# Activity Report 2014

# Section Application Domains

<span style="color:red">**ALF Project-Team**</span>

# 4. Application Domains

## 4.1. Any computer usage

The ALF team is working on the fundamental technologies for computer science: processor architecture and performance-oriented compilation. The research results have impacts on any application domain that requires high performance executions (telecommunication, multimedia, biology, health, engineering, environment ...), but also on many embedded applications that exhibit other constraints such as power consumption, code size and guaranteed response time. Our research activity implies the development of software prototypes.

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

# 4. Application Domains

## 4.1. Overview

The results of the research targeted in ASAP span a wide range of applications. Below are a few examples.

- Personalized web search.
- Recommendation.
- Social networks.
- Notification systems.
- Distributed storage.
- Video streaming.

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

# 4. Application Domains

## 4.1. Enterprise Information Systems and Services

Large IT infrastructures typically evolve by adding new third-party or internally-developed components, but also frequently by integrating already existing information systems. Integration frequently requires the addition of glue code that mediates between different software components and infrastructures but may also consist in more invasive modifications to implementations, in particular to implement crosscutting functionalities. In more abstract terms, enterprise information systems are subject to structuring problems involving horizontal composition (composition of top-level functionalities) as well as vertical composition (reuse and sharing of implementations among several top-level functionalities). Moreover, information systems have to be more and more dynamic.

Service-Oriented Computing (SOC) that is frequently used for solving some of the integration problems discussed above. Indeed, service-oriented computing has two main advantages:

- Loose-coupling: services are autonomous, in that they do not require other services to be executed;
- Ease of integration: Services communicate over standard protocols.

Our current work is based on the following observation: similar to other compositional structuring mechanisms, SOAs are subject to the problem of crosscutting functionalities, that is, functionalities that are scattered and tangled over large parts of the architecture and the underlying implementation. Security functionalities, such as access control and monitoring for intrusion detection, are a prime example of such a functionality in that it is not possible to modularize security issues in a well-separated module. Aspect-Oriented Software Development is precisely an application-structuring method that addresses in a systemic way the problem of the lack of modularization facilities for crosscutting functionalities.

We are considering solutions to secure SOAs by providing an aspect-oriented structuring and programming model that allows security functionalities to be modularized. Two levels of research have been identified:

- Service level: as services can be composed to build processes, aspect weaving will deal with the orchestration and the choreography of services.
- Implementation level: as services are abstractly specified, aspect weaving will require to extend service interfaces in order to describe the effects of the executed services on the sensitive resources they control.

In 2014, we have published results on constructive mechanisms for security and accountability properties in service-based system as well as results on service provisioning problems, in particular, service interoperability and mediation, see Sec. 6.3 . Furthermore, we take part in the European project A4Cloud on accountability challenges, that is, the responsible stewardship of third-party data and computations, see Sec. 8.3 .

## 4.2. Capacity Planning in Cluster, Grid and Cloud Computing

Cluster, Grid and more recently Cloud computing platforms aim at delivering large capacities of computing power. These capacities can be used to improve performance (for scientific applications) or availability (e.g., for Internet services hosted by datacenters). These distributed infrastructures consist of a group of coupled computers that work together and may be spread across a LAN (cluster), across a WAN (Grid), and across the Internet (Clouds). Due to their large scale, these architectures require permanent adaptation, from the application to the system level and call for automation of the corresponding adaptation processes. We focus on self-configuration and self-optimization functionalities across the whole software stack: from the lower levels (systems mechanisms such as distributed file systems for instance) to the higher ones (i.e. the applications themselves such as J2EE clustered servers or scientific grid applications).

In 2014, we have proposed a mechanism to take into account locality aspects in the DVMS proposal, a fully distributed VM scheduler. Concretely, our mechanism leverages Vivaldi coordinates in order to favor live migration of virtual machines between servers belonging to the same site before performing inter-site live migrations. By such a means, we have improved the reactivity of DVMS, establishing it as one of the most scalable and reactive scheduler of virtual machines for large-scale cloud computing infrastructures. Finally, we have also provided several results on the energy efficient management of Cloud applications and infrastructures, see Sec. 6.4 .

In the energy field, we have designed a set of techniques, named Optiplace, for cloud management with flexible power models through constraint programming. OptiPlace supports external models, named views. Specifically, we have developed a power view, based on generic server models, to define and reduce the power consumption of a datacenter's physical servers. We have shown that OptiPlace behaves at least as good as our previous system, Entropy, requiring as low as half the time to find a solution for the constrained-based placement of tasks for large datacenters.

## 4.3. Pervasive Systems

Pervasive systems are another class of systems raising interesting challenges in terms of software structuring. Such systems are highly concurrent and distributed. Moreover, they assume a high-level of mobility and context-aware interactions between numerous and heterogeneous devices (laptops, PDAs, smartphones, cameras, electronic appliances...). Programming such systems requires proper support for handling various interfering concerns like software customization and evolution, security, privacy, context-awareness... Additionally, service composition occurs spontaneously at runtime.

In 2014, we have extended the language EScala, which integrates reactive programming through events with aspect-oriented and object-oriented mechanisms, see Sec. 6.3 .

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**ASPI Project-Team**

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# 4. Application Domains

## 4.1. Localisation, navigation and tracking

Among the many application domains of particle methods, or interacting Monte Carlo methods, ASPI has decided to focus on applications in localisation (or positioning), navigation and tracking  [39], [33], which already covers a very broad spectrum of application domains. The objective here is to estimate the position (and also velocity, attitude, etc.) of a mobile object, from the combination of different sources of information, including

- a prior dynamical model of typical evolutions of the mobile, such as inertial estimates and prior model for inertial errors,
- measurements provided by sensors,
- and possibly a digital map providing some useful feature (terrain altitude, power attenuation, etc.) at each possible position.

In some applications, another useful source of information is provided by

- a map of constrained admissible displacements, for instance in the form of an indoor building map,

which particle methods can easily handle (map-matching). This Bayesian dynamical estimation problem is also called filtering, and its numerical implementation using particle methods, known as particle filtering, has been introduced by the target tracking community  [38], [52], which has already contributed to many of the most interesting algorithmic improvements and is still very active, and has found applications in

> target tracking, integrated navigation, points and / or objects tracking in video sequences, mobile robotics, wireless communications, ubiquitous computing and ambient intelligence, sensor networks, etc.

ASPI is contributing (or has contributed recently) to several applications of particle filtering in positioning, navigation and tracking, such as geolocalisation and tracking in a wireless network, terrain–aided navigation, and data fusion for indoor localisation.

