study of the incoming changes, numerical simulations are needed, using general circulation models of a climate system. Simulations can be of different types: HPC applications (*e.g.,* the NEMO framework [40] for ocean modelization), code-coupling applications (*e.g.,* the OASIS coupler [46] for global climate modeling), or workflows (long term global climate modeling).

As for most applications the team is targeting, the challenge is to thoroughly analyze climate-forecasting applications to model their needs in terms of programing model, execution model, energy consumption, data access pattern, and computing needs. Once a proper model of an application has been set up, appropriate scheduling heuristics could be designed, tested, and compared. The team has a long tradition of working with CERFACS on this topic, for example in the LEGO (2006-09) and SPADES (2009-12) French ANR projects.

4.3. Astrophysics

Astrophysics is a major field to produce large volumes of data. For instance, the Large Synoptic Survey Telescope (https://www.lsst.org/lsst/) will produce 15 TB of data every night, with the goals of discovering thousands of exoplanets and of uncovering the nature of dark matter and dark energy in the universe. The Square Kilometer Array (http://www.skatelescope.org/) produces 9 Tbits/s of raw data. One of the scientific projects related to this instrument called Evolutionary Map of the Universe is working on more than 100 TB of images. The Euclid Imaging Consortium (https://www.euclid-ec.org/) will generate 1 PB data per year.

AVALON collaborates with the *Institut de Physique Nucléaire de Lyon* (IPNL) laboratory on large scale numerical simulations in astronomy and astrophysics. Contributions of the AVALON members have been related to algorithmic skeletons to demonstrate large scale connectivity, the development of procedures for the generation of realistic mock catalogs, and the development of a web interface to launch large cosmological simulations on GRID'5000.

This collaboration, that continues around the topics addressed by the CLUES project (http://www.clues-project.org), has been extended thanks to the tight links with the CC-IN2P3. Major astrophysics projects execute part of their computing, and store part of their data on the resources provided by the CC-IN2P3. Among them, we can mention SNFactory, Euclid, or LSST. These applications constitute typical use cases for the research developed in the AVALON team: they are generally structured as workflows and a huge amount of data (from TB to PB) is involved.

4.4. Bioinformatics

Large-scale data management is certainly one of the most important applications of distributed systems in the future. Bioinformatics is a field producing such kinds of applications. For example, DNA sequencing applications make use of MapReduce skeletons.

The AVALON team is a member of BioSyL (http://www.biosyl.org), a Federative Research Structure attached to University of Lyon. It gathers about 50 local research teams working on systems biology. Moreover, the team cooperated with the French Institute of Biology and Chemistry of Proteins (IBCP http://www.ibcp.fr) in particular through the ANR MapReduce project where the team focuses on a bio-chemistry application dealing with protein structure analysis. AVALON has also started working with the Inria Beagle team (https://team.inria.fr/beagle/) on artificial evolution and computational biology as the challenges are around high performance computation and data management.

CTRL-A Project-Team

4. Application Domains

4.1. Self-adaptive and reconfigurable computing systems in HPC and the IoT

We are attacking the problem of designing well-regulated and efficient self-adaptive computing systems by the development of novel strategies for systems management.

The kind of systems we typically target involve relatively coarse grained computation tasks (e.g. image processing or HPC tasks, components or services), assembled in workflows, application dependency graphs, or composites. At that level, there can be parallel and conditional branches, as well as choices that can be made between alternative branches, corresponding to different ways to perform that part of the application. Such tasks can be achieved following a choice of implementations or versions, such as in service oriented approaches. Each implementation has its own characteristics and requirements, e.g., w.r.t. resources consumed and QoS offered. The systems execution infrastructures present heterogeneity, with different computing processors, a variety of peripheral devices (e.g., I/O, video port, accelerators), and different means of communications. This hardware or middleware level also presents adaptation potential e.g., in varying quantities of resources or sleep and stand-by modes.

The kinds of control problems encountered in these adaptive systems concern the navigation in the configurations space defined by choice points at the levels of applications, tasks, and architecture. Upon events or conditions triggering reconfiguration and adaptation, the controller has to choose a next configuration where, on the one hand, all consistency constraints are satisfied w.r.t. dependencies and resources requirements. On the other hand, it has to apply a policy or strategy deciding between correct configurations which one to chose e.g. by optimizing one or more criteria, or by insuring reachability of some later configuration (goal or fallback). This targeted class of computing systems we consider is mid-sized, in the sense that the combinatorial complexity is large enough for manual solving to be impossible, while remaining within the range where supervisory control techniques are tractable. The pace of control is more sporadic, and slower than the instruction-level computation performance within the coarse-grained tasks.

The objectives of CTRL-A will be achieved and evaluated in both of our main application domains, thereby exhibiting their similarities from the point of view of reconfiguration control. A first application domain is High Performance Computing. In this area, we currently focus especially on the management of Dynamic Partial Reconfiguration in FPGA based hardware, at the level of middleware. Here the particular application we consider is, as in our ANR project HPeC starting end of 2015, video image flow processing for smart cameras implemented on DPR FPGASs themselves embedded in drones.

A second general application domain to confront our models is the Internet of Things (IoT), more specifically self-adaptive middleware platforms for Smart Environments, or Industry 4.0 related topics, like SCADA. We focus on providing coordination components and controllers of software components and services, or rule-based middleware platforms. The adaptation problems concern both the functional aspects of the applications in a smart building, and the middleware support deployment and reconfiguration issues. We are considering perspectives concerning self-protection and security.

<p align="center" style="color:red">**DANTE Project-Team**</p>

4. Application Domains

4.1. Life Science & Health

In parallel to the advances in modern medicine, health sciences and public health policy, epidemic models aided by computer simulations and information technologies offer an increasingly important tool for the understanding of transmission dynamics and of epidemic patterns. The increased computational power and use of Information and Communication Technologies make feasible sophisticated modelling approaches augmented by detailed in vivo data sets, and allow to study a variety of possible scenarios and control strategies, helping and supporting the decision process at the scientific, medical and public health level. The research conducted in the DANTE project finds direct applications in the domain of LSH since modelling approaches crucially depend on our ability to describe the interactions of individuals in the population. In the TUBEXPO and ARIBO projects, we are collaborating with Pr. Jean-Christopge Lucet (Professeur des université Paris VII, Praticien hospitalier APHP). Within PhD work of G. Frusque, we collaborate with Dr. Julien Jung from Hôpital de Neurologie de Bron (HCL) and with Nadine Ravel, DR CNRS (CRNL, INSERM).

