Activity Report 2015

Section Application Domains

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

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.

ARIC Project-Team

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.

AVALON Project-Team

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 bring 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 [69] for ocean modelization), code-coupling applications (*e.g.,* the OASIS coupler [75] 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 comsunption, 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 volume of data. For instance, the Large Synoptic Survey Telescope (http://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 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 cooperates 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. These collaborations bring scientific applications that are both dynamic and data-intensive.

BEAGLE Project-Team

4. Application Domains

4.1. Domain

- Genome Evolution
- Computational Systems Biology
- Evolution of Genetic Regulation
- Intracellular Signal Transduction

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

4. Application Domains

4.1. Computational neuroscience

Modeling in neuroscience makes extensive use of nonlinear dynamical systems with a huge number of interconnected elements. Our current theoretical understanding of the properties of neural systems is mainly based on numerical simulations, from single cell models to neural networks. To handle correctly the discontinuous nature of integrate-and-fire networks, specific numerical schemes have to be developed. Our current works focus on event-driven, time-stepping and voltage-stepping strategies, to simulate accurately and efficiently neuronal networks. Our activity also includes a mathematical analysis of the dynamical properties of neural systems. One of our aims is to understand neural computation and to develop it as a new type of information science [19], [20].

4.2. Electronic circuits

Whether they are integrated on a single substrate or as a set of components on a board, electronic circuits are very often a complex assembly of many basic components with non linear characteristics. The IC technologies now allow the integration of hundreds of millions of transistors switching at GHz frequencies on a die of $1cm^2$. It is out of the question to simulate a complete IC with standard tools such as the SPICE simulator. We currently work on a dedicated plug-in able to simulate a whole circuit comprising various components, some modelled in a nonsmooth way [1].

4.3. Walking robots

As compared to rolling robots, the walking ones – for example hexapods – possess definite advantages whenever the ground is not flat or free: clearing obstacles is easier, holding on the ground is lighter, adaptivity is improved. However, if the working environment of the system is adapted to man, the biped technology must be preferred, to preserve good displacement abilities without modifying the environment. This explains the interest displayed by the international community in robotics toward humanoid systems, whose aim is to back man in some of his activities, professional or others. For example, a certain form of help at home to disabled persons could be done by biped robots, as they are able to move without any special adaptation of the environment.

4.4. Computer graphics animation

Computer graphics animation is dedicated to the numerical modeling and simulation of physical phenomena featuring a high visual impact. Typically, deformable objects prone to strong deformation, large displacements, complex and nonlinear or even nonsmooth behavior, are of interest for this community. We are interested in two main mechanical phenomena: on the one hand, the behavior of slender (nonlinear) structures such as rods, plates and shells; on the other hand, the effect of frictional contact between rigid or deformable bodies. In both cases the goal is to design realistic, efficient, robust, and controllable computational models. Whereas the problem of collision detection has become a mature field those recent years, simulating the collision response (in particular frictional contacts) in a realistic, robust and efficient way, still remains an important challenge. Another related issue we began to study is the simulation of heterogeneous objects such as granular or fibrous materials, which requires the design of new high-scales models for dynamics and contacts; indeed, for such large systems, simulating each interacting particle/fiber individually would be too much time-consuming for typical graphics applications. We also pursue some study on the design of high-order models for slender structures such as rods, plates or shells. Our current activity includes the static inversion of mechanical objects, which is of great importance in the field of artistic design, for the making of movies

and video games for example. Such problems typically involve geometric fitting and parameters identification issues, both resolved with the help of constrained optimization. Finally, we are interested in studying certain discrepancies (inexistence of solution) due to the combination of incompatible models such as contacting rigid bodies subject to Coulomb friction.

4.5. Multibody Systems: Modeling, Control, Waves, Simulation

Multibody systems are assemblies of rigid or flexible bodies, typically modeled with Newton-Euler or Lagrange dynamics, with bilateral and unilateral constraints, with or without tangential effects like friction. These systems are highly nonlinear and nonsmooth, and are therefore challenging for modeling aspects (impact dynamics, especially multiple –simultaneous– collisions), feedback control [10], state observation, as well as numerical analysis and simulation (software development) [2], [4], [5]. Biped robots are a particular, interesting subclass of multibody systems subject to various constraints. Granular materials are another important field, in which nonlinear waves transmissions are crucial (one celebrated example being Newton's cradle) [18], [13], [6], [14]. Fibers assemblies [11], circuit breakers, systems with clearances, are also studied in the team.

4.6. Stability and Feedback Control

Lyapunov stability of nonsmooth, complementarity dynamical systems is challenging, because of possible state jumps, and varying system's dimension (the system may live on lower-dimensional subspaces), which may induce instability if not incorporated in the analysis [8], [9], [7]. On the other hand, the nonsmoothness (or the set-valuedness) may be introduced through the feedback control, like for instance the well-known sliding-mode controllers or state observers. The time-discretisation of set-valued controllers is in turn of big interest [3]. The techniques we study originate from numerical analysis in Contact Mechanics (the Moreau-Jean time-stepping algorithm) and are shown to be very efficient for chattering suppression and Lyapunov finite-time stability.

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

4. Application Domains

4.1. 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).

Over the last 8 years we have collaborated with Toyota and with Renault-Nissan on these applications (bilateral contracts, PhD Theses, shared patents). We are also strongly involved (since 3 years) in the innovation project Perfect of the IRT Nanoelec (transportation domain). Recently, we have been awarded an important European 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 Thales and also with the Inria exploratory team ESTASYS (Rennes). Chroma is also involved in the new 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, which are maintained by the SED and that allow the team to perform experiments in realistic traffic conditions (Urban, road and highway environments).

4.2. Services, intervention, and human assistance robotics

Service robotics is an application domain currently rapidly 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, and 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 (Turtlebot2 robots) or aerial ones (ANR VIMAD [0]).

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. We address the problem of assisting the user for joining a group of people and navigating in crowded environments, in cooperation with Inria Lagadic team.

Another emerging application to assist people is telepresence robot. We are involved in a project aiming to improve the driving by providing a social and autonomous navigation to the robot, in cooperation with Awabot and Hoomano startups.

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[0] Advanced Driver Assistance Systems
[0] ENABLE-S3: European Initiative to Enable Validation for Highly Automated Safe and Secure Systems.
[0] Navigation autonome des drones aériens avec la fusion des données visuelles et inertielles, lead by A. Martinelli, Chroma.
[0] Personnaly assisted Living

We are also investigating service robotics in outdoor environment. In particular, since two years, we work with the ToutiTerre startup to develop navigation models and sensors to allow agricultural pick-up to be autonomously moved in rows of a field.

<div align="center" style="color:red">COMPSYS Project-Team</div>

4. Application Domains

4.1. Compilers for Embedded Computing Systems

The previous sections described our main activities in terms of research directions, but also places Compsys within the embedded computing systems domain, especially in Europe. We will therefore not come back here to the importance, for industry, of compilation and embedded computing systems design.