## 4.2. Rare event simulation

*See 3.3 , and 5.1 , 5.2 , and 5.3 .*

Another application domain of particle methods, or interacting Monte Carlo methods, that ASPI has decided to focus on is the estimation of the small probability of a rare but critical event, in complex dynamical systems. This is a crucial issue in industrial areas such as

> nuclear power plants, food industry, telecommunication networks, finance and insurance industry, air traffic management, etc.

In such complex systems, analytical methods cannot be used, and naive Monte Carlo methods are clearly unefficient to estimate accurately very small probabilities. Besides importance sampling, an alternate widespread technique consists in multilevel splitting  [46], where trajectories going towards the critical set are given offsprings, thus increasing the number of trajectories that eventually reach the critical set. This approach not only makes it possible to estimate the probability of the rare event, but also provides realizations of the random trajectory, given that it reaches the critical set, i.e. provides realizations of typical critical trajectories, an important feature that methods based on importance sampling usually miss.

ASPI is contributing (or has contributed recently) to several applications of multilevel splitting for rare event simulation, such as risk assessment in air traffic management, detection in sensor networks, and protection of digital documents.

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**ATLANMOD Project-Team**

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# 4. Application Domains

## 4.1. Application domains

By definition, MDE can be applied to any software domain. Core MDE techniques developed by the team have been successfully applied to a large variety of industrial domains from information systems to embedded systems. MDE is not even restricted to software engineering, but also applies to data engineering [47] and to system engineering [38]. There are a lot of problems in these application domains that may be addressed by means of modeling and model transformation techniques.

As a result, AtlanMod has collaborated with a great variety of different companies ranging from the Automotive to the Insurances domains and from SMEs to large enterprises through the projects described later on in this same report. AtlanMod hopes to continue this trend in the future.

<span style="color:red">**CAIRN Project-Team**</span>

# 4. Application Domains

## 4.1. Panorama

**keywords:** telecommunications, wireless communications, wireless sensor networks, content-based image retrieval, video coding, intelligent transportation systems, automotive, security

Our research is based on realistic applications, in order to both discover the main needs created by these applications and to invent realistic and interesting solutions.

The high complexity of the **Next-Generation (4G) Wireless Communication Systems** leads to the design of real-time high-performance specific architectures. The study of these techniques is one of the main field of applications for our research, based on our experience on WCDMA for 3G implementation.

In **Wireless Sensor Networks** (WSN), where each wireless node has to operate without battery replacement for a long time, energy consumption is the most important constraint. In this domain, we mainly study energy-efficient architectures and wireless cooperative techniques for WSN.

**Intelligent Transportation Systems** (ITS), and especially Automotive Systems, more and more take advantage of information technology advances. While wireless transmissions allow a car to communicate with another one or even with road infrastructure, **automotive industry** can also propose driver assistance and more secure vehicles thanks to improvements in computation accuracy for embedded systems.

Other important fields will also be considered: hardware cryptographic and security modules, specialized hardware systems for the filtering of the network traffic at high-speed, high-speed true-random number generation for security, content-based image retrieval and video processing.

## 4.2. 4G Wireless Communication Systems

With the advent of the next generation (4G) broadband wireless communications, the combination of MIMO (Multiple-Input Multiple-Output) wireless technology with Multi-Carrier CDMA (MC-CDMA) has been recognized as one of the most promising techniques to support high data rate and high performance. Moreover, future mobile devices will have to propose interoperability between wireless communication standards (4G, WiMax ...) and then implement MIMO pre-coding, already used by WiMax standard. Finally, in order to maximize mobile devices lifetime and guarantee quality of services to consumers, 4G systems will certainly use cooperative MIMO schemes or MIMO relays. Our research activity focuses on MIMO pre-coding and MIMO cooperative communications with the aim of algorithmic optimization and implementation prototyping.

## 4.3. Wireless Sensor Networks

Sensor networks are a very dynamic domain of research due, on the one hand, to the opportunity to develop innovative applications that are linked to a specific environment, and on the other hand to the challenge of designing totally autonomous communicating objects. Cross-layer optimizations lead to energy-efficient architectures and cooperative techniques dedicated to sensor networks applications. In particular, cooperative MIMO techniques are used to decrease the energy consumption of the communications.

## 4.4. Multimedia processing

In multimedia applications, audio and video processing is the major challenge embedded systems have to face. It is computationally intensive with power requirements to meet. Video or image processing at pixel level, like image filtering, edge detection and pixel correlation or at block-level such as transforms, quantization, entropy coding and motion estimation have to be accelerated. We investigate the potential of reconfigurable architectures for the design of efficient and flexible accelerators in the context of multimedia applications.

# CELTIQUE Project-Team  (section vide)

<span style="color:red">**CIDRE Project-Team**</span>

# 4. Application Domains

## 4.1. Domain

With the infiltration of computers and software in almost all aspects of our modern life, security can nowadays be seen as an absolutely general concern. As such, the results of the research targeted by CIDRE apply to a wide range of domains. It is clear that critical systems, in which security (and safety) is a major concern can benefit from ideas such as dynamic security policy monitoring. On the other hand, systems used by general public (basically, the internet and services such as web or cloud services, social networks, location-based services, etc.) can also benefit from results obtained by CIDRE, in particular to solve some of the privacy issues raised by these systems that manipulate huge amount of personal data. In addition, systems are getting more and more complex, decentralized, distributed, or spontaneous. Cloud computing brings many challenges that could benefit from ideas, approaches and solutions studied by CIDRE in the context of distributed systems.

# DIONYSOS Project-Team  (section vide)

<center>**DIVERSE Project-Team**</center>

# 4. Application Domains

## 4.1. From Embedded Systems to Service Oriented Architectures

From small embedded systems such as home automation products or automotive systems to medium sized systems such as medical equipment, office equipment, household appliances, smart phones; up to large Service Oriented Architectures (SOA), building a new application from scratch is no longer possible. Such applications reside in (group of) machines that are expected to run continuously for years without unrecoverable errors. Special care has then to be taken to design and validate embedded software, making the appropriate trade-off between various extra-functional properties such as reliability, timeliness, safety and security but also development and production cost, including resource usage of processor, memory, bandwidth, power, etc.

Leveraging ongoing advances in hardware, embedded software is playing an evermore crucial role in our society, bound to increase even more when embedded systems get interconnected to deliver ubiquitous SOA. For this reason, embedded software has been growing in size and complexity at an exponential rate for the past 20 years, pleading for a component based approach to embedded software development. There is a real need for flexible solutions allowing to deal at the same time with a wide range of needs (product lines modeling and methodologies for managing them), while preserving quality and reducing the time to market (such as derivation and validation tools).

We believe that building flexible, reliable and efficient embedded software will be achieved by reducing the gap between executable programs, their models, and the platform on which they execute, and by developing new composition mechanisms as well as transformation techniques with a sound formal basis for mapping between the different levels.