4.2. Network Science / Complex networks

In the last ten years the science of complex networks has been assigned an increasingly relevant role in defining a conceptual framework for the analysis of complex systems. Network science is concerned with graphs that map entities and their interactions to nodes and links. For a long time, this mathematical abstraction has contributed to the understanding of real-world systems in physics, computer science, biology, chemistry, social sciences, and economics. Recently, however, enormous amounts of detailed data, electronically collected and meticulously catalogued, have finally become available for scientific analysis and study. This has led to the discovery that most networks describing real world systems show the presence of complex properties and heterogeneities, which cannot be neglected in their topological and dynamical description. This has called forth a major effort in developing the methodology to characterise the topology and temporal behaviour of complex networks, to describe the observed structural and temporal heterogeneities, to detect and measure emerging community structure, to see how the functionality of networks determines their evolving structure, and to determine what kinds of correlations play a role in their dynamics. All these efforts have brought us to a point where the science of complex networks has become advanced enough to help us to disclose the deeper roles of complexity and gain understanding about the behaviour of very complicated systems.

In this endeavour the DANTE project targets the study of dynamically evolving networks, concentrating on questions about the evolving structure and dynamical processes taking place on them. During the last year we developed developed several projects along these lines concerning three major datasets:

- Mobile telephony data: In projects with academic partners and Grandata we performed projects based on two large independent datasets collecting the telephone call and SMS event records for million of anonymised individuals. The datasets record the time and duration of mobile phone interactions and some coarse grained location and demographic data for some users. In addition one of the dataset is coupled with anonymised bank credit information allowing us to study directly the socioeconomic structure of a society and how it determines the communication dynamics and structure of individuals.

- Skype data: Together with Skype Labs/STACC and other academic groups we were leading projects in the subject of social spreading phenomena. These projects were based on observations taken from a temporally detailed description of the evolving social network of (anonymised) Skype users registered between 2003 and 2011. This data contains dates of registration and link creation together with gradual information about their location and service usage dynamics.

- Twitter data: In collaboration with ICAR-ENS Lyon we collected a large dataset about the microblogs and communications of millions of Twitter users in the French Twitter space. This data allows us to follow the spreading of fads/opinions/hashtags/ideas and more importantly linguistic features in online communities. The aim of this collaboration is to set the ground for a quantitative framework studying the evolution of linguistic features and dialects in an social-communication space mediated by online social interactions.

4.3. Social Sciences / Epistemology

Political impacts of the internet and of networks begin to be well known (Cambridge Analytica, Russian trolls, etc.). Hence the public at large begins to be aware of the abuses of the leaders of the internet (privacy by firms and advertising, surveillance by states, fake news by activists, etc.). In the same time, on-line exchanges now give scientific estimations of the political life [61] and policital sciences begin to consider the internet as a relevant subject of study. As the internet is a *technology*, philosophy is the best approach to understand what socially happens (or can be made) with the internet. We develop it by two ways:

- political philosophy. Some Dante members are working with Triangle laboratory (social sciences, philosophy and politics; Ens de Lyon and CNRS).

- epistemology, because computer sciences discoveries are related with the evolution of science(s): we discovered that, in the case of the internet, political philosophy can do few if not strongly related to epistemology [62]. Epistemological approach is developed in collaboration with Jean Dhombres (who holds a seminar at Enssib: http://barthes.enssib.fr/cours/Dhombres2018-2019.html and with Hcéres (new relations between social and exact sciences, cf. point 9.2.6).

This approach should help computer scientists to understand how their research may depend on foreign initiatives and to create new links between social sciences and Inria.

<p align="center" style="color:red">DATAMOVE Project-Team</p>

4. Application Domains

4.1. Data Aware Batch Scheduling

Large scale high performance computing platforms are becoming increasingly complex. Determining efficient allocation and scheduling strategies that can adapt to technological evolutions is a strategic and difficult challenge. We are interested in scheduling jobs in hierarchical and heterogeneous large scale platforms. On such platforms, application developers typically submit their jobs in centralized waiting queues. The job management system aims at determining a suitable allocation for the jobs, which all compete against each other for the available computing resources. Performances are measured using different classical metrics like maximum completion time or slowdown. Current systems make use of very simple (but fast) algorithms that however rely on simplistic platform and execution models, and thus, have limited performances.

For all target scheduling problems we aim to provide both theoretical analysis and complementary analysis through simulations. Achieving meaningful results will require strong improvements on existing models (on power for example) and the design of new approximation algorithms with various objectives such as stretch, reliability, throughput or energy consumption, while keeping in focus the need for a low-degree polynomial complexity.

4.1.1. Algorithms

The most common batch scheduling policy is to consider the jobs according to the First Come First Served order (FCFS) with backfilling (BF). BF is the most widely used policy due to its easy and robust implementation and known benefits such as high system utilization. It is well-known that this strategy does not optimize any sophisticated function, but it is simple to implement and it guarantees that there is no starvation (i.e. every job will be scheduled at some moment).

More advanced algorithms are seldom used on production platforms due to both the gap between theoretical models and practical systems and speed constraints. When looking at theoretical scheduling problems, the generally accepted goal is to provide polynomial algorithms (in the number of submitted jobs and the number of involved computing units). However, with millions of processing cores where every process and data transfer have to be individually scheduled, polynomial algorithms are prohibitive as soon as the polynomial degree is too large. The model of *parallel tasks* simplifies this problem by bundling many threads and communications into single boxes, either rigid, rectangular or malleable. Especially malleable tasks capture the dynamicity of the execution. Yet these models are ill-adapted to heterogeneous platforms, as the running time depends on more than simply the number of allotted resources, and some of the common underlying assumptions on the speed-up functions (such as monotony or concavity) are most often only partially verified.

In practice, the job execution times depend on their allocation (due to communication interferences and heterogeneity in both computation and communication), while theoretical models of parallel jobs usually consider jobs as black boxes with a fixed (maximum) execution time. Though interesting and powerful, the classical models (namely, synchronous PRAM model, delay, LogP) and their variants (such as hierarchical delay), are not well-suited to large scale parallelism on platforms where the cost of moving data is significant, non uniform and may change over time. Recent studies are still refining such models in order to take into account communication contentions more accurately while remaining tractable enough to provide a useful tool for algorithm design.

Today, all algorithms in use in production systems are oblivious to communications. One of our main goals is to **design a new generation of scheduling algorithms fitting more closely job schedules according to platform topologies**.

4.1.2. Locality Aware Allocations

Recently, we developed modifications of the standard back-filling algorithm taking into account platform topologies. The proposed algorithms take into account locality and contiguity in order to hide communication patterns within parallel tasks. The main result here is to establish good lower bounds and small approximation ratios for policies respecting the locality constraints. The algorithms work in an online fashion, improving the global behavior of the system while still keeping a low running time. These improvements rely mainly on our past experience in designing approximation algorithms. Instead of relying on complex networking models and communication patterns for estimating execution times, the communications are disconnected from the execution time. Then, the scheduling problem leads to a trade-off: optimizing locality of communications on one side and a performance objective (like the makespan or stretch) on the other side.