In terms of application domain, the embedded computing systems we consider are mostly used for multimedia: phones, TV sets, game platforms, etc. But, more than the final applications developed as programs, our main application is the computer itself: how the system is organized (architecture) and designed, how it is programmed (software), how programs are mapped to it (compilation and high-level synthesis).

The industry that can be impacted by our research is thus all the companies that develop embedded processors, hardware accelerators (programmable or not), embedded systems, and those (the same plus other) that need software tools to map applications to these platforms, i.e., that need to use or even develop programming languages, program optimization techniques, compilers, operating systems. Compsys do not focus on all these critical parts, but our activities are connected to them.

4.2. Users of HPC Platforms and Scientific Computing

The convergence between embedded computing systems and high-performance computing (HPC) technologies offers new computing platforms and tools for the users of scientific computing (e.g., people working in numerical analysis, in simulation, modeling, etc.). The proliferation of "cheap" hardware accelerators and multicores makes the "small HPC" (as opposed to computing centers with more powerful computers, grid computing, and exascale computing) accessible to a larger number of users, even though it is still difficult to exploit, due to the complexity of parallel programming, code tuning, interaction with compilers, which result from the multiple levels of parallelism and of memories in the recent architectures. The link between compiler and code optimization research (as in Compsys) and such users are still to be reinforced, both to guarantee the relevance of compiler research efforts with respect to application needs, and to help users better interact with compiler choices and understand performance issues.

The support of Labex MILYON (through its thematic quarters, such as the thematic quarter on compilation we organized in 2013 [0], or the upcoming 2016 thematic quarter on high-performance computing) and the activities of the LyonCalcul initiative [0] are means to get closer to users of scientific computing, even if it is too early to know if Compsys will indeed be directly helpful to them.

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[0]Thematic quarter on compilation: http://labexcompilation.ens-lyon.fr/
[0]Lyon Calcul federation: http://lyoncalcul.univ-lyon1.fr

<p align="center" 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,
- *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.

CORSE Team

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 runtime 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, Bull, Kalray, or Aselta.

Applying our techniques to a specific real application domain is cherished by all members of the team. In particular we believe (multi-scale) computational mechanics (such as fluid mechanics, molecular dynamics) to be a challenging domain that could take advantage both of compiler and run-time technologies that we intend to develop in CORSE. The goal is to provide an end-to-end solution to the automatic optimization (thus targeting portability of optimized code) of a specific application that requires extensive computational power. If we succeed our research should contribute indirectly to advances in that domain. We are still in the process of prospecting for the most appropriate application.

4. Application Domains

4.1. Distributed systems and High-Performance Computing

Distributed systems have grown to levels of scale and complexity where it is difficult to master their administration and resources management, in dynamic ans open environments. One of the growing concerns is that the energy consumption has reached levels where it can not be considered negligible anymore, ecologically or economically. Data centers or high performance computing grids need to be controlled in order to combine minimized power needs with sustained performance and quality of service. As mentioned above, this motivates the automation of their management, and is the major topic of, amongst others, our ANR project Ctrl-Green.

Another challenge in distributed systems is in the fast growing amounts of data to process and store. Currently one of the most common ways of dealing with these challenges is the parallel programming paradigm MapReduce which is slowly becoming the de facto tool for Big Data analytics. While its use is already widespread in the industry, ensuring performance constraints while also minimizing costs provides considerable challenges. Current approaches to ensure performance in cloud systems can be separated into three categories: static, reactive, predictive and hybrid approaches. In the industry, static deployments are the standard and usually tuned based on the application peak demand and are generally over-provisioned. Reactive approaches are usually based on reacting to an input metric such as the current CPU utilisation, request rate, response time by adding and removing servers as necessary. Some public cloud providers offer reactive techniques such as the Amazon Auto Scaler. They provide the basic mechanisms for reactive controllers, but it is up to the user to define the static scaling thresholds which is difficult and not optimal. To deal with this issue, we propose a control theoretical approach, based on techniques that have already proved their usefulness for the control community.

In the domain of parallel systems and High Performance Computing, systems are traditionally less open and more controlled by administrators, but this trend is changing, as they are facing the same challenges in energy consumption, needs for adaptivity in reaction to changing workloads, and security issues in computation outsourcing. Topics of interest for us in this domain concern problem in dynamical management of memory and communications features, which we are exploring in the HPES project of the Labex Persybal-lab (see 9.1).

4.2. Reconfigurable architectures in embedded systems

Dynamically reconfigurable hardware has been identified as a promising solution for the design of energy efficient embedded systems. A common argument in favor of this kind of architecture is the specialization of processing elements, that can be adapted to application functions in order to minimize the delay, the control cost and to improve data locality. Another key benefit is the hardware reuse to minimise the area, and therefore the static power and cost. Further advantages such as hardware updates in long-life products and self-healing capabilities are also often mentioned. In presence of context changes (e.g. environment or application functionality), self-adaptive technique can be applied as a solution to fully benefit from the runtime reconfigurability of a system.

Dynamic Partial Reconfiguration (DPR) of FPGA is another accessible solution to implement and experiment reconfigurable hardware. It has been widely explored and detailed in literature. However, it appears that such solutions are not extensively exploited in practice for two main reasons: i) the design effort is extremely high and strongly depends on the available chip and tool versions; and ii) the simulation process, which is already complex for non-reconfigurable systems, is prohibitively large for reconfigurable architectures. As a result, new adequate methods are required to fully exploit the potential of dynamically reconfigurable and self-adaptive architectures. We are working in this topic, especially on the reconfiguration control aspect, in cooperation with teams specialized in reconfigurable architectures such as the former DaRT team at Inria Lille, and LabSticc in Lorient, as in the recently ended ANR project Famous.

A new ANR project in this application domain, starting end of 2015, is called HPeC, in cooperation with amongst others LabSticc in Lorient and Clermont-Ferrand U., will consider embedded video processing on drones (see 9.2.1).

4.3. Smart environments and Internet of Things

Another application domain for autonomic systems design and control is the Internet of Things, and especially the design of smart environments, at the level of homes, buildings, or cities. These domains are often considered at the level of sensors networks, with a strong emphasis on the acquisition of data in massive scales. The infrastructures are sometimes also equipped with actuators, with a wide range of applications, for example concerning lighting or heating, or access and security aspects. We are interested in closing the control loop in such environments, which is less often studied. In particular, rule-based languages are often used to define the automated systems, and we want to contribute to the safe design of such controllers with guarantees on their behaviors. We are working in this topic in cooperation with teams specialized in infrastructures for smart environments at CEA LETI/DACLE and Orange labs (see 8.1 ,8.2).