Reliability is an essential requirement in a context where a huge number of softwares (and sometimes several versions of the same program) may coexist in a large system. On one hand, software should be able to evolve very fast, as new features or services are frequently added to existing ones, but on the other hand, the occurrence of a fault in a system can be very costly, and time consuming. While we think that formal methods may help solving this kind of problems, we develop approaches where they are kept "behind the scene" in a global process taking into account constraints and objectives coming from user requirements.

Software testing is another aspect of reliable development. Testing activities mostly consist in trying to exhibit cases where a system implementation does not conform to its specifications. Whatever the efforts spent for development, this phase is of real importance to raise the confidence level in the fact that a system behaves properly in a complex environment. We also put a particular emphasis on on-line approaches, in which test and observation are dynamically computed during execution.

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

# 4. Application Domains

## 4.1. Introduction

The Dream project-team research applications have been oriented towards surveillance, monitoring and decision support. Our domains of application are:

- Agriculture and environment
- Health
- Exploitation of execution traces in an industrial setting

## 4.2. Environmental decision making

environment, decision methods

The need for decision support systems in the environmental domain is now well-recognized. It is especially true in the domain of water quality. The challenge is to preserve the water quality from pollutants as nitrates and herbicides, when these pollutants are massively used by farmers to weed their agricultural plots and improve the quality and increase the quantity of their crops. The difficulty is then to find solutions which satisfy contradictory interests and to get a better knowledge on pollutant transfer.

In this context, we are cooperating with INRA (Institut National de Recherche Agronomique) and developing decision support systems to help regional managers in preserving the river water quality. This work began in ANR projects like APPEAU and ACASSYA or the PSDR GO CLIMASTER project (Changement climatique, systèmes agricoles, ressources naturelles et développement territorial).

The approach we advocate is to rely on a qualitative modeling, in order to model biophysical processes in an explicative and understandable way. The SACADEAU model associates a qualitative biophysical model, able to simulate the biophysical process, and a management model, able to simulate farmers' decisions. One of our main contributions is the use of qualitative spatial modeling, based on runoff trees, to simulate the pollutant transfer through agricultural catchments.

The second issue is the use of learning/data mining techniques to discover, from model simulation results, the discriminant variables and automatically acquire rules relating these variables. One of the main challenges is that we are faced with spatiotemporal data. The learned rules are then analyzed in order to recommend actions to improve a current "unsatisfactory" situation.

Our main partners are the SAS INRA research group, located in Rennes and the BIA INRA and AGIR INRA research groups in Toulouse.

**Ecosystem Management.**
The objective of ecosystem management is to ensure sustainable ecosystems even when submitted to various stressors such as natural disturbances or human pressures. Several studies have already shown the interest of qualitative modelling for ecosystems [38]. In our case, we propose to couple a qualitative modelling with model-checking tools to explore marine ecosystems (as explained section 3.2). We applied our approach on a small-scale subsistence fishery in a coral reef lagoon (Uvea, New Caledonia). A well described foodweb model provides us with useful input data for steady-state biomass data and estimates of production and consumption. A timed automata model was developed using EcoMata to investigate the direct and indirect effects of various fishing strategies on a subset of the trophic network.

This work has been realized in collaboration with ecologists: Yves-Marie Bozec (today in position in Marine Spatial Ecology, University of Queensland, Australia) and Guy Fontenelle (Professeur at Agrocampus Ouest).

A second application has been studied in the dairy management area. Over an hybrid modelling on the grazing activities, four methods to generate the best grazing management activity has been proposed. The expert partners are researchers from the SAS INRA research group, located in Rennes.

## 4.3. Health

health-care, patient monitoring, medicament usage, pharmaco-immunology, health-care pathways, wireless sensors

Clinical monitoring, electronic patient records and computer supported disease management produce more and larger volumes of clinical data. This data is a strategic resource for healthcare institutions. Data mining brings the facility to discover patterns and correlation hidden within the data repository and assists professionals to uncover these patterns and to exploit them to improve medical care.

We are working on two aspects of health-care:

- exploitation of data from the french care insurance (Assurance Maladie) that contains records of medicament reimbursements for pharmaco-immunology purposes. Our goal is to reconstruct and mine patients' healthcare pathways in order to detect regularities and anomalies in the way patients take medicaments and alert medical authorities in case some problem is detected, such as non expected negative consequences of medicament intake. We are working in the framework of a project funded by the National Medicament Security Agency (ANSM - Agence Nationale de la Sécurité du Médicament) for building a platfom enabling focused studies on specific medicaments as well as discovering potential problems with medicament usage. This means selecting from billions of patients records, patients sharing similar medical contexts and showing different consequences of medicament intake,

- veterinary monitoring of feedlot cattle in big farms from sensors recording behavioral and physio-logical data. As farms are becoming bigger and bigger, detecting ill animals by visual appraisal is becoming more and more difficult. With the advent of cheap wireless sensors, animals (i.e. cows or steers) may be monitored in quasi real time for detecting relevant changes in their behavior that could be related to specific diseases. We are exploring diverse methods for detecting changes on multivari-ate data, such as cusum charts, specific sequential patterns or distribution of frequent patterns. We are specifically working with veterinaries from the university of Calgary (Canada) for monitoring feedlot cattle in farms growing up to 50.000 animals.

## 4.4. Exploitation of execution traces

log analysis, data mining, embedded systems.

We have an ongoing collaborations with STMicroelectronics, which is one of the world top-5 electronic chip makers. Nowadays, set-top boxes, smartphones or onboard car computers are powered by highly integrated chips called *System-on-Chip (SoC)*. Such chips contain on a single die processing units, memories, IO units and specialized accelerators (such as audio and video encoding/decoding). Programming SoC is a hard task due to their inherent parallelism, leading to subtle bugs when several components do not deliver their results within a given time frame. Existing debuggers and profilers are ill-adapted in this case because of their high intrusivity that modifies the timings. Hence the most used technique is to capture a *trace* of the execution and analyze it post-mortem. While Alexandre Termier was in Grenoble he initiated several works for analyzing such traces with data mining techniques [55], [50], which he is now pursuing with his colleagues of the Dream project-team [14].

## 4.5. Software components monitoring

software components, web services, distributed diagnosis

Web-services cover nowadays more and more application areas, from travel booking to goods supplying in supermarkets or the management of an e-learning platform. Such applications need to process requests from users and other services on line, and respond accurately in real time. Errors may occur, which need to be addressed in order to still be able to provide the correct response with a satisfactory quality of service (QoS): on-line monitoring, especially diagnosis and repair capabilities, becomes then a crucial concern.

We have been working on this problem within the WS-DIAMOND project [61], a large European funded project involving eight partners in Italy, France, Austria and Netherlands http://wsdiamond.di.unito.it/.