In the perspective of taking care of locality, other ongoing works include the study of schedulers for platforms whose interconnection network is a static structured topology (like the 3D-torus of the BlueWaters platform we work on in collaboration with the Argonne National Laboratory). One main characteristic of this 3D-torus platform is to provide I/O nodes at specific locations in the topology. Applications generate and access specific data and are thus bounded to specific I/O nodes. Resource allocations are constrained in a strong and unusual way. This problem is close for actual hierarchical platforms. The scheduler needs to compute a schedule such that I/O nodes requirements are filled for each application while at the same time avoiding communication interferences. Moreover, extra constraints can arise for applications requiring accelerators that are gathered on the nodes at the edge of the network topology.

While current results are encouraging, they are however limited in performance by the low amount of information available to the scheduler. We look forward to extend ongoing work by progressively increasing application and network knowledge (by technical mechanisms like profiling or monitoring or by more sophisticated methods like learning). It is also important to anticipate on application resource usage in terms of compute units, memory as well as network and I/Os to efficiently schedule a mix of applications with different profiles. For instance, a simple solution is to partition the jobs as "communication intensive" or "low communications". Such a tag could be achieved by the users them selves or obtained by learning techniques. We could then schedule low communications jobs using leftover spaces while taking care of high communication jobs. More sophisticated options are possible, for instance those that use more detailed communication patterns and networking models. Such options would leverage the work proposed in Section 4.2 for gathering application traces.

4.1.3. Data-Centric Processing

Exascale computing is shifting away from the traditional compute-centric models to a more data-centric one. This is driven by the evolving nature of large scale distributed computing, no longer dominated by pure computations but also by the need to handle and analyze large volumes of data. These data can be large databases of results, data streamed from a running application or another scientific instrument (collider for instance). These new workloads call for specific resource allocation strategies.

Data movements and storage are expected to be a major energy and performance bottleneck on next generation platforms. Storage architectures are also evolving, the standard centralized parallel file system being complemented with local persistent storage (Burst Buffers, NVRAM). Thus, one data producer can stage data on some nodes' local storage, requiring to schedule close by the associated analytics tasks to limit data movements. This kind of configuration, often referred as *in-situ analytics*, is expected to become common as it enables to switch from the traditional I/O intensive workflow (batch-processing followed by *post mortem* analysis and visualization) to a more storage conscious approach where data are processed as closely as possible to where and when they are produced (in-situ processing is addressed in details in section 4.3). By reducing data movements and scheduling the extra processing on resources not fully exploited yet, in-situ processing is expected to have also a significant positive energetic impact. Analytics codes can be executed in the same nodes than the application, often on dedicated cores commonly called helper cores, or on dedicated nodes called staging nodes. The results are either forwarded to the users for visualization or saved to disk through I/O nodes. In-situ analytics can also take benefit of node local disks or burst buffers to reduce data movements.

Future job scheduling strategies should take into account in-situ processes in addition to the job allocation to optimize both energy consumption and execution time. On the one hand, this problem can be reduced to an allocation problem of extra asynchronous tasks to idle computing units. But on the other hand, embedding analytics in applications brings extra difficulties by making the application more heterogeneous and imposing more constraints (data affinity) on the required resources. Thus, the main point here is to develop efficient algorithms for dealing with heterogeneity without increasing the global computational cost.

4.1.4. Learning

Another important issue is to adapt the job management system to deal with the bad effects of uncertainties, which may be catastrophic in large scale heterogeneous HPC platforms (jobs delayed arbitrarly far or jobs killed). A natural question is then: *is it possible to have a good estimation of the job and platform parameters in order to be able to obtain a better scheduling ?* Many important parameters (like the number or type of required resources or the estimated running time of the jobs) are asked to the users when they submit their jobs. However, some of these values are not accurate and in many cases, they are not even provided by the end-users. In DataMove, we propose to study new methods for a better prediction of the characteristics of the jobs and their execution in order to improve the optimization process. In particular, the methods well-studied in the field of big data (in supervised Machine Learning, like classical regression methods, Support Vector Methods, random forests, learning to rank techniques or deep learning) could and must be used to improve job scheduling in large scale HPC platforms. This topic received a great attention recently in the field of parallel and distributed processing. A preliminary study has been done recently by our team with the target of predicting the job running times (called wall times). We succeeded to improve significantly in average the reference EASY Back Filling algorithm by estimating the wall time of the jobs, however, this method leads to big delay for the stretch of few jobs. Even if we succeed in determining more precisely hidden parameters, like the wall time of the jobs, this is not enough to determine an optimized solution. The shift is not only to learn on dedicated parameters but also on the scheduling policy. The data collected from the accounting and profiling of jobs can be used to better understand the needs of the jobs and through learning to propose adaptations for future submissions. The goal is to propose extensions to further improve the job scheduling and improve the performance and energy efficiency of the application. For instance preference learning may enable to compute on-line new priorities to back-fill the ready jobs.

4.1.5. Multi-objective Optimization

Several optimization questions that arise in allocation and scheduling problems lead to the study of several objectives at the same time. The goal is then not a single optimal solution, but a more complicated mathematical object that captures the notion of trade-off. In broader terms, the goal of multi-objective optimization is not to externally arbitrate on disputes between entities with different goals, but rather to explore the possible solutions to highlight the whole range of interesting compromises. A classical tool for studying such multi-objective optimization problems is to use *Pareto curves*. However, the full description of the Pareto curve can be very hard because of both the number of solutions and the hardness of computing each point. Addressing this problem will opens new methodologies for the analysis of algorithms.

To further illustrate this point here are three possible case studies with emphasis on conflicting interests measured with different objectives. While these cases are good representatives of our HPC context, there are other pertinent trade-offs we may investigate depending on the technology evolution in the coming years. This enumeration is certainly not limitative.

Energy versus Performance. The classical scheduling algorithms designed for the purpose of performance can no longer be used because performance and energy are contradictory objectives to some extent. The scheduling problem with energy becomes a multi-objective problem in nature since the energy consumption should be considered as equally important as performance at exascale. A global constraint on energy could be a first idea for determining trade-offs but the knowledge of the Pareto set (or an approximation of it) is also very useful.

Administrators versus application developers. Both are naturally interested in different objectives: In current algorithms, the performance is mainly computed from the point of view of administrators, but the users should be in the loop since they can give useful information and help to the construction of better schedules. Hence, we face again a multi-objective problem where, as in the above case, the approximation of the Pareto set provides the trade-off between the administrator view and user demands. Moreover, the objectives are usually of the same nature. For example, *max stretch* and *average stretch* are two objectives based on the slowdown factor that can interest administrators and users, respectively. In this case the study of the norm of stretch can be also used to describe the trade-off (recall that the L_1-norm corresponds to the average objective while the L_∞-norm to the max objective). Ideally, we would like to design an algorithm that gives good approximate solutions at the same time for all norms. The L_2 or L_3-norm are useful since they describe the performance of the whole schedule from the administrator point of view as well as they provide a fairness indication to the users. The hard point here is to derive theoretical analysis for such complicated tools.