DANTE Project-Team

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 modeling 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 modeling approaches crucially depend on our ability to describe the interactions of individuals in the population. In the MOSAR/iBird project we are collaborating with the team of Pr. Didier Guillemot (Inserm/Institut. Pasteur/Université de Versailles). Within the TUBEXPO and ARIBO projects, we are collaborating with Pr. Jean-Christopge Lucet (Professeur des université Paris VII, Praticien hospitalier APHP).

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 characterize the topology and temporal behavior 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 behavior of very complicated systems.

In this endeavor 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 anonymized 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 (anonymized) 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.

DICE Team

4. Application Domains

4.1. Two-sided markets

Intermediation platforms operate in two-sided markets, that is in environments with two types of actors, producers of good or services on one side, and consumers on the other side. Intermediaries play a fundamental role by allowing the connection of both thypes of actors. If intermediaries already existed in the pre-digital era — banks constitute a historical example of intermediaries — it is really only the advent of digital technologies which boosts the development of intermediation. A large number of activity sectors fall in such a framework, including transportation, press, education, health, etc. We decided to focus on some of them in greater details for their particular relevance.

4.2. Education platforms

Education institutions are at stake because of the new technologies that not only change the access to knowledge, and therefore the traditional euilibrium between teachers and students, but also provide new means to produce knowledge, and share studying experiences.

Our objective is to develop a platform - called Jumplyn - that offers disruptive services for students, helps them produce their work, connects them to other students in the same area, and preserves their contribution online. The platforms targets students. It also aims at offering services on the other side of the education market, i.e. to institutions, by allowing them to organise the work of their students, as well as their evaluation. Jumplyn is accessible online and, as other platforms, evolves continuously.

4.3. Decentralised Voting

Online voting systems are controversial. They are advocated for their simplicity, which could contribute to enhance participation, but criticised for their failure to ensure the same properties as traditional voting systems. We propose an alternative path to online voting relying on decentralised systems with no concentration of data. A patent is under evaluation for the BitBallot protocol.

4.4. City administration

The team is actively participating to the Inria International Project Lab IPL CityLab on smart cities. We work also with the metropole of Lyon, and its Chief Data Officer in particular, to better understand the equilibrium between online plateforms and the public administration, and the policy regarding data and its accessibility to other parties.

4.5. Metrics for Digital Economy

While economic metrics based on trade of goods and services, as well as financial exchanges are well-established, exchanges of data, and more generally transborder activities on platforms are not included in standard economic measurements. Defining such metrics both theoretically and practically with means to evaluate them is of great relevance in economy, and beyond.

DRACULA Project-Team

4. Application Domains

4.1. Normal hematopoiesis

4.1.1. Introduction

Modelling normal hematopoiesis will allow us to explore the dynamical appearance of the various cell types, originating from the stem cell compartment, through the bone marrow development up to the blood stream. The differentiated cell types will both fulfill physiological functions, and play a key role on the feedback control on homeostasis (balance of the system) in their own lineages. We will describe the hematopoiesis from three different points of view:

- The initial cell type, the hematopoietic stem cell (HSC);
- The lineage choice question;
- Three differentiated lineages that are responsible for specific function, namely oxygen transport, immune response and coagulation.

The basic mechanisms of our modelling approach are as follows:

- Any cell type can have two possibilities at each time step: to divide or to die.
- At any division step, the cell can either give rise to two daughter cells which are identical to the mother cell (self-renewal) or that are more advanced in their differentiation.

All these processes will be first modelled at the cellular level. In parallel, we will develop models of intracellular molecular networks (as some proteins controlling the cell cycle) influencing this decision making process, so as to be able to describe both micro-to-macro effects (molecules influencing the global cell behaviour) as well as macro-to-micro effects (like the global state of the cell population influencing the molecular behaviour).

4.1.2. Hematopoietic stem cells (HSC)

Although widely studied by biologists, HSC are still poorly understood and many questions remain open: How fast and how frequently do they divide? How many of them are in the bone marrow and where? How is their behaviour modified under stress conditions such as blood loss or transfusion?

Our modelling approach will be based on two methods: deterministic and stochastic differential equations with delays (discrete and distributed), on one hand, and the DPD method using the individual based modelling on the other hand. The differential equation models based on the work initiated by Mackey [43] will describe the HSC compartment in normal conditions and the behaviour of these cells under some stress. The DPD method, as a complementary approach, will emphasize the spatial regulation of stem cell behaviour, and we will focus our attention to give a possible answer regarding their location in the bone marrow and the roles of the niche, their number in the system, their possible role under stress (that is their reaction under the different feedback controls).

4.1.3. Blood cell functions

(i) O2 transport: red lineage

O_2 transport is provided by red blood cells (RBC) also called erythrocytes. Many different stages of maturity (including progenitors, precursors, reticulocytes and erythrocytes) are necessary to achieve the complete formation of RBC. These latter are then released in the blood stream where they transport oxygen. The whole process is tightly dependent on a robust well-balanced equilibrium called homeostasis.

It has been shown in the 1990's that apoptosis is regulated by EPO, a growth factor released by the kidneys under hypoxia. But also, under severe stress (like an important blood loss) some other molecules known as glucocorticoids can be released leading to an increase of the self-renewing rate for each generation. This led to the formulation of a first model, demonstrating the role of self-renewal.

The study of the red blood cell lineage will involve different scale levels, from the molecular one, with the effects of the hormones on the surface and internal parts of the cell, the cell contacts in each stage of RBC formation, and the red branch population in its whole with all the interactions taken into account (see Figure 3) in normal and stress conditions.
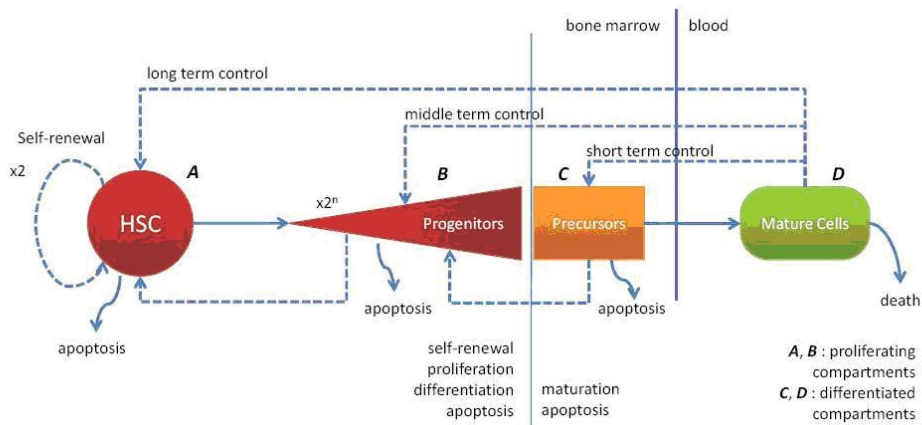

Figure 3. Scheme of Erythropoiesis Modelling ([34]). Without considering explicitly growth factor mediated regulation, all controls (proliferation, self-renewal, differentiation, apoptosis) are mediated by cell populations (dashed arrows). Mature cells can either regulate immature (HSC, progenitors) or almost mature (precursors) cells, precursors may act on progenitor dynamics, etc..