We do not work anymore on the diagnosis of web services, now we aim at coupling diagnosing and repair, in order to implement *adaptive web services*. We started this study by proposing an architecture inspired from the one developed during the WS-DIAMOND project and dedicated to the adaptive processing when faults occur and propagate through the orchestration.

# 4. Application Domains

## 4.1. Formal models in molecular biology

As mentioned before, our main goal in biology is to characterize groups of genetic actors that control the response of living species capable of facing extreme environments. To focus our developments, applications and collaborations, we have identified three biological questions which deserve integrative studies. Each axis may be considered independently from the others although their combination, a mid-term challenge, will have the best impact in practice towards the long-term perspective of identifying proteins controlling the production of a metabolite of industrial interest. It is illustrated in our presentation for a major algae product: polyunsaturated fatty acids (PUFAs) and their derivatives.

**Biological data integration.** The first axis of the project (data integration) aims at identifying *who* is involved in the specific response of a biological system to an environmental stress. Targeted actors will mainly consist in groups of genetic products or biological pathways. For instance, which pathways are implied in the specific production of PUFAs in brown algae? The main work is to represent in a system of logical constraints the full knowledge at hand concerning the genetic or metabolic actors, the available observations and the effects of the system dynamics. To this aim, we focus on the use of Answer Set Programming as we are experienced in modeling with this paradigm and we have a strong partnership with a computer science team leader in the development of dedicated grounders and solvers (Potsdam university). See Sec. 3.1 .

**Asymptotic dynamics of a biological system** Once a model is built and its main actors are identified, the next step is to clarify *how* they combine to control the system. This is the second axis of the project. Roughly, the fine tuning of the system response may be of two types. Either it results from the discrete combinatorics of the actors, as the result of a genetic adaptation to extreme environmental conditions or the difference between species is rather at the enzyme-efficiency level. For instance, if Pufa's are found to be produced using a set of pathways specific to brown algae, the work in axis 2 will consist to apply constraint-based combinatorial approaches to select consistent combinations of pathways controlling the metabolite production. Otherwise, if enzymes controlling the production of Pufa's are found to be expressed in other algaes, it suggests that the response of the system is rather governed by a fine quantitative tuning of pathways. In this case, we use symbolic dynamics and average-case analysis of algorithms to weight the respective importance of interactions in observed phenotypes (see Sec. 3.2  and Fig. 2 ). This specific approach is motivated by the quite restricted spectrum of available physiological observations over the asymptotic dynamics of the biological system.

**Biological sequence annotation** In order to check the accuracy of in-silico predictions, a third research axis of the team is to extract genetic actors responsible of biological pathways of interest in the targeted organism and locate them in the genome. In our guiding example, active proteins implied in Pufa's controlling pathways have to be precisely identified. Actors structures are represented by syntactic models (see Fig. 4 ). We use  knowledge-based induction on far instances for the recognition of new members of a given sequence family within non-model genomes (see Fig. 3 ). A main objective is to model enzyme specificity with  highly expressive syntactic structures - context-free model - in order to take into account constraints imposed by local domains or long-distance interactions within a protein sequence. See Sec. 3.3  for details.

## 4.2. Application fields

Our methods are applied in several fields of molecular biology.

Our main application field is **marine biology**, as it is a transversal field with respect to issues in integrative biology, dynamical systems and sequence analysis. Our main collaborators work at the Station Biologique de Roscoff. We are strongly involved in the study of brown algae: the *meneco, memap and memerge* tools were designed to realize a complete reconstruction of metabolic networks for non-benchmark species [22], [19]. On the same application model, the pattern discovery tool *protomata learner* combined with supervised bi-clustering based on formal concept analysis allows for the classification of sub-families of specific proteins [28]. The same tool also allowed us to gain a better understanding of cyanobacteria proteins [2]. Finally, in dynamical systems, we use asymptotic analysis (tool *pogg*) to decipher the initiation of sea urchin translation [47]. We are currently initiating two new research programs in this domain: the team will participate to a collaboration program with the Biocore and Ange Inria teams, focused on the understanding on green micro-algae; and we will be involved in the deciphering of phytoplancton variability at the system biology level in collaboration with the Station Biologique de Roscoff.

In **micro-biology**, our main issue is the understanding of bacteria living in extreme environments, mainly in collaboration with the group of bioinformatics at Universidad de Chile (funded by CMM, CRG and Inria-Chile). In order to elucidate the main characteristics of these bacteria, we develop efficient methods to identify the main groups of regulators for their specific response in their living environment. To that purpose, we use constraints-based modeling and combinatorial optimization. The integrative biology tools *bioquali, ingranalysis, shogun, lombarde* were designed in this context [5]. In parallel, in collaboration with Ifremer (Brest), we have conducted similar work to decipher protein-protein interactions within archebacteria [55]. Our sequence analysis tool (*logol*) allowed us to build and maintain a very expressive CRISPR database [9] [27].

Similarly, in **animal biology**, our goal is to propose methods to identify regulators of very complex phenotypes related to nutritional issues. In collaboration with researchers from Inra/Pegase and Inra/Igeep laboratories, we develop methods to distinguish the response of cows, chicken or porks to different diaries or treatments and characterize upstream transcriptional regulators for such a response. The system biology tool *nutritional analyzer* was designed in this framework [14]. The pattern matching tool *logol* also allows for a fine identification of transcription factor motifs [51] [27]. Constraints-based programming also allows us to decipher regulators of reproduction for pea aphids [30], [13]. Semantic-based analysis was useful for interpreting differences of gene expression in pork meat [20].

We are less involved in **bio-medical applications** as the models and data studied in this application field are well informed and rather data-driven. In collaboration with Institut Curie, we have studied the Ewing Sarcoma regulation network to test the capability of our tool *bioquali* to accurately correct and predict a large-scale network behavior [46]. Our ongoing studies in this field focus on the exhaustive learning of discrete dynamical networks matching with experimental data, as a case study for modeling experimental design with constraints-based approaches. To that purpose, we collaborate with J. Saez Rodriguez group at EBI [23] and N. Theret group at Inserm/Irset (Rennes) [15]. The dynamical system tools *caspo and cadbiom* were designed within these collaborations. Future studies will focus on the understanding of the metabolism of xenobiotics, still in collaboration with Inserm/Irset (Rennes).

<span style="color:red">**ESTASYS Exploratory Action**</span>

# 4. Application Domains

## 4.1. Application Domains

In two years, ESTASYS should lead to the creation of a top class research team at Inria as well as to an interdisciplinary community of researchers and practitioners at the world level.