Resource Augmentation. The classical resource augmentation models, i.e. speed and machine augmentation, are not sufficient to get good results when the execution of jobs cannot be frequently interrupted. However, based on a resource augmentation model recently introduced, where the algorithm may reject a small number of jobs, some members of our team have given the first interesting results in the non-preemptive direction. In general, resource augmentation can explain the intuitive good behavior of some greedy algorithms while, more interestingly, it can give ideas for new algorithms. For example, in the rejection context we could dedicate a small number of nodes for the usually problematic rejected jobs. Some initial experiments show that this can lead to a schedule for the remaining jobs that is very close to the optimal one.

4.2. Empirical Studies of Large Scale Platforms

Experiments or realistic simulations are required to take into account the impact of allocations and assess the real behavior of scheduling algorithms. While theoretical models still have their interest to lay the groundwork for algorithmic designs, the models are necessarily reflecting a purified view of the reality. As transferring our algorithm in a more practical setting is an important part of our creed, we need to ensure that the theoretical results found using simplified models can really be transposed to real situations. On the way to exascale computing, large scale systems become harder to study, to develop or to calibrate because of the costs in both time and energy of such processes. It is often impossible to convince managers to use a production cluster for several hours simply to test modifications in the RJMS. Moreover, as the existing RJMS production systems need to be highly reliable, each evolution requires several real scale test iterations. The consequence is that scheduling algorithms used in production systems are mostly outdated and not customized correctly. To circumvent this pitfall, we need to develop tools and methodologies for alternative empirical studies, from analysis of workload traces, to job models, simulation and emulation with reproducibility concerns.

4.2.1. *Workload Traces with Resource Consumption*

Workload traces are the base element to capture the behavior of complete systems composed of submitted jobs, running applications, and operating tools. These traces must be obtained on production platforms to provide relevant and representative data. To get a better understanding of the use of such systems, we need to look at both, how the jobs interact with the job management system, and how they use the allocated resources. We propose a general workload trace format that adds jobs resource consumption to the commonly used SWF [0] workload trace format. This requires to instrument the platforms, in particular to trace resource consumptions like CPU, data movements at memory, network and I/O levels, with an acceptable performance impact. In a previous work we studied and proposed a dedicated job monitoring tool whose impact on the system has been measured as lightweight (0.35% speed-down) with a 1 minute sampling rate. Other tools also explore job monitoring, like TACC Stats. A unique feature from our tool is its ability to monitor distinctly jobs sharing common nodes.

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[0] Standard Workload Format: http://www.cs.huji.ac.il/labs/parallel/workload/swf.html

Collected workload traces with jobs resource consumption will be publicly released and serve to provide data for works presented in Section 4.1 . The trace analysis is expected to give valuable insights to define models encompassing complex behaviours like network topology sensitivity, network congestion and resource interferences.

We expect to join efforts with partners for collecting quality traces (ATOS/Bull, Ciment meso center, Joint Laboratory on Extreme Scale Computing) and will collaborate with the Inria team POLARIS for their analysis.

4.2.2. *Simulation*

Simulations of large scale systems are faster by multiple orders of magnitude than real experiments. Unfortunately, replacing experiments with simulations is not as easy as it may sound, as it brings a host of new problems to address in order to ensure that the simulations are closely approximating the execution of typical workloads on real production clusters. Most of these problems are actually not directly related to scheduling algorithms assessment, in the sense that the workload and platform models should be defined independently from the algorithm evaluations, in order to ensure a fair assessment of the algorithms' strengths and weaknesses. These research topics (namely platform modeling, job models and simulator calibration) are addressed in the other subsections.

We developed an open source platform simulator within DataMove (in conjunction with the OAR development team) to provide a widely distributable test bed for reproducible scheduling algorithm evaluation. Our simulator, named Batsim, allows to simulate the behavior of a computational platform executing a workload scheduled by any given scheduling algorithm. To obtain sound simulation results and to broaden the scope of the experiments that can be done thanks to Batsim, we did not chose to create a (necessarily limited) simulator from scratch, but instead to build on top of the SimGrid simulation framework.

To be open to as many batch schedulers as possible, Batsim decouples the platform simulation and the scheduling decisions in two clearly-separated software components communicating through a complete and documented protocol. The Batsim component is in charge of simulating the computational resources behaviour whereas the scheduler component is in charge of taking scheduling decisions. The scheduler component may be both a resource and a job management system. For jobs, scheduling decisions can be to execute a job, to delay its execution or simply to reject it. For resources, other decisions can be taken, for example to change the power state of a machine i.e. to change its speed (in order to lower its energy consumption) or to switch it on or off. This separation of concerns also enables interfacing with potentially any commercial RJMS, as long as the communication protocol with Batsim is implemented. A proof of concept is already available with the OAR RJMS.

Using this test bed opens new research perspectives. It allows to test a large range of platforms and workloads to better understand the real behavior of our algorithms in a production setting. In turn, this opens the possibility to tailor algorithms for a particular platform or application, and to precisely identify the possible shortcomings of the theoretical models used.

4.2.3. *Job and Platform Models*

The central purpose of the Batsim simulator is to simulate job behaviors on a given target platform under a given resource allocation policy. Depending on the workload, a significant number of jobs are parallel applications with communications and file system accesses. It is not conceivable to simulate individually all these operations for each job on large plaforms with their associated workload due to implied simulation complexity. The challenge is to define a coarse grain job model accurate enough to reproduce parallel application behavior according to the target platform characteristics. We will explore models similar to the BSP (Bulk Synchronous Program) approach that decomposes an application in local computation supersteps ended by global communications and a global synchronization. The model parameters will be established by means of trace analysis as discussed previously, but also by instrumenting some parallel applications to capture communication patterns. This instrumentation will have a significant impact on the concerned application performance, restricting its use to a few applications only. There are a lot of recurrent applications executed on HPC platform, this fact will help to reduce the required number of instrumentations and captures. To assign

each job a model, we are considering to adapt the concept of application signatures as proposed in. Platform models and their calibration are also required. Large parts of these models, like those related to network, are provided by Simgrid. Other parts as the filesystem and energy models are comparatively recent and will need to be enhanced or reworked to reflect the HPC platform evolutions. These models are then generally calibrated by running suitable benchmarks.

4.2.4. Emulation and Reproducibility

The use of coarse models in simulation implies to set aside some details. This simplification may hide system behaviors that could impact significantly and negatively the metrics we try to enhance. This issue is particularly relevant when large scale platforms are considered due to the impossibility to run tests at nominal scale on these real platforms. A common approach to circumvent this issue is the use of emulation techniques to reproduce, under certain conditions, the behavior of large platforms on smaller ones. Emulation represents a natural complement to simulation by allowing to execute directly large parts of the actual evaluated software and system, but at the price of larger compute times and a need for more resources. The emulation approach was chosen in to compare two job management systems from workload traces of the CURIE supercomputer (80000 cores). The challenge is to design methods and tools to emulate with sufficient accuracy the platform and the workload (data movement, I/O transfers, communication, applications interference). We will also intend to leverage emulation tools like Distem from the MADYNES team. It is also important to note that the Batsim simulator also uses emulation techniques to support the core scheduling module from actual RJMS. But the integration level is not the same when considering emulation for larger parts of the system (RJMS, compute node, network and filesystem).