In order to couple the cellular behaviour to explicit molecular events, we will describe the events through a molecular network that is based upon the work of [47]. A first version of this model is shown in Figure 2 .

(ii) Immune response

We will focus on the production of T-cells during an immune response. This represents an important activity of the lymphoid branch, part of leucopoiesis (white blood cell production). Several models of the myeloid branch of leucopoiesis have been investigated in the frame of specific diseases (for instance cyclical neutropenia ([42], [39]), chronic myelogenous leukemia [44]).

Time evolution of T-cell counts during an infection is well known: following the antigen presentation, the number of cells quickly increases (expansion), then decreases more slowly (contraction) and stabilizes around a value higher than the initial value. Memory cells have been produced, and will allow a faster response when encountering the antigen for a second time. Mechanisms that regulate this behaviour are however not well known.

A recent collaboration just started with immunologists (J. Marvel, Ch. Arpin) from the INSERM U851 in Lyon, who provide experimental data that are essential to assess the significance of models, based on strongly nonlinear ordinary differential equations, that can be proposed for T-cell production (Figure 4). By considering molecular events leading to cell activation when encountering a virus, we will propose a multi-scale model of the immune response.
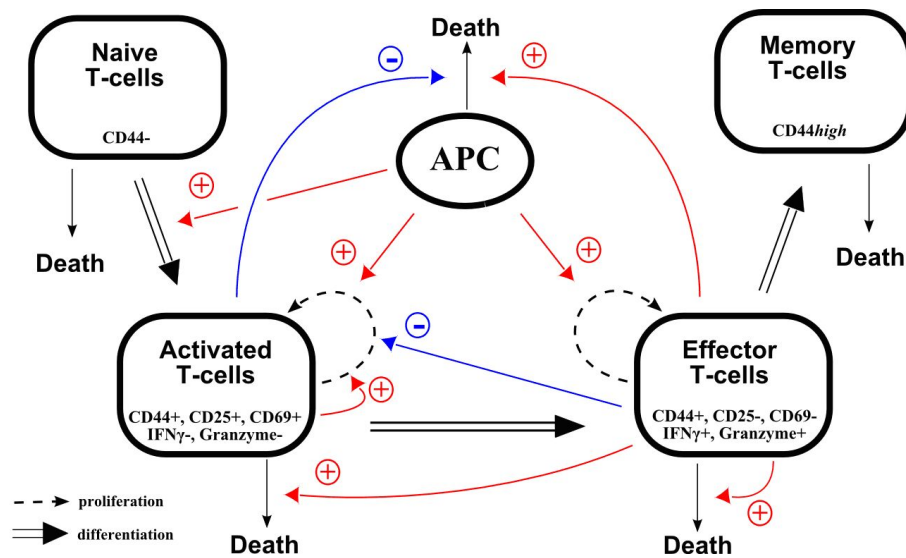
Figure 4. Model of the immune response resulting in the generation of CD8 memory T cells. The response starts with a viral infection resulting in the presentation of viral antigens through antigen presenting cells (APC) to naive T-cells. These latter, once activated, differentiate into activated cells which, under specific feedback loops will either die, differentiate into effector cells or self-renew. Differentiation of effector cells (killer cells) will result in the production of memory cells.

(iii) Coagulation: platelet lineage

Thrombopoiesis, the process of production and regulation of platelets, is similar to erythropoiesis although important differences are observed. These two processes have an immature progenitor (MEP) in common. Platelets are involved in blood coagulation, and can be the source of blood diseases (thrombopenia, thrombocytosis). Their production is mainly regulated by thrombopoietin (TPO), a growth factor similar to EPO.

It is important to mention that very few experimental data exist in the literature, and mathematical modelling of thrombopoiesis did not attract so much attention in the past 20 years. However, collaboration with some leading hematologists in this domain will allow us to get updated and new data regarding this process.

Deterministic models, in the form of structured transport partial differential equations, will be proposed to describe platelet dynamics, through the description of HSC, megakaryocytic progenitor and megacaryocyte (platelet precursor) compartments. Circulating TPO, regulated by platelets, will induce feedback loops in thrombopoiesis, and we will investigate the dynamics of platelet production and emergence of platelet-related diseases.

4.2. Pathological hematopoiesis

The knowledge of hematopoiesis and related diseases has evolved to become a great deal in the past years, and Mackey's previous models (ref. [37]) do not allow us to correctly answer current questions that are clearly oriented toward the investigation of cell signalling pathways. These models nevertheless bring relevant ideas about the essential features of such modelling. It is also noteworthy that even though models of hematopoiesis have existed for quite a long time, their application to questions of explanation and prediction of hematopoiesis dynamics that are encountered in the clinic is still not sufficiently frequent, even though much progress has been achieved in the cooperation between hematologists and mathematicians [45]. This is in the optic of testable experimental predictions that the multi-scale model for pathological hematopoiesis will be developed. For instance, we will concentrate on myeloid leukemias (CML and AML) and their treatment.

4.2.1. Leukemia Modelling

(i) Chronic Myeloid Leukemia

The strong tyrosine kinase activity of the BCR-ABL protein is the basis for the main cell effects that are observed in CML: significant proliferation, anti-apoptotic effect, disruption of stroma adhesion properties, genomic instability. This explains the presence in CML blood of a very important number of cells belonging to the myeloid lineage, at all stages of maturation.

We will consider models based on ordinary differential equations for the action of the main intra- and extracellular proteins involved in CML (as BCR-ABL protein), and of transport equations (with or without delay, physiologically structured or not to represent healthy and leukemic cell populations, take into account many interactions between proteins (especially BCR-ABL), cells (anti-apoptotic effect, etc.), and their environment (disruption of stroma adhesion properties, for example). Transport pertains thus to cells from one compartment (or a group of compartments) to another compartment, with a determined speed of aging or maturation. These compartments may be detailed or not: the less mature are stem cells, then progenitor cells, etc.

(ii) Acute Myeloid Leukemia

The natural history of CML leads to its transformation ("blast crisis") in acute myeloid leukemia (AML), following supplementary genetic alterations that produce a maturation arrest (myeloid in $3/4$ of cases, lymphoid in $1/4$ of cases, confirming the insult to pluripotent stem cells), leading to an accumulation of immature cells in the bone marrow and in the general circulation, resulting in deep medullary impairment and fast fatal outcome, in spite of chemotherapy. This phenomenon is the same as the one observed in de novo AML, i.e., AML without a previous chronic phase.

The different modelling methods of AML will be similar to the ones described for CML, with some exceptions: the appearance of BCR-ABL mutations, which are not relevant in the case of AML, the appearance of a gene (spi-1) involved in the differentiation arrest, and constitutive activation of EPO receptor or Kit activating mutations promote proliferation and survival. This explains the accumulation of immature cells in the bone marrow and in the blood stream.