**ESTASYS sets the foundations for an engineering domain dedicated to SoS that will benefit the European software industry**. This is achieved by creating mathematical models that capture the computational power, autonomous decisions and complex stochastic and real-time dynamics of SoS. ESTASYS produces new decidability and complexity results, simulation-based techniques, and algorithms with correctness arguments. All aim at efficient reasoning about SoS and are traced back to case studies. **Our strategy to work in close collaboration with contact in industry will guarantee their wider adoption by the european software industry.**

In the near future, The ESTASYS-PLASMA toolset will be distributed as open source whenever possible, but will create a new market of tools for SoS.

<span style="color:red">**FLUMINANCE Project-Team**</span>

# 4. Application Domains

## 4.1. Introduction

By designing new approaches for the analysis of fluid-image sequences the FLUMINANCE group aims at contributing to several application domains of great interest for the community and in which the analysis of complex fluid flows plays a central role. The group focuses mainly on two broad application domains:

- Environmental sciences;
- Experimental fluid mechanics and industrial flows.

We detail hereafter these two application domains.

## 4.2. Environmental sciences

The first huge application domain concerns all the sciences that aim at observing the biosphere evolution such as meteorology, climatology or oceanography but also remote sensing study for the monitoring of meteorological events or human activities consequences. For all these domains image analysis is a practical and unique tool to *observe, detect, measure, characterize or analyze* the evolution of physical parameters over a large domain. The design of generic image processing techniques for all these domains might offer practical software tools to measure precisely the evolution of fluid flows for weather forecasting or climatology studies. It might also offer possibilities of close surveillance of human and natural activities in sensible areas such as forests, river edges, and valley in order to monitor pollution, floods or fire. The need in terms of local weather forecasting, risk prevention, or local climate change is becoming crucial for our tomorrow's life. At a more local scale, image sensors may also be of major utility to analyze precisely the effect of air curtains for safe packaging in agro-industrial.

## 4.3. Experimental fluid mechanics and industrial flows

In the domain of **experimental fluid mechanics**, the visualization of fluid flows plays a major role, especially for turbulence study since high frequency imaging has been made currently available. Together with analysis of turbulence at different scales, one of the major goals pursued at the moment by many scientists and engineers consists in studying the ability to manipulate a flow to induce a desired change. This is of huge technological importance to enhance or inhibit mixing in shear flows, improve energetic efficiency or control the physical effects of strain and stresses. This is for instance of particular interest for:

- military applications, for example to limit the infra-red signatures of fighter aircraft;
- aeronautics and transportation, to limit fuel consumption by controlling drag and lift effects of turbulence and boundary layer behavior;
- industrial applications, for example to monitor flowing, melting, mixing or swelling of processed materials, or preserve manufactured products from contamination by airborne pollutants, or in industrial chemistry to increase chemical reactions by acting on turbulence phenomena.

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

# 4. Application Domains

## 4.1. Sequence comparison

Historically, sequence comparison has been one of the most important topics in bioinformatics. BLAST is a famous software tool particularly designed for solving problems related to sequence comparisons. Initially conceived to perform searches in databases, it has mostly been used as a general-purpose sequence comparison tool. Nowadays, together with the inflation of genomic data, other software comparison tools that are able to provide better quality solutions (w.r.t the ones provided by BLAST) have been developed. They generally target specific comparison demands, such as read mapping, bank-to-bank comparison, meta-genomic sample analysis, etc. Today, sequence comparison algorithms must clearly be revisited to scale up with the very large number of sequence objects that new NGS problems have to handle.

## 4.2. Genome comparison

This application domain aims at providing a global relationship between genomes. The problem lies in the different structures that genomes can have: segments of genome can be rearranged, duplicated or deleted (the alignment can no longer be done in one piece). Therefore one major aim is the study of chromosomal rearrangements, breaking points, structural variation between individuals of the same species, etc. However, even analyses focused on smaller variations such as Single Nucleotide Polymorphisms (SNP) at the whole genome scale are different from the sequence comparison problem, since one needs first to identify common (orthologous) parts between whole genome sequences and thus obtain this global relationship (or map) between genomes. New challenges in genome comparison are emerging with the evolution of sequencing techniques. Nowadays, they allow for comparing genomes at intra-species level, and to deal simultaneously with hundreds or thousands of complete genomes. New methods are needed to find the sequence and structural variants between such a large number of non-assembled genomes. Even for the comparison of more distant species, classical methods must be revisited to deal with the increasing number of genomes but more importantly their decreasing quality: genomes are no longer fully assembled nor annotated.

## 4.3. Protein comparison

Comparing protein is important for understanding their evolutionary relationships and for predicting their structures and their functions. While annotating functions for new proteins, such as those solved in structural genomics projects, protein structural alignment methods may be able to identify functionally related proteins when the sequence identity between a given query protein and the related proteins are low (i.e. lower than 20%). Moreover, protein comparison allows for solving the so-called protein family identification problem. Given an unclassified protein structure (query), the comparison of protein structures can be used for assigning a score measuring the "similarity" between the query and the proteins belonging to a set of families. Based on this score, the query is assigned to one of the families of the set. The knowledge acquired by performing such analyses can then be exploited in methods for protein structure prediction that are based on a homology modeling approach.

<span style="color:red">**HYBRID Project-Team**</span>

# 4. Application Domains

## 4.1. Overview

The research program of Hybrid team aims at next generations of virtual reality and 3D user interfaces which could possibly address both the "body" and "mind" of the user. Novel interaction schemes are designed, for one or multiple users. We target better integrated systems and more compelling user experiences.

The applications of our research program correspond to the applications of virtual reality technologies which could benefit from the addition of novel body-based or mind-based interaction capabilities:

- **Industry**: with training systems, virtual prototyping, or scientific visualization;
- **Medicine**: with rehabilitation and reeducation systems, or surgical training simulators;
- **Entertainment**: with 3D web navigations, video games, or attractions in theme parks,
- **Construction**: with virtual mock-ups design and review, or historical/architectural visits.

<span style="color:red">**HYCOMES Team**</span>

# 4. Application Domains

## 4.1. Modeling cyber-physical systems

Hybrid systems modeling plays a particular role in the design of cyber-physical systems, eg. systems mixing physical devices, computing platforms, communication buses and control and diagnosis software. A faithful modeling of the physical environment is a key element in a successful design of a cyber-physical system.

Several types of physical components can be found in a system, for example: mechanical, hydraulic or electrical. Component models should cover several viewpoints. For instance, the three viewpoints of an electronic device would be its electrical, thermal and reliability models. All these viewpoints interact, and it is not possible to analyze any of them in isolation. Let alone these complex cross-viewpoint interactions, modeling physics requires refined mathematics. For instance, it is a misconception to assume that physical laws result in smooth dynamics that can be captured by systems of ordinary differential equations. On the contrary, physics is often nonsmooth, meaning that trajectories may be discontinuous — consider the example of colliding billiard balls. Physical systems are networks of elementary components. The dynamics of each component can often be captured by a simple (differential) equation. However, these (differential) equations are coupled by network equations (Kirchhoff laws, mechanical couplings, ...) resulting from the structure of the system. The end result, is a system mixing differential equations with linear or algebraic constraints: a system of differential algebraic equations (DAE).