Replaying traces implies to prepare and manage complex software stacks including the OS, the resource management system, the distributed filesystem and the applications as well as the tools required to conduct experiments. Preparing these stacks generate specific issues, one of the major one being the support for re-producibility. We propose to further develop the concept of reconstructability to improve experiment reproducibility by capturing the build process of the complete software stack. This approach ensures reproducibility over time better than other ways by keeping all data (original packages, build recipe and Kameleon engine) needed to build the software stack.

In this context, the Grid'5000 (see Sec. 5.4) experimentation infrastructure that gives users the control on the complete software stack is a crucial tool for our research goals. We will pursue our strong implication in this infrastructure.

4.3. Integration of High Performance Computing and Data Analytics

Data produced by large simulations are traditionally handled by an I/O layer that moves them from the compute cores to the file system. Analysis of these data are performed after reading them back from files, using some domain specific codes or some scientific visualisation libraries like VTK. But writing and then reading back these data generates a lot of data movements and puts under pressure the file system. To reduce these data movements, **the in situ analytics paradigm proposes to process the data as closely as possible to where and when the data are produced**. Some early solutions emerged either as extensions of visualisation tools or of I/O libraries like ADIOS. But significant progresses are still required to provide efficient and flexible high performance scientific data analysis tools. Integrating data analytics in the HPC context will have an impact on resource allocation strategies, analysis algorithms, data storage and access, as well as computer architectures and software infrastructures. But this paradigm shift imposed by the machine performance also sets the basis for a deep change on the way users work with numerical simulations. The traditional workflow needs to be reinvented to make HPC more user-centric, more interactive and turn HPC into a commodity tool for scientific discovery and engineering developments. In this context DataMove aims at investigating programming environments for in situ analytics with a specific focus on task scheduling in particular, to ensure an efficient sharing of resources with the simulation.

4.3.1. Programming Model and Software Architecture

In situ creates a tighter loop between the scientist and her/his simulation. As such, an in situ framework needs to be flexible to let the user define and deploy its own set of analysis. A manageable flexibility requires to favor simplicity and understandability, while still enabling an efficient use of parallel resources. Visualization libraries like VTK or Visit, as well as domain specific environments like VMD have initially been developed for traditional post-mortem data analysis. They have been extended to support in situ processing with some simple resource allocation strategies but the level of performance, flexibility and ease of use that is expected requires to rethink new environments. There is a need to develop a middleware and programming environment taking into account in its fundations this specific context of high performance scientific analytics.

Similar needs for new data processing architectures occurred for the emerging area of Big Data Analytics, mainly targeted to web data on cloud-based infrastructures. Google Map/Reduce and its successors like Spark or Stratosphere/Flink have been designed to match the specific context of efficient analytics for large volumes of data produced on the web, on social networks, or generated by business applications. These systems have mainly been developed for cloud infrastructures based on commodity architectures. They do not leverage the specifics of HPC infrastructures. Some preliminary adaptations have been proposed for handling scientific data in a HPC context. However, these approaches do not support in situ processing.

Following the initial development of FlowVR, our middleware for in situ processing, we will pursue our effort to develop a programming environment and software architecture for high performance scientific data analytics. Like FlowVR, the map/reduce tools, as well as the machine learning frameworks like TensorFlow, adopted a dataflow graph for expressing analytics pipe-lines. We are convinced that this dataflow approach is both easy to understand and yet expresses enough concurrency to enable efficient executions. The graph description can be compiled towards lower level representations, a mechanism that is intensively used by Stratosphere/Flink for instance. Existing in situ frameworks, including FlowVR, inherit from the HPC way of programming with a thiner software stack and a programming model close to the machine. Though this approach enables to program high performance applications, this is usually too low level to enable the scientist to write its analysis pipe-line in a short amount of time. The data model, i.e. the data semantics level accessible at the framework level for error check and optimizations, is also a fundamental aspect of such environments. The key/value store has been adopted by all map/reduce tools. Except in some situations, it cannot be adopted as such for scientific data. Results from numerical simulations are often more structured than web data, associated with acceleration data structures to be processed efficiently. We will investigate data models for scientific data building on existing approaches like Adios or DataSpaces.

4.3.2. Resource Sharing

To alleviate the I/O bottleneck, the in situ paradigm proposes to start processing data as soon as made available by the simulation, while still residing in the memory of the compute node. In situ processings include data compression, indexing, computation of various types of descriptors (1D, 2D, images, etc.). Per se, reducing data output to limit I/O related performance drops or keep the output data size manageable is not new. Scientists have relied on solutions as simple as decreasing the frequency of result savings. In situ processing proposes to move one step further, by providing a full fledged processing framework enabling scientists to more easily and thoroughly manage the available I/O budget.

The most direct way to perform in situ analytics is to inline computations directly in the simulation code. In this case, in situ processing is executed in sequence with the simulation that is suspended meanwhile. Though this approach is direct to implement and does not require complex framework environments, it does not enable to overlap analytics related computations and data movements with the simulation execution, preventing to efficiently use the available resources. Instead of relying on this simple time sharing approach, several works propose to rely on space sharing where one or several cores per node, called *helper cores*, are dedicated to analytics. The simulation responsibility is simply to handle a copy of the relevant data to the node-local in situ processes, both codes being executed concurrently. This approach often lead to significantly beter performance than in-simulation analytics.

For a better isolation of the simulation and in situ processes, one solution consists in offloading in situ tasks from the simulation nodes towards extra dedicated nodes, usually called *staging nodes*. These computations are said to be performed *in-transit*. But this approach may not always be beneficial compared to processing on simulation nodes due to the costs of moving the data from the simulation nodes to the staging nodes.

FlowVR enables to mix these different resources allocation strategies for the different stages of an analytics pile-line. Based on a component model, the scientist designs analytics workflows by first developing processing components that are next assembled in a dataflow graph through a Python script. At runtime the graph is instantiated according to the execution context, FlowVR taking care of deploying the application on the target architecture, and of coordinating the analytics workflows with the simulation execution.

But today the choice of the resource allocation strategy is mostly ad-hoc and defined by the programmer. We will investigate solutions that enable a cooperative use of the resource between the analytics and the simulation with minimal hints from the programmer. In situ processings inherit from the parallelization scale and data distribution adopted by the simulation, and must execute with minimal perturbations on the simulation execution (whose actual resource usage is difficult to know a priori). We need to develop adapted scheduling strategies that operate at compile and run time. Because analysis are often data intensive, such solutions must take into consideration data movements, a point that classical scheduling strategies designed first for compute intensive applications often overlook. We expect to develop new scheduling strategies relying on the methodologies developed in Sec. 4.1.5 . Simulations as well as analysis are iterative processes exposing a strong spatial and temporal coherency that we can take benefit of to anticipate their behavior and then take more relevant resources allocation strategies, possibly based on advanced learning algorithms or as developed in Section 4.1 .