4.2.2. Treatment

As far as treatment of pathological hematopoiesis is concerned, two main strategies currently exist that aim at slowing down or eliminating damaged cell proliferation. The first of these strategies consists in launching the apoptotic process during the cell division cycle. This process is activated, for example when the cell is unable to repair damages, e.g., after exposure to cytostatic drugs. A typical example is apoptosis induced by chemotherapy-induced DNA damage: The damage is recognised by the cell, which then activates the sentinel protein p53 ("guardian of the genome") that arrests the cell cycle to allow, if possible, damage repair. If the latter is unrecoverable, then p53 activates the endogenous apoptotic processes.

The second strategy aims at pushing damaged cells toward the differentiation that has been stopped in the course of their genetic mutation. Since a few years back, a new approach has been developed around the strategy of differentiation therapy. This therapy relies on molecules (growth factors and specific cytokines) that are able to re-initialise the cell differentiation programs that have been modified during malignant transformation. The cancer that is most concerned by the development of this differentiation therapy is AML whose malignant cells present highly undifferentiated features and the ones that present a translocation responsible for the differentiation (PML/RAR of the promyelocytic form, AML1/ETO and CBFbeta/MyH11, involving Core Binding Factors alpha and beta).

Mathematical models based on ordinary differential equations will be developed to describe the action of drugs (in the two cases mentioned above). They will take into account interactions between drugs and their environment. Our goal will be the optimization of possible synergies between drugs acting on distinct cellular targets, and the control of resistances to these treatments as well as their toxicities.

Curative and palliative strategies must take into account the dynamics of healthy and leukemic hematopoietic cells at multiple scales. In time, from optimal scheduling of combination therapy (hours) to avoiding the development of resistances and relapse (months to years). In space, from the stem cell niche to circulating blood. In organization, from gene and signalling networks (JAK/STAT, BCR-ABL) to cell populations and cytokine regulation (EPO, CSFs). Several recent qualitative models have provided insight in the complex dynamics of the disease and the response to treatments. Many of these models focus on the control or regulation processes that promote homeostasis or oscillatory behavior in cell number. However, as A. Morley points out, "once the control-systems features of hematopoiesis are accepted, the ability to construct a model that shows oscillatory behavior, even if the model incorporates the latest advances in hematopoietic cell biology, really adds little new knowledge. Rather, the challenge to modellers would seem to be to provide detailed predictions for the input-output characteristics of the different parts of the various control systems so that these predictions can be tested by experimental hematologists and a truly quantitative description of hematopoiesis can emerge".

We propose for instance, to use models in the form of structured transport partial differential equations (with or without delay, physiologically structured or not) to represent the competition between target, resistant and healthy cell populations. The resulting models to describe the dynamic of these cell populations under the action of drugs are multi-scale systems of the form (Hyperbolic PDE)-ODE or DDE-ODE. For instance, we will develop mathematical models of chronotherapy and pharmacotherapy for CML and AML.

ERABLE Project-Team

4. Application Domains

4.1. Biology

The main area of application of ERABLE is biology understood in its more general sense, with a special focus on symbiosis and on intracellular interactions.

<div align="center">

EXMO Project-Team

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4. Application Domains

4.1. Semantic web technologies

The main application context motivating our work is the "semantic web" infrastructure.

Internet technologies support organisations and people in accessing and sharing knowledge, often difficult to access in a documentary form. However, these technologies quickly reach their limits: web site organisation is expensive and full-text search inefficient. Content-based information search is becoming a necessity. Content representation enables computers to manipulate knowledge on a more formal ground and to carry out similarity or generality search. Knowledge representation formalisms are good candidates for expressing content.

The vision of a "semantic web" [21] complements the web, with formal knowledge representation spanning across sites. Taking advantage of this semantic web requires the manipulation of various knowledge representation formats. EXMO concerns are thus central to the semantic web implementation. Our work aims at enhancing content understanding, including the intelligibility of communicated knowledge and formal knowledge transformations.

In addition, EXMO considers more specific uses of semantic web technologies in wider context (typically in the smart city context, §9.2.1.1).

IBIS Project-Team (section vide)

IMAGINE Project-Team (section vide)

4. Application Domains

4.1. Application Domains

A solution to the general problem of visual recognition and scene understanding will enable a wide variety of applications in areas including human-computer interaction, retrieval and data mining, medical and scientific image analysis, manufacturing, transportation, personal and industrial robotics, and surveillance and security. With the ever expanding array of image and video sources, visual recognition technology is likely to become an integral part of many information systems. A complete solution to the recognition problem is unlikely in the near future, but partial solutions in these areas enable many applications. LEAR's research focuses on developing basic methods and general purpose solutions rather than on a specific application area. Nevertheless, we have applied our methods in several different contexts.

Semantic-level image and video access. This is an area with considerable potential for future expansion owing to the huge amount of visual data that is archived. Besides the many commercial image and video archives, it has been estimated that as much as 96% of the new data generated by humanity is in the form of personal videos and images [0], and there are also applications centering on on-line treatment of images from camera equipped mobile devices (e.g. navigation aids, recognizing and answering queries about a product seen in a store). Technologies such as MPEG-7 provide a framework for this, but they will not become generally useful until the required mark-up can be supplied automatically. The base technology that needs to be developed is efficient, reliable recognition and hyperlinking of semantic-level domain categories (people, particular individuals, scene type, generic classes such as vehicles or types of animals, actions such as football goals, etc).

Visual (example based) search. The essential requirement here is robust correspondence between observed images and reference ones, despite large differences in viewpoint or malicious attacks of the images. The reference database is typically large, requiring efficient indexing of visual appearance. Visual search is a key component of many applications. One application is navigation through image and video datasets, which is essential due to the growing number of digital capture devices used by industry and individuals. Another application that currently receives significant attention is copyright protection. Indeed, many images and videos covered by copyright are illegally copied on the Internet, in particular on peer-to-peer networks or on the so-called user-generated content sites such as Flickr, YouTube or DailyMotion. Another type of application is the detection of specific content from images and videos, which can, for example, be used for finding product related information given an image of the product.

Automated object detection. Many applications require the reliable detection and localization of one or a few object classes. Examples are pedestrian detection for automatic vehicle control, airplane detection for military applications and car detection for traffic control. Object detection has often to be performed in less common imaging modalities such as infrared and under significant processing constraints. The main challenges are the relatively poor image resolution, the small size of the object regions and the changeable appearance of the objects.

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[0] http://www.sims.berkeley.edu/research/projects/how-much-info/summary.html

MAVERICK Project-Team (section vide)

MESCAL Project-Team

4. Application Domains

4.1. Cloud, Grid, Multi-core and Desktop Computing

Participants: Arnaud Legrand, Olivier Richard, Jean-Marc Vincent.