The Hycomes team is focusing on the design of hybrid systems modeling languages with DAE and nonsmooth dynamics (Fillipov differential inclusions, or complementarity systems), with applications in the energy industry (power plants, smart grids), and in the railway, automotive and aeronautic industries — see section <span style="color:red">3.1</span> for a deeper insight on the research program.

## 4.2. Supporting requirements engineering for aeronautic systems design

The design of embedded systems onboard certified civil aircrafts, for instance navigation, fly-by-wire and FADEC (Full Authority Digital Engine Control) applications, has to follow a stringent discipline imposed by civil aviation authorities. Designers have to provide evidence that both the design process they used and the system under design meet several industry standards, including the well-known ED-79/ARP-4754A and the DO-178 A/B regarding hardware and software artifacts.

These standards prescribe that every feature of a design can be traced back to one or several system-level requirements. Conversely, evidence shall be provided that every requirement has been accounted for. Correctness, consistency, compatibility and completeness of requirements are four key properties described in the ED-79/ARP-4754A standard that should also be assessed every time requirements are transformed. This puts a high burden on designers, especially on the system architect: requirements capture and analysis is by large a heuristic and manual process.

Formal requirements engineering is in its infancy: mathematical models, formal analysis techniques and links to system implementation must be developed. We advocate the use of contract-based reasoning techniques (see section <span style="color:red">3.3</span> ) to support requirements engineering activities, during the early stages of the design process [4].

# 4. Application Domains

## 4.1. Civil Engineering

For at least three decades, monitoring the integrity of the civil infrastructure has been an active research topic because of major economical and societal issues, such as durability and safety of infrastructures, buildings and networks. Control of civil structures began a century ago. At stake is the mastering either the aging of the bridges, as in America (US, Canada) and Great Britain, or the resistance to seismic events and the protection of the cultural heritage, as in Italy and Greece. The research effort in France is very ancient since for example early developments of optical methods to monitor civil structures began in the 70s and SHM practice can be traced back to the 50s with the vibrating wire sensors as strain gauges for dams. Stille the number of sensors actually placed on civil structures is kept to a minimum, mainly for cost reasons, but also because the return on investment sensing and data processing technologies is not properly established for civil structures. One of the current thematic priorities of the C2D2 governmental initiative is devoted to construction monitoring and diagnostics. The picture in Asia (Japan, and also China) is somewhat different, in that recent or currently built bridges are equipped with hundreds if not thousands of sensors, in particular the Hong Kong-Shenzen Western Corridor and Stonecutter Bridge projects. However, the actual use of available data for operational purpose remains unclear.

Among the challenges for vibration-based bridges health monitoring, two major issues are the different kinds of (non measured) excitation sources and the environmental effects. Typically the traffic on *and* under the bridge, the wind and also the rain, contribute to excite the structure, and influence the measured dynamics. Moreover, the temperature is also known to affect the eigenfrequencies and mode-shapes, to an extent which can be significant w.r.t. the deviations to be monitored.

Thermomechanical prestress states affect the dynamic and the static behavior of most bridges, not only of very long and flexible ones. So, the reliable and fast determination of the state of prestress and prestrain associated with a temperature field becomes a crucial step in several engineering processes such as the health monitoring of civil structures. The best possible reconstruction of the temperature field could then become part of a complete process including massively distributed sensing of thermomechanical information on the structure, modeling and algorithms for the on-line detection of damages in the sense of abnormalities with regard to a nominal state, the whole chain being encapsulated in professional tools used by engineers in charge of real-life structural monitoring. For lack of an adequate mobilization of the useful multidisciplinary skills, this way remains about unexplored today.

## 4.2. Electrical cable and network monitoring

The fast development of electronic devices in modern engineering systems comes with more and more connections through cables, and consequently, the reliability of electric connections becomes a crucial issue. For example, in a modern automotive vehicle, the total length of onboard cables has tremendously increased during the last decades and is now up to 4km. These wires and connectors are subject to aging or degradation because of severe environmental conditions. In this area, reliability becomes a safety issue. In some other domains, cable defects may have catastrophic consequences. It is thus a crucial challenge to design smart embedded diagnosis systems able to detect wired connection defects in real time. This fact has motivated research projects on methods for fault diagnosis in electric transmission lines and wired networks. Original methods have been recently developed by Inria, notably based on the inverse scattering theory, for cable and network monitoring. Further developments concern both theoretic study and industrial applications.

## 4.3. Aeronautics

Improved safety and performance and reduced aircraft development and operating costs are major concerns in aeronautics industry. One critical design objective is to clear the aircraft from unstable aero-elastic vibrations (flutter) in all flight conditions. Opening of flight domain requires a careful exploration of the dynamical behavior of the structure subject to vibration and aero-servo-elastic forces. This is achieved via a combination of ground vibration tests and in flight tests. For both types of tests, various sensors data are recorded, and modal analyses are performed. Important challenges of the in-flight modal analyses are the limited choices for measured excitation inputs, and the presence of unmeasured natural excitation inputs (turbulence). Today, structural flight tests require controlled excitation by ailerons or other devices, stationary flight conditions (constant elevation and speed), and no turbulence. As a consequence, flight domain opening requires a lot of test flights and its costly. This is even worse for aircrafts having a large number of variants (business jets, military aircrafts). A key challenge is therefore to allow for exploiting more data under more conditions during flight tests: uncontrolled excitation, nonstationary conditions.

<div align="center">

## IPSO Project-Team

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# 4. Application Domains

## 4.1. Laser physics

Laser physics considers the propagation over long space (or time) scales of high frequency waves. Typically, one has to deal with the propagation of a wave having a wavelength of the order of $10^{-6}m$, over distances of the order $10^{-2}m$ to $10^{4}m$. In these situations, the propagation produces both a short-scale oscillation and exhibits a long term trend (drift, dispersion, nonlinear interaction with the medium, or so), which contains the physically important feature. For this reason, one needs to develop ways of filtering the irrelevant high-oscillations, and to build up models and/or numerical schemes that do give information on the long-term behavior. In other terms, one needs to develop high-frequency models and/or high-frequency schemes.

Generally speaking, the demand in developing such models or schemes in the context of laser physics, or laser/matter interaction, is large. It involves both modeling and numerics (description of oscillations, structure preserving algorithms to capture the long-time behaviour, etc).

In a very similar spirit, but at a different level of modelling, one would like to understand the very coupling between a laser propagating in, say, a fiber, and the atoms that build up the fiber itself.