In situ analytics represent a specific workload that needs to be scheduled very closely to the simulation, but not necessarily active during the full extent of the simulation execution and that may also require to access data from previous runs (stored in the file system or on specific burst-buffers). Several users may also need to run concurrent analytics pipe-lines on shared data. This departs significantly from the traditional batch scheduling model, motivating the need for a more elastic approach to resource provisioning. These issues will be conjointly addressed with research on batch scheduling policies (Sec. 4.1).

4.3.3. *Co-Design with Data Scientists*

Given the importance of users in this context, it is of primary importance that in situ tools be co-designed with advanced users, even if such multidisciplinary collaborations are challenging and require constant long term investments to learn and understand the specific practices and expectations of the other domain.

We will tightly collaborate with scientists of some application domains, like molecular dynamics or fluid simulation, to design, develop, deploy and assess in situ analytics scenarios, as already done with Marc Baaden, a computational biologist from LBT.

We recently extended our collaboration network. We started in 2015 a PhD co-advised with CEA DAM to investigate in situ analytics scenarios in the context of atomistic material simulations. CEA DAM is a French energy lab hosting one of the largest european supercomputer. They gather physicists, numerical scientists as well as high performance computer engineers, making it a very interesting partner for developing new scientific data analysis solutions. We also got a national grant (2015-2018) to compute in situ statistics for multi-parametric parallel studies with the research department of French power company EDF. In this context we collaborate with statisticians and fluid simulation experts to define in situ scenarios, revisit the statistic operators to be amenable to in situ processing, and define an adapted in situ framework.

<p align="center" style="color:red">POLARIS Project-Team</p>

4. Application Domains

4.1. Large Computing Infrastructures

Supercomputers typically comprise thousands to millions of multi-core CPUs with GPU accelerators interconnected by complex interconnection networks that are typically structured as an intricate hierarchy of network switches. Capacity planning and management of such systems not only raises challenges in term of computing efficiency but also in term of energy consumption. Most legacy (SPMD) applications struggle to benefit from such infrastructure since the slightest failure or load imbalance immediately causes the whole program to stop or at best to waste resources. To scale and handle the stochastic nature of resources, these applications have to rely on dynamic runtimes that schedule computations and communications in an opportunistic way. Such evolution raises challenges not only in terms of programming but also in terms of observation (complexity and dynamicity prevents experiment reproducibility, intrusiveness hinders large scale data collection, ...) and analysis (dynamic and flexible application structures make classical visualization and simulation techniques totally ineffective and require to build on *ad hoc* information on the application structure).

4.2. Next-Generation Wireless Networks

Considerable interest has arisen from the seminal prediction that the use of multiple-input, multiple-output (MIMO) technologies can lead to substantial gains in information throughput in wireless communications, especially when used at a massive level. In particular, by employing multiple inexpensive service antennas, it is possible to exploit spatial multiplexing in the transmission and reception of radio signals, the only physical limit being the number of antennas that can be deployed on a portable device. As a result, the wireless medium can accommodate greater volumes of data traffic without requiring the reallocation (and subsequent re-regulation) of additional frequency bands. In this context, throughput maximization in the presence of interference by neighboring transmitters leads to games with convex action sets (covariance matrices with trace constraints) and individually concave utility functions (each user's Shannon throughput); developing efficient and distributed optimization protocols for such systems is one of the core objectives of Theme 5.

Another major challenge that occurs here is due to the fact that the efficient physical layer optimization of wireless networks relies on perfect (or close to perfect) channel state information (CSI), on both the uplink and the downlink. Due to the vastly increased computational overhead of this feedback – especially in decentralized, small-cell environments – the ongoing transition to fifth generation (5G) wireless networks is expected to go hand-in-hand with distributed learning and optimization methods that can operate reliably in feedback-starved environments. Accordingly, one of POLARIS' application-driven goals will be to leverage the algorithmic output of Theme 5 into a highly adaptive resource allocation framework for next-géneration wireless systems that can effectively "learn in the dark", without requiring crippling amounts of feedback.

4.3. Energy and Transportation

Smart urban transport systems and smart grids are two examples of collective adaptive systems. They consist of a large number of heterogeneous entities with decentralised control and varying degrees of complex autonomous behaviour. We develop an analysis tools to help to reason about such systems. Our work relies on tools from fluid and mean-field approximation to build decentralized algorithms that solve complex optimization problems. We focus on two problems: decentralized control of electric grids and capacity planning in vehicle-sharing systems to improve load balancing.

4.4. Social Computing Systems

Social computing systems are online digital systems that use personal data of their users at their core to deliver personalized services directly to the users. They are omnipresent and include for instance recommendation systems, social networks, online medias, daily apps, etc. Despite their interest and utility for users, these systems pose critical challenges of privacy, security, transparency, and respect of certain ethical constraints such as fairness. Solving these challenges involves a mix of measurement and/or audit to understand and assess issues, and modeling and optimization to propose and calibrate solutions.

<p style="text-align:center">**ROMA Project-Team**</p>

4. Application Domains

4.1. Applications of sparse direct solvers

Sparse direct (e.g., multifrontal solvers that we develop) solvers have a wide range of applications as they are used at the heart of many numerical methods in computational science: whether a model uses finite elements or finite differences, or requires the optimization of a complex linear or nonlinear function, one often ends up solving a system of linear equations involving sparse matrices. There are therefore a number of application fields, among which some of the ones cited by the users of our sparse direct solver MUMPS are: structural mechanics, seismic modeling, biomechanics, medical image processing, tomography, geophysics, electromagnetism, fluid dynamics, econometric models, oil reservoir simulation, magneto-hydro-dynamics, chemistry, acoustics, glaciology, astrophysics, circuit simulation, and work on hybrid direct-iterative methods.

SOCRATE Project-Team (section vide)

<p style="text-align: center; color: red;">**Chroma Project-Team**</p>

4. Application Domains

4.1. Introduction

Applications in Chroma are organized in two main domains : **i) Future cars and transportation systems and ii) Services robotics.** These domains correspond to the experimental fields initiated in Grenoble (eMotion team) and in Lyon (CITI lab). However, the scientific objectives described in the previous sections are intended to apply equally to both applicative domains. Even our work on Bayesian Perception is today applied to the intelligent vehicle domain, we aim to generalize to any mobile robots. The same remark applies to the work on multi-agent decision making. We aim to apply algorithms to any fleet of mobile robots (service robots, connected vehicles, UAVs). This is the philosophy of the team since its creation.

Figure 4. Most of the Chroma platforms: the Pepper robot, a fleet of (22) Turtlebot 2, one of the 4 Bebop drones and the equipped Toyota Lexus.