Software tools were developed to carry experiments on clouds and grids (Kameleon and Expo). Other tools (Pajé, Viva, Framesoc and Ocelotl) have been designed to monitor, trace and analyse applications running on multi-core and grid computers Such traces have also been used in SIMGRID to simulate volunteer computing systems at unprecedented scale.

4.2. Wireless Networks

Participants: Bruno Gaujal, Panayotis Mertikopoulos.

MESCAL is involved in the common laboratory between Inria and Alcatel-Lucent. Bruno Gaujal is leading the Selfnets research action. This action was started in 2008 and was renewed for four more years (from 2012 to 2016). In our collaboration with Alcatel we use game theory techniques as well as evolutionary algorithms to compute optimal configurations in wireless networks (typically 3G or LTE networks) in a distributed manner. We have also been working on optimal spectrum management of MIMO systems, routing in ad-hoc works and power allocation in future 5G networks.

4.3. On-demand Geographical Maps

Participant: Jean-Marc Vincent.

This joint work involves the UMR 8504 Géographie-Cité, LIG, UMS RIATE and the Maisons de l'Homme et de la Société.

Improvements in the Web developments have opened new perspectives in interactive cartography. Nevertheless existing architectures have some problems to perform spatial analysis methods that require complex calculus over large data sets. Such a situation involves some limitations in the query capabilities and analysis methods proposed to users. The HyperCarte consortium with LIG, Géographie-cité and UMR RIATE proposes innovative solutions to these problems. Our approach deals with various areas such as spatio-temporal modeling, parallel computing and cartographic visualization that are related to spatial organizations of social phenomena.

4.4. Energy and Transportation

Participant: Nicolas Gast.

This work is mainly done within the Quanticol European project.

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. Within the QUANTICOL project, 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.

MISTIS Project-Team

4. Application Domains

4.1. Image Analysis

Participants: Alexis Arnaud, Aina Frau Pascual, Florence Forbes, Stéphane Girard, Pascal Rubini, Alessandro Chiancone, Thomas Perret, Pablo Mesejo Santiago.

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 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 Laboratoire de Planétologie de Grenoble. We worked on hyperspectral images. In the context of the "pole de competivite" project I-VP, we worked of images of PC Boards.

4.2. Biology, Environment and Medicine

Participants: Pablo Mesejo Santiago, Aina Frau Pascual, Florence Forbes, Stéphane Girard, Seydou-Nourou Sylla, Marie-José Martinez, Jean-Baptiste Durand.

A second domain of applications concerns biology and medicine. We consider the use of missing data models in epidemiology. We also investigated statistical tools for the analysis of bacterial genomes beyond gene detection. Applications in neurosiences are also considered. Finally, in the context of the ANR VMC project Medup, we studied the uncertainties on the forecasting and climate projection for Mediterranean high-impact weather events.

MOAIS Project-Team (section vide)

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

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 scans 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 analyzes 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 or new anthropometric datasets.

4.3. Human Motion Analysis

The recovery of dense motion information enables the combined analyses 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 analysed. 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. Interaction

The ability to build models of humans in real time allows to develop interactive applications where users interact with virtual worlds. The recent Kinect proposed by Microsoft illustrates this principle with game applications using human inputs perceived with a depth camera. Other examples include gesture interfaces using visual inputs. A challenging issue in this domain is the ability to capture complex scenes in natural environments. Multi-modal visual perception, e.g. depth and color cameras, is one objective in that respect.

<center>**NANO-D Project-Team**</center>

4. Application Domains

4.1. Overview

NANO-D is *a priori* concerned with all applications domains involving atomistic representations, including chemistry, physics, electronics, material science, biology, etc.

Historically, though, our first applications have been in biology, as the next two sections detail. Thanks to the development of algorithms to efficiently simulate reactive force fields, as well as to perform interactive quantum mechanical calculations, however, we now have the possibility to address problems in chemistry, and physics.

4.2. Structural Biology

Structural biology is a branch of molecular biology, biochemistry, and biophysics concerned with the molecular structure of biological macromolecules, especially proteins and nucleic acids. Structural biology studies how these macromolecules acquire the structures they have, and how alterations in their structures affect their function. The methods that structural biologists use to determine the structure typically involve measurements on vast numbers of identical molecules at the same time, such as X-Ray crystallography, NMR, cryo-electron microscopy, etc. In many cases these methods do not directly provide the structural answer, therefore new combinations of methods and modeling techniques are often required to advance further.

We develop a set of tools that help biologists to model structural features and motifs not resolved experimentally and to understand the function of different structural fragments.

- Symmetry is a frequent structural trait in molecular systems. For example, most of the water-soluble and membrane proteins found in living cells are composed of symmetrical subunits, and nearly all structural proteins form long oligomeric chains of identical subunits. Only a limited number of symmetry groups is allowed in crystallography, and thus, in many cases the native macromolecular conformation is not present on high-resolution X-ray structures. Therefore, to understand the realistic macromolecular packing, modeling techniques are required.

- Many biological experiments are rather costly and time-demanding. For instance, the complexity of mutagenesis experiments grows exponentially with the number of mutations tried simultaneously. In other experiments, many candidates are tried to obtain a desired function. For example, about 250,000 candidates were tested for the recently discovered antibiotic Platensimycin. Therefore, there is a vast need in advance modeling techniques that can predict interactions and foresee the function of new structures.

- Structure of many macromolecules is still unknown. For other complexes, it is known only partially. Thus, software tools and new algorithms are needed by biologists to model missing structural fragments or predict the structure of those molecule, where there is no experimental structural information available.

4.3. Pharmaceutics and Drug Design

Drug design is the inventive process of finding new medications based on the knowledge of the biological target. The drug is most commonly an organic small molecule which activates or inhibits the function of a biomolecule such as a protein, which in turn results in a therapeutic benefit to the patient. In the most basic sense, drug design involves design of small molecules that are complementary in shape and charge to the biomolecular target to which they interact and therefore will bind to it. Drug design frequently relies on computer modeling techniques. This type of modeling is often referred to as computer-aided drug design.

Structure-based drug design attempts to use the structure of proteins as a basis for designing new ligands by applying accepted principles of molecular recognition. The basic assumption underlying structure-based drug design is that a good ligand molecule should bind tightly to its target. Thus, one of the most important principles for designing or obtaining potential new ligands is to predict the binding affinity of a certain ligand to its target and use it as a criterion for selection.