The standard, quantum, model in this direction is called the Bloch model: it is a Schrödinger like equation that describes the evolution of the atoms, when coupled to the laser field. Here the laser field induces a potential that acts directly on the atom, and the link between this potential and the laser itself is given by the so-called dipolar matrix, a matrix made up of physical coefficients that describe the polarization of the atom under the applied field.

The scientific objective here is twofold. First, one wishes to obtain tractable asymptotic models that average out the high oscillations of the atomic system and of the laser field. A typical phenomenon here is the *resonance* between the field and the energy levels of the atomic system. Second, one wishes to obtain good numerical schemes in order to solve the Bloch equation, beyond the oscillatory phenomena entailed by this model.

## 4.2. Molecular Dynamics

In classical molecular dynamics, the equations describe the evolution of atoms or molecules under the action of forces deriving from several interaction potentials. These potentials may be short-range or long-range and are treated differently in most molecular simulation codes. In fact, long-range potentials are computed at only a fraction of the number of steps. By doing so, one replaces the vector field by an approximate one and alternates steps with the exact field and steps with the approximate one. Although such methods have been known and used with success for years, very little is known on how the "space" approximation (of the vector field) and the time discretization should be combined in order to optimize the convergence. Also, the fraction of steps where the exact field is used for the computation is mainly determined by heuristic reasons and a more precise analysis seems necessary. Finally, let us mention that similar questions arise when dealing with constrained differential equations, which are a by-product of many simplified models in molecular dynamics (this is the case for instance if one replaces the highly-oscillatory components by constraints).

## 4.3. Plasma physics

The development of efficient numerical methods is essential for the simulation of plasmas and beams at the kinetic level of description (Vlasov type equations). It is well known that plasmas or beams give rise to small scales (Debye length, Larmor radius, gyroperiod, mean free path...) which make numerical simulations challenging. Instead of solving the limit or averaged models by considering these small scales equal to zero, our aim is to explore a different strategy, which consists in using the original kinetic equation. Specific numerical scheme called 'Asymptotic Preserving" scheme is then built to discretize the original kinetic

equation. Such a scheme allows to pass to the limit with no stability problems, and provide in the limit a consistent approximation of the limit or average model. A systematic and robust way to design such a scheme is the micro-macro decomposition in which the solution of the original model is decomposed into an averaged part and a remainder.

<span style="color:red">**KerData Project-Team**</span>

# 4. Application Domains

## 4.1. Joint genetic and neuroimaging data analysis on Azure clouds

Joint acquisition of neuroimaging and genetic data on large cohorts of subjects is a new approach used to assess and understand the variability that exists between individuals. It has remained poorly understood so far. Both neuroimaging- and genetic-domain observations include a huge amount of variables (of the order of millions). Performing rigorous statistical analyses on such amounts of data is a major computational challenge that cannot be addressed with conventional computational techniques only. On the one hand, sophisticated regression techniques need to be used in order to perform significant analysis on these large datasets; on the other hand, the cost entailed by parameter optimization and statistical validation procedures (e.g. permutation tests) is very high.

The A-Brain (AzureBrain) Project was carried out within the Microsoft Research-Inria Joint Research Center. It was co-led by the KerData (Rennes) and Parietal (Saclay) Inria teams. They jointly address this computational problem using cloud related techniques on the Microsoft Azure cloud infrastructure. The two teams bring together their complementary expertise: KerData in the area of scalable cloud data management, and Parietal in the field of neuroimaging and genetics data analysis. This project is a typical multi-disciplinary Data Science project which serves as background for several on-going research activities.

In particular, KerData brings its expertise in designing solutions for optimized data storage and management for the Map-Reduce programming model. This model has recently arisen as a very effective approach to develop high-performance applications over very large distributed systems such as grids and now clouds. The computations involved in the statistical analysis designed by the Parietal team fit particularly well with this model.

## 4.2. Structural protein analysis on Nimbus clouds

Proteins are major components of the life. They are involved in lots of biochemical reactions and vital mechanisms for living organisms. The three-dimensional (3D) structure of a protein is essential for its function and for its participation to the whole metabolism of a living organism. However, due to experimental limitations, only few protein structures (roughly, 60,000) have been experimentally determined, compared to the millions of proteins sequences which are known. In the case of structural genomics, the knowledge of the 3D structure may be not sufficient to infer the function. A usual way to make a structural analysis of a protein or to infer its function is to compare its known, or potential, structure to the whole set of structures referenced in the *Protein Data Bank* (PDB).

In the framework of the MapReduce ANR project led by KerData, we focus on the SuMo application (*Surf the Molecules*) proposed by Institute for Biology and Chemistry of the Proteins from Lyon (IBCP, a partner in the MapReduce project). This application performs structural protein analysis by comparing a set of protein structures against a very large set of structures stored in a huge database. This is a typical data-intensive application that can leverage the Map-Reduce model for a scalable execution on large-scale distributed platforms. Our goal is to explore storage-level concurrency-oriented optimizations to make the SuMo application scalable for large-scale experiments of protein structures comparison on cloud infrastructures managed using the Nimbus IaaS toolkit developed at Argonne National Lab (USA).

If the results are convincing, then they can immediately be applied to the derived version of this application for drug design in an industrial context, called MED-SuMo, a software managed by the MEDIT SME (also a partner in this project). For pharmaceutical and biotech industries, using a cloud computing facility unlocks several new applications for drug design. Rather than searching for 3D similarity into biostructural data, it will become possible to classify the entire biostructural space and to update all derivative predictive models periodically with new experimental data. The applications in this complete chemo-proteomic vision address the identification of new druggable protein targets, and thereby the generation of new drug candidates.

## 4.3. I/O intensive climate simulations for the Blue Waters post-Petascale machine

A major research topic in the context of HPC simulations running on post-Petascale supercomputers is to explore how to record and visualize data during the simulation efficiently without impacting the performance of the computation generating that data. Conventional practice consists in storing data on disk, moving them off-site, reading them into a workflow, and analyzing them. This approach becomes increasingly harder to use because of the large data volumes generated at fast rates, in contrast to limited back-end performance. Scalable approaches to deal with these I/O limitations are thus of utmost importance. This is one of the main challenges explicitly stated in the roadmap of the Blue Waters Project (http://www.ncsa.illinois.edu/BlueWaters/), which aims to build one of the most powerful supercomputers in the world.

In this context, the KerData project-team started to explore ways to remove the limitations mentioned above through collaborative work in the framework of the Joint Inria-UIUC Lab for Petascale Computing (JLPC, Urbana-Champaign, Illinois, USA), whose research activity focuses on the Blue Waters project. As a starting point, we are focusing on a particular tornado simulation code called CM1 (Cloud Model 1), which is intended to be run on the Blue Waters machine. Preliminary investigation demonstrated the inefficiency of the current I/O approach, which typically consists in periodically writing a very large number of small files. This causes bursts of I/O in the parallel file system, leading to poor performance and extreme variability (*jitter*) compared to what could be expected from the underlying hardware. The challenge here is to investigate how to make an efficient use of the underlying file system, by avoiding synchronization and contention as much as possible. In collaboration with the JLPC, we started to address these challenges through an approach based on dedicated I/O cores.