4.2. Future cars and transportation systems

Thanks to the introduction of new sensor and ICT technologies in cars and in mass transportation systems, and also to the pressure of economical and security requirements of our modern society, this application domain is quickly changing. Various technologies are currently developed by both research and industrial laboratories. These technologies are progressively arriving at maturity, as it is witnessed by the results of large scale experiments and challenges such as the Google's car project and several future products announcements made by the car industry. Moreover, the legal issue starts to be addressed in USA (see for instance the recent laws in Nevada and in California authorizing autonomous vehicles on roads) and in several other countries (including France).

In this context, we are interested in the development of ADAS [0] systems aimed at improving comfort and safety of the cars users (e.g., ACC, emergency braking, danger warnings), and of Fully Autonomous Driving functions for controlling the displacements of private or public vehicles in some particular driving situations and/or in some equipped areas (e.g., automated car parks or captive fleets in downtown centers or private sites).

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[0] Advanced Driver Assistance Systems

Since about 8 years, we are collaborating with Toyota and with Renault-Nissan on these applications (bilateral contracts, PhD Theses, shared patents), but also recently with Volvo group (PhD thesis started in 2016). We are also strongly involved (since 2012) in the innovation project Perfect then now Security for autonomous vehicle of the IRT [0] Nanoelec (transportation domain). In 2016, we have been awarded a European H2020 ECSEL project [0] involving major European automotive constructors and car suppliers. In this project, Chroma is focusing on the embedded perception component (models and algorithms, including the certification issue), in collaboration with Renault, Valeo and also with the Inria team TAMIS (Rennes). Chroma is also involved in the ANR project "Valet" (2015-2018) coordinated by the Inria team RITS (Rocquencourt), dealing with automatic redistribution of car-sharing vehicles and parking valet; Chroma is involved in the pedestrian-vehicle interaction for a safe navigation.

In this context, Chroma has two experimental vehicles equipped with various sensors (a Toyota Lexus and a Renault Zoe, see. Fig. 4 and Fig. 2 .b), which are maintained by Inria-SED [0] and that allow the team to perform experiments in realistic traffic conditions (Urban, road and highway environments). The Zoe car has been automated in December 2016, through our collaboration with the team of P. Martinet (IRCCyN Lab, Nantes), that allow new experiments in the team.

4.3. Services robotics

Service robotics is an application domain quickly emerging, and more and more industrial companies (e.g., IS-Robotics, Samsung, LG) are now commercializing service and intervention robotics products such as vacuum cleaner robots, drones for civil or military applications, entertainment robots ... One of the main challenges is to propose robots which are sufficiently robust and autonomous, easily usable by non-specialists, and marked at a reasonable cost. We are involved in developing observation and surveillance systems, by using ground robots and aerial ones, see Fig. 4 . Since 2016, we develop solutions for 3D observation/exploration of complex scenes or environments with a fleet of UAVs (Inria ADT CORDES [0]) or mobile robots (COMODYS FIL project [32]).

A more recent challenge for the coming decade is to develop robotized systems for assisting elderly and/or disabled people. In the continuity of our work in the IPL PAL [0], we aim to propose smart technologies to assist electric wheelchair users in their displacements and also to conttrol autonomous cars in human crowds. This concerns our recent "Hianic" ANR project. Another emerging application is humanoid robots helping humans at their home or work. In this context, we address the problem of NAMO (Navigation Among Movable Obstacles) in human populated environments (eg. PhD of B. Renault started on 2018). More generally we address navigation and reconnaissance tasks with Pepper humanoids in the context of the RoboCup-Social League.

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[0]Institut de Recherche Technologique
[0]ENABLE-S3: European Initiative to Enable Validation for Highly Automated Safe and Secure Systems.
[0]Service Expérimentation et Développement
[0]Coordination d'une Flotte de Drones Connectés pour la Cartographie 3D d'édifices, led by O. Simonin.
[0]Personnaly assisted Living

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IMAGINE Project-Team

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4. Application Domains

4.1. Visual arts

Our research can be applied to any situation where users need to create new, imaginary, 3D content. Our work should be instrumental, in the long term, for the visual arts, from the creation of 3D films and games to the development of new digital planning tools for theater or cinema directors. Our models can also be used in interactive prototyping environments for engineering. They can help promoting interactive digital design to scientists, as a tool to quickly express, test and refine models, as well as an efficient way for conveying them to other people. Lastly, we expect our new methodology to put digital modeling within the reach of the general public, enabling educators, media and other practitioners to author their own 3D content.

The diversity of users these domains bring, from digital experts to other professionals and novices, gives us excellent opportunities to validate our general methodology with different categories of users. Our ongoing projects in these various application domains are listed in Section 6.

- Sculpture.
- Modeling and animation for 3D films and games.
- Virtual cinematography and tools for theater directors.

4.2. Engineering

- Industrial design.
- Mechanical & civil engineering.

4.3. Natural sciences

- Geology.
- Virtual functional anatomy.

4.4. Education and creative tools

- Sketch-based teaching.
- Creative environments for novice users.
- Museography

<p align="center" style="color:red">MAVERICK Project-Team</p>

4. Application Domains

4.1. Application Domains

The natural application domain for our research is the production of digital images, for example for movies and special effects, virtual prototyping, video games... Our research have also been applied to tools for generating and editing images and textures, for example generating textures for maps. Our current application domains are:

- Offline and real-time rendering in movie special effects and video games;
- Virtual prototyping;
- Scientific visualization;
- Content modeling and generation (e.g. generating texture for video games, capturing reflectance properties, etc);
- Image creation and manipulation.

MOEX Project-Team (section vide)

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MORPHEO Project-Team

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4. Application Domains

4.1. 4D modeling

Modeling shapes that evolve over time, analyzing and interpreting their motion has been a subject of increasing interest of many research communities including the computer vision, the computer graphics and the medical imaging communities. Recent evolutions in acquisition technologies including 3D depth cameras (Time-of-Flight and Kinect), multi-camera systems, marker based motion capture systems, ultrasound and CT scanners have made those communities consider capturing the real scene and their dynamics, create 4D spatio-temporal models, analyze and interpret them. A number of applications including dense motion capture, dynamic shape modeling and animation, temporally consistent 3D reconstruction, motion analysis and interpretation have therefore emerged.

4.2. Shape Analysis

Most existing shape analysis tools are local, in the sense that they give local insight about an object's geometry or purpose. The use of both geometry and motion cues makes it possible to recover more global information, in order to get extensive knowledge about a shape. For instance, motion can help to decompose a 3D model of a character into semantically significant parts, such as legs, arms, torso and head. Possible applications of such high-level shape understanding include accurate feature computation, comparison between models to detect defects or medical pathologies, and the design of new biometric models.

4.3. Human Motion Analysis

The recovery of dense motion information enables the combined analysis of shapes and their motions. Typical examples include the estimation of mean shapes given a set of 3D models or the identification of abnormal deformations of a shape given its typical evolutions. The interest arises in several application domains where temporal surface deformations need to be captured and analyzed. It includes human body analyses for which potential applications are anyway numerous and important, from the identification of pathologies to the design of new prostheses.