We develop new methods to estimate the binding affinity using an approximation to the binding free energy. This approximation is assumed to depend on various structural characteristics of a representative set of native complexes with their structure solved to a high resolution. We study and verify different structural characteristics, such as radial distribution functions, and their affect on the binding free energy approximation.
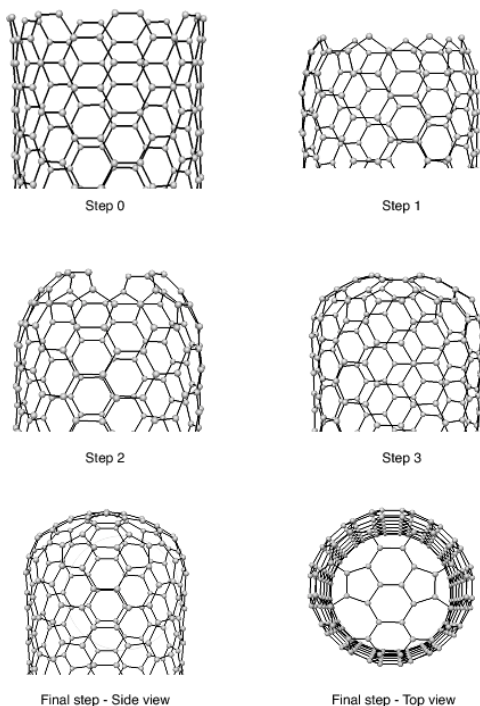
4.4. Nano-engineering

Figure 1. Snapshots of a nanotube capping process with the adaptive interactive modeler. Thanks to the adaptive methodology, this operation can be done in a few minutes.

In general, we want to develop methods to ease nano-engineering of artificial nanosystems, such as the ones described above (DNA nanotechnology, nano-mechanisms, etc.). We have shown, for example, that our incremental and adaptive algorithms allow us to easily edit and model complex shapes, such as a nanotube (Fig. 1) and the "nano-pillow" below (Fig. 2). Please read more about the SAMSON software platform for more examples.
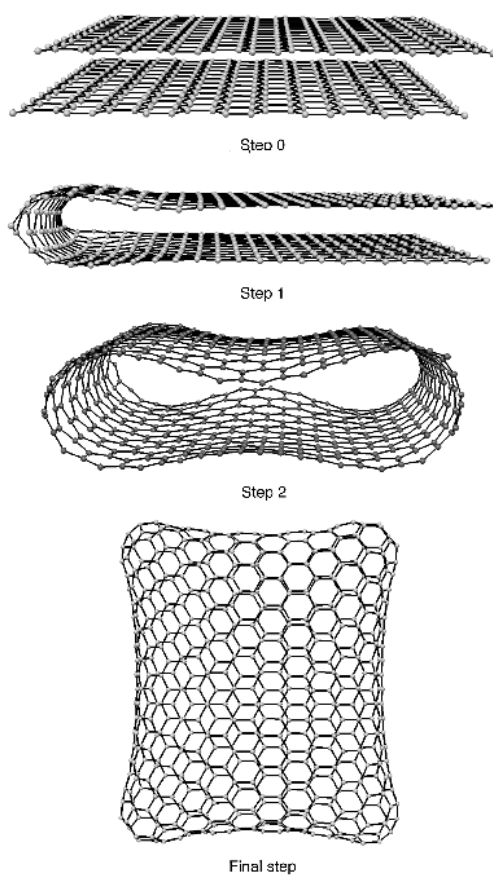
Step 0

Step 1

Step 2

Final step

Figure 2. Different steps to prototype a "nano-pillow" with the adaptive interactive modeler.

NECS Project-Team

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. Vehicular transportation systems

4.2.1. 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: forecasting, so as to provide accurate information to users, e.g., travel times; and 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/)

4.2.2. Advanced and interactive vehicle control

Car industry has been already identified as a potential homeland application for Networked Control [36], as the evolution of micro-electronics paved the way for introducing distributed control in vehicles. In addition, automotive control systems are becoming the more complex and iterative, as more on-board sensors and actuators are made available through technology innovations. The increasing number of subsystems, coupled with overwhelming information made available through on-board and off-board sensors and communication systems, rises new and interesting challenges to achieve optimal performance while maintaining the safety and the robustness of the total system. Causes of such an increase of complexity/difficulties are diverse: interaction between several control sub-systems (ABS, TCS, ESP, etc.), loss of synchrony between sub-systems, limitations in the computation capabilities of each dedicate processor, etc. The team had several past collaborations with the car industry (Renault since 1992, and Ford).

More recently, in the ANR project VOLHAND (2009-2013), the team has been developing a new generation of electrical power-assisted steering specifically designed for disabled and aged persons.

Currently, on-going work under a grant with IFPEN studies how to save energy and reduce pollution, by controlling a vehicle's speed in a smart urban environment, where infrastructure-to-vehicle and vehicle-to-vehicle communications happen and can be taken into account in the control.

4.3. Inertial navigation

Inertial navigation is a research area related to the determination of 3D attitude and position of a rigid body. Attitude estimation is based on data fusion from accelerometers, magnetometers and gyroscopes. Attitude is used in general to determine the linear acceleration, which needs to be integrated after to calculate the position. More recently, in the Persyval project LOCATE-ME (2014-2015), the team has started exploring Pedestrian navigation algorithms in collaboration with the Tyrex team (INRIA-Rhône-Alpes). The goal is to provide guidance to pedestriants, e.g., to first responders after a disaster, or to blind people walking in unfamiliar environments. This tasks is particularly challenging for indoor navigation, where no GPS is available.

4.4. Multi-robot collaborative coordination

Due to the cost or the risks of using human operators, many tasks of exploration, or of after-disaster intervention are performed by un-manned drones. When communication becomes difficult, e.g., under water, or in spatial exploration, such robots must be autonomous. Complex tasks, such as exploration, or patrolling, or rescue, cannot be achieved by a single robot, and require a self-coordinated fleet of autonomous devices. NECS team has studied the marine research application, where a fleet of Autonomous Underwater Vehicles (AUVs) self-organize in a formation, adapting to the environment, and reaching a source, e.g., of a pollutant. This has been done in collaboration with IFREMER, within the national project ANR CONNECT and the European FP7 project FeedNetBack [1]. On-going research in the team concerns source localization, with a fleet of mobile robots, including wheeled land vehicles.

4.5. Control design of hydroelectric powerplants

We have started a collaboration with ALSTOM HYDRO, on collaborative and reconfigurable resilient control design of hydroelectric power plants. This work is within the framework of the joint laboratory Inria/ALSTOM (see http://www.inria.fr/innovation/actualites/laboratoire-commun-inria-alstom). A first concrete collaboration has been established with the CIFRE thesis of Simon Gerwig, who is currently studying how to improve performance of a hydro-electric power-plant outside its design operation conditions, by cancellation of oscillations that occur in such operation range.

NUMED Project-Team (section vide)

PERCEPTION Project-Team (section vide)

PRIMA Project-Team (section vide)

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

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.