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

# 4. Application Domains

## 4.1. Application Domains

The natural applications of our research are obviously in robotics. In fact, researches undertaken in the Lagadic group can apply to all the fields of robotics implying a vision sensor. They are indeed conceived to be independent of the system considered (and the robot and the vision sensor can even be virtual for some applications).

Currently, we are mostly interested in using visual servoing for aerial and space application, micromanipulation, autonomous vehicle navigation in large urban environments or for disabled or elderly people.

We also address the field of medical robotics. The applications we consider turn around new functionalities of assistance to the clinician during a medical examination: visual servoing on echographic images, needle insertion, compensation of organ motion, etc.

Robotics is not the only possible application field to our researches. In the past, we were interested in applying visual servoing in computer animation, either for controlling the motions of virtual humanoids according to their pseudo-perception, or for controlling the point of view of visual restitution of an animation. In both cases, potential applications are in the field of virtual reality, for example for the design of video games, or virtual cinematography.

Applications also exist in computer vision and augmented reality. It is then a question of carrying out a virtual visual servoing for the 3D localization of a tool with respect to the vision sensor, or for the estimation of its 3D motion. This field of application is very promising, because it is in full rise for the realization of special effects in the multi-media field or for the design and the inspection of objects manufactured in the industrial world.

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

# 4. Application Domains

## 4.1. Asset management in the entertainement business

Regardless of the ingestion and storage issues, media asset management—archiving, describing and retrieving multimedia content—has turned into a key factor and a huge business for content and service providers. Most content providers, with television channels at the forefront, rely on multimedia asset management systems to annotate, describe, archive and search for content. So do archivists such as the Institut National de l'Audiovisuel, the Nederlands Instituut voor Beeld en Geluid or the British Broadcast Corporation, as well as media monitoring companies, such as Yacast in France. Protecting copyrighted content is another aspect of media asset management.

## 4.2. Multimedia Internet

One of the most visible application domains of linked multimedia content is that of multimedia portals on the Internet. Search engines now offer many features for image and video search. Video sharing sites also feature search engines as well as recommendation capabilities. All news sites provide multimedia content with links between related items. News sites also implement content aggregation, enriching proprietary content with user-generated content and reactions from social networks. Most public search engines and Internet service providers offer news aggregation portals.

## 4.3. Multiscreen TV

The convergence between television and the Internet has accelerated significantly over the past few years, with the democratization of TV on-demand and replay services and the emergence of social TV services and multiscreen applications. These evolutions and the ever growing number of innovative applications incurred offer a unique playground for multimedia technologies. Recommendation plays a major role in connected TV. Enriching multimedia content, with explicit links targeting either multimedia material or knowledge databases, appears as a key feature in this context, at the core of rich TV and second screen applications.

## 4.4. E-learning

On-line courses are rapidly gaining interest with the recent movement for massive open on-line courses (MOOCs). Such courses usually aggregate multimedia material, such as a video of the course with handouts and potentially text books, exercises and other related resources. This setting is very similar to that of the media aggregation sites though in a different domain. Automatically analyzing and describing video and textual content, synchronizing all material available across modalities, creating and characterizing links between related material or between different courses are all necessary features for on-line courses authoring.

<h2 style="text-align:center;color:red;">MIMETIC Project-Team</h2>

# 4. Application Domains

## 4.1. Autonomous Characters

Autonomous characters are becoming more and more popular has they are used in an increasing number of application domains. In the field of special effects, virtual characters are used to replace secondary actors and generate highly populated scenes that would be hard and costly to produce with real actors. In video games and virtual storytelling, autonomous characters play the role of actors that are driven by a scenario. Their autonomy allows them to react to unpredictable user interactions and adapt their behavior accordingly. In the field of simulation, autonomous characters are used to simulate the behavior of humans in different kind of situations. They enable to study new situations and their possible outcomes.

One of the main challenges in the field of autonomous characters is to provide a unified architecture for the modeling of their behavior. This architecture includes perception, action and decisional parts. This decisional part needs to mix different kinds of models, acting at different time scale and working with different nature of data, ranging from numerical (motion control, reactive behaviors) to symbolic (goal oriented behaviors, reasoning about actions and changes).

In the MimeTIC team, we focus on autonomous virtual humans. Our problem is not to reproduce the human intelligence but to propose an architecture making it possible to model credible behaviors of anthropomorphic virtual actors evolving/moving in real time in virtual worlds. The latter can represent particular situations studied by psychologists of the behavior or to correspond to an imaginary universe described by a scenario writer. The proposed architecture should mimic all the human intellectual and physical functions.

## 4.2. Biomechanics and Motion Analysis

Biomechanics is obviously a very large domain. This large set can be divided regarding to the scale at which the analysis is performed going from microscopic evaluation of biological tissues' mechanical properties to macroscopic analysis and modeling of whole body motion. Our topics in the domain of biomechanics mainly lie within this last scope.

The first goal of such kind of research projects is a better understanding of human motion. The MimeTic team addresses three different situations: everyday motions of a lambda subject, locomotion of pathological subjects and sports gesture.

In the first set, Mimetic is interested in studying how subjects maintain their balance in highly dynamic conditions. Until now, balance havec nearly always been considered in static or quasi-static conditions. The knowledge of much more dynamic cases still has to be improved. Our approach has demonstrated that first of all, the question of the parameter that will allow to do this is still open. We have also taken interest into collision avoidance between two pedestrian. This topic includes the research of the parameters that are interactively controlled and the study of each one's role within this interaction.

When patients, in particular those suffering from central nervous system affection, cannot have an efficient walking it becomes very useful for practicians to benefit from an objective evaluation of their capacities. To propose such help to patients following, we have developed two complementary indices, one based on kinematics and the other one on muscles activations. One major point of our research is that such indices are usually only developed for children whereas adults with these affections are much more numerous.

Finally, in sports, where gesture can be considered, in some way, as abnormal, the goal is more precisely to understand the determinants of performance. This could then be used to improve training programs or devices. Two different sports have been studied: the tennis serve, where the goal was to understand the contribution of each segments of the body in ball's speed and the influence of the mechanical characteristics of the fin in fin swimming.

After having improved the knowledge of these different gestures a second goal is then to propose modeling solutions that can be used in VR environments for other research topics within MimeTic. This has been the case, for exemple, for the colision avoidance.

## 4.3. Crowds

Crowd simulation is a very active and concurrent domain. Various disciplines are interested in crowds modeling and