4.4. Virtual and Augmented Reality

This domain has actually seen new devices emerged that enable now full 3D visualization, for instance the HTC Vive, the Microsoft Hololens and the Magic leap one. These devices create a need for adapted animated 3D contents that can either be generated or captured. We believe that captured 4D models will gain interest in this context since they provide realistic visual information on moving shapes that tend to avoid negative perception effects such as the uncanny valley effect. Besides 3D visualization devices, many recent applications also rely on everyday devices, such as mobile phones, to display augmented reality contents with free viewpoint ability. In this case, 3D and 4D contents are also expected.

PERCEPTION Project-Team (section vide)

PERVASIVE Project-Team

4. Application Domains

4.1. Smart Energy Systems

Participants: Amr Alyafi, Amine Awada, Patrick Reignier Partners: UMR G-SCOP, UMR LIG (Persuasive Interaction, IIHM), CEA Liten, PACTE, Vesta Systems and Elithis.

Work in this area explores techniques for a user centric energy management system, where user needs and tacit knowledge drive the search of solutions. These are calculated using a flexible energy model of the living areas. The system is personified by energy consultants with which building actors such as building owners, building managers, technical operators but also occupants, can interact in order to co-define energy strategies, benefiting of both assets: tacit knowledge of human actors, and measurement with computation capabilities of calculators. Putting actors in the loop, i.e. making energy not only visible but also controllable is the needed step before large deployment of energy management solutions. It is proposed to develop interactive energy consultants for all the actors, which are energy management aided systems embedding models in order to support the decision making processes. MIRROR (interactive monitoring), WHAT-IF (interactive quantitative simulation), EXPLAIN (interactive qualitative simulation), SUGGEST-AND-ADJUST (interactive management) and RECOMMEND (interactive diagnosis) functionalities will be developed.

4.2. E-Textile

Participant: Sabine Coquillart

Partner: LIMSI

Collaboration with the HAPCO team from LIMSI on e-textiles. A patent application has been filed related to this work:

- F. Bimbard, M. Bobin, M. Ammi, S. Coquillart "Procédé de conception d'un capteur de flexion textile piézorésistif à partir de fils fonctionnels", Patent Application, 2017.

4.3. Interaction with Pervasive Media

Participants: Sabine Coquillart, Jingtao Chen

Partners: Inria GRA, GIPSA, G-SCOP

Pseudo-haptic feedback is a technique aiming to simulate haptic sensations without active haptic feedback devices. Peudo-haptic techniques have been used to simulate various haptic feedbacks such as stiffness, torques, and mass. In the framework of Jingtao Chen PhD thesis, a novel pseudo-haptic experiment has been set up. The aim of this experiment is to study the EMG signals during a pseudo-haptic task. A stiffness discrimination task similar to the one published in Lecuyer's PhD thesis has been chosen. The experimental set-up has been developed, as well as the software controlling the experiment. Pre-tests are under way. They will be followed by the tests with subjects.

4.4. Bayesian Reasoning

Participants: Emmanuel Mazer, Raphael Frisch, Augustin Lux, Didier Piau, Marvin Faix, Jeremy Belot

The development of modern computers is mainly based on increase of performances and decrease of size and energy consumption, with no notable modification of the basic principles of computation. In particular, all the components perform deterministic and exact operations on sets of binary signals. These constraints obviously impede further sizable progresses in terms of speed, miniaturization and power consumption. The main goal of the project MicroBayes is to investigate a radically different approach, using stochastic bit streams to perform computations. The aim of this project is to show that stochastic architectures can outperform standard computers to solve complex inference problems both in terms of execution speed and of power consumption. We will demonstrate the feasibility on two applications involving low level information processing from sensor signals, namely sound source localization and separation.

THOTH Project-Team

4. Application Domains

4.1. Visual applications

Any solution to automatically understanding images and videos on a semantic level will have an immediate impact on a wide range of applications. For example:

- Semantic-level image and video access is highly relevant for visual search on the Web, in professional archives and personal collections.

- Visual data organization is applicable to organizing family photo and video albums as well as to large-scale information retrieval.

- Visual object recognition has potential applications ranging from surveillance, service robotics for assistance in day-to-day activities as well as the medical domain.

- Action recognition is highly relevant to visual surveillance, assisted driving and video access.

- Real-time scene understanding is relevant for human interaction through devices such as HoloLens, Oculus Rift.

4.2. Pluri-disciplinary research

Machine learning is intrinsically pluri-disciplinary. By developing large-scale machine learning models and algorithms for processing data, the Thoth team became naturally involved in pluri-disciplinary collaborations that go beyond visual modelling. In particular,

- extensions of unsupervised learning techniques originally developed for modelling the statistics of natural images have been deployed in neuro-imaging for fMRI data with the collaboration of the Parietal team from Inria.

- similarly, deep convolutional data representations, also originally developed for visual data, have been successfully extended to the processing of biological sequences, with collaborators from bio-informatics.

- Thoth also collaborates with experts in natural language and text processing, for applications where visual modalities need to be combined with text data.

<p style="text-align:center">**TYREX Project-Team**</p>

4. Application Domains

4.1. Querying Large Graphs

Increasingly large amounts of graph-structured data become available. The methods we develop apply for the efficient evaluation of graph queries over large — and potentially distributed — graphs. In particular, we consider the SPARQL query language, which is the standard language for querying graphs structured in the Resource Description Format (RDF). We also consider other increasingly popular graph query languages such as Cypher queries for extracting information from property graphs.

We compile graph queries into lower-level distributed primitives found in big data frameworks such as Apache Spark, Flink, etc. Applications of graph querying are ubiquitous and include: large knowledge bases, social networks, road networks, trust networks and fraud detection for cryptocurrencies, publications graphs, web graphs, recommenders, etc.

4.2. Predictive Analytics for Healthcare

One major expectation of data science in healthcare is the ability to leverage on digitized health information and computer systems to better apprehend and improve care. The availability of large amounts of clinical data and in particular electronic health records opens the way to the development of quantitative models for patients that can be used to predict health status, as well as to help prevent disease and adverse effects.

In collaboration with the CHU Grenoble, we explore solutions to the problem of predicting important clinical outcomes such as patient mortality, based on clinical data. This raises many challenges including dealing with the very high number of potential predictor variables and very resource-consuming data preparation stages.

4.3. Mobile and Augmented Reality Applications

The term Augmented Environments refers collectively to ubiquitous computing, context-aware computing, and intelligent environments. The goal of our research on these environments is to introduce personal Augmented Reality (AR) devices, taking advantage of their embedded sensors. These environments offer the possibility of using ubiquitous computation, communication, and sensing to enable the presentation of context-sensitive information and services to the user. AR applications often rely on 3D content and employ specialized hardware and computer vision techniques for both tracking and scene reconstruction and exploration. Our approach tries to seek a balance between these traditional AR contexts and what has come to be known as mobile AR browsing, based for instance on attitude estimation.