4. Application Domains

4.1. Applications of sparse direct solvers

Sparse direct (multifrontal) 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 linear system of 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 (see Section 6.1) are: structural mechanics, 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)

<h1 style="text-align:center; color:red;">SPADES Project-Team</h1>

4. Application Domains

4.1. Industrial Applications

Our applications are in the embedded system area, typically: transportation, energy production, robotics, telecommunications, 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

STEEP Project-Team (section vide)

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

4. Application Domains

4.1. Web Programming Technologies

Despite the major social and economic impacts of the web revolution, current web programming methods and content representation are lagging behind and remain severely limited and in many respects archaic. Dangerously, designing web applications even becomes increasingly complex as it relies more and more on a jungle of programming languages, tools and data formats, each targeted toward a different application layer (presentation, application and storage). This often yields complex and opaque applications organized in silos, which are costly, inefficient, hard to maintain and evolve, and vulnerable to errors and security holes. In addition, the communication aspects are often handled independently via remote service invocations and represent another source of complexity and vulnerability. We believe that we reached a level where there is an urgent need and a growing demand for alternative programming frameworks that capture the essence of web applications: advanced content, data and communication. Therefore, successful candidate frameworks must capture rich document formats, data models and communication patterns. A crucial aspect is to offer correction guarantees and flexibility in the application architecture. For instance, applications need to be checked, optimized and managed as a whole while leveraging on the consistency of their individual components and data fragments. For all these reasons, we believe that a new generation of tools must be created and developed in order to overcome the aforementioned limitations of current web technologies.

4.2. Multimedia and Augmented Environments

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. We believe that personal AR devices such as mobile phones or tablets will play a central role in augmented environments. 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. It first acknowledges that mobile augmented environment browsing does not require that 3D content be the primary means of authoring. It provides instead a method for HTML5 and audio content to be authored, positioned in the surrounding environments and manipulated as freely as in modern web browsers. The applications we develop to guide and validate our concepts are pedestrian navigation techniques and applications for cultural heritage visits. Features found in augmented environments are demanding for the other activities in the team. They require all kinds of multimedia information, that they have to combine. This information has to be processed efficiently and safely, often in real time, and it also, for a significant part, has to be created by human users.

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

4. Application Domains

4.1. Smart urban infrastructure

Unlike the communication infrastructure that went through a continuous development in the last decades, the distribution networks in our cities including water, gas and electricity are still based on 19th century infrastructure. With the introduction of new methods for producing renewable but unpredictable energy and with the increased attention towards environmental problems, modernizing distribution networks became one of the major concerns in the urban world. An essential component of these enhanced systems is their integration with information and communications technology, the result being a smart distribution infrastructure, with improved efficiency and reliability. This evolution is mainly based on the increased deployment of automatic equipment and the use of machine-to-machine and sensor-to-actuator communications that would allow taking into account the behavior and necessities of both consumers and suppliers

Another fundamental urban infrastructure is the transportation system. The progress made in the transportation industry over the last century has been an essential factor in the development of today's urban society, while also triggering the birth and growth of other economic branches. However, the current transportation system has serious difficulties coping with the continuous growth in the number of vehicles, especially in an urban environment. As a major increase in the capacity of a city road infrastructure, already in place for tens or even hundreds of years, would imply dissuasive costs, the more realistic approach is to optimize the use of the existing transportation system. As in the case of distribution networks, the intelligence of the system can be achieved through the integration of information and communication capabilities. However, for smart transportation the challenges are somehow different, because the intelligence is no longer limited to the infrastructure, but propagates to vehicles themselves. Moreover, the degree of automation is reduced in transportation systems, as most actions resulting in reduced road congestion, higher reliability or improved safety must come from the human driver (at least in the foreseeable future)

Finally, smart spaces are becoming an essential component of our cities. The classical architecture tools used to design and shape the urban environment are more and more challenged by the idea of automatically modifying private and public spaces in order to adapt to the requirements and preferences of their users. Among the objectives of this new urban planning current, we can find the transformation of the home in a proactive health care center, fast reconfigurable and customizable workplaces, or the addition of digital content in the public spaces in order to reshape the urban scene. Bringing these changing places in our daily lives is conditioned by a major shift in the construction industry, but it also involves important advancements in digital infrastructure, sensing, and communications

4.2. Urban participatory sensing

Urban sensing can be seen as the same evolution of the environment digitalization as social networking has been for information flows. Indeed, besides dedicated and deployed sensors and actuators, still required for specific sensing operations such as the real-time monitoring of pollution levels, there is a wide range of relevant urban data that can be collected without the need for new communication infrastructures, leveraging instead on the pervasiveness of smart mobile terminals. With more than 80% of the population owning a mobile phone, the mobile market has a deeper penetration than electricity or safe drinking water. Originally designed for voice transmitted over cellular networks, mobile phones are today complete computing, communication and sensing devices, offering in a handheld device multiple sensors and communication technologies.

Mobile devices such as smartphones or tablets are indeed able to gather a wealth of informations through embedded cameras, GPS receivers, accelerometers, and cellular, WiFi and bluetooth radio interfaces. When collected by a single device, such data may have small value per-se, however its fusion over large scales could prove critical for urban sensing to become an economically viable mainstream paradigm.

This is even more true when less traditional mobile terminals are taken into account: privately-owned cars, public transport means, commercial fleets, and even city bikes are starting to feature communication capabilities and the Floating Car Data (FCD) they generate can bring a dramatic contribution to the cause of urban sensing. Indeed, other than enlarging the sensing scope even further, e.g., through Electronic Control Units (ECUs), these mobile terminals are not burdened by strong energy constraints and can thus significantly increase the granularity of data collection. This data can be used by authorities to improve public services, or by citizens who can integrate it in their choices. However, in order to kindle this hidden information, important problems related to data gathering, aggregation, communication, data mining, or even energy efficiency need to be solved.

4.3. Human-centric networks

Combining location awareness and data recovered from multiple sources like social networks or sensing devices can surface previously unknown characteristics of the urban environment, and enable important new services. As a few examples, one could think of informing citizens about often disobeyed (and thus risky) traffic signs, polluted neighborhoods, or queue waiting times at current exhibitions in the urban area.

Beyond letting their own devices or vehicles autonomously harvest data from the environment through embedded or onboard sensors, mobile users can actively take part in the participatory sensing process because they can, in return, benefit from citizen-centric services which aim at improving their experience of the urban life. Crowdsourcing applications have the potential to turn citizens into both sources of information and interactive actors of the city. It is not a surprise that emerging services built on live mobile user feedback are rapidly meeting a large success. In particular, improving everyone's mobility is probably one of the main services that a smart city shall offer to its inhabitants and visitors. This implies providing, through network broadcast data or urban smart-furniture, an accurate and user-tailored information on where people should head in order to find what they are looking for (from a specific kind of shop to a free parking slot), on their current travel time estimates, on the availability of better alternate means of transport to destination. Depending on the context, such information may need to be provided under hard real-time constraints, e.g., in presence of road accidents, unauthorized public manifestations, or delayed public transport schedules.

In some cases, information can also be provided to mobile users so as to bias or even enforce their mobility: drivers can be alerted of the arrival of an emergency vehicle so that they leave the leftmost lane available, or participants leaving vast public events can be directed out of the event venue through diverse routes displayed on their smartphones so as to dynamically balance the pedestrian flows and reduce their waiting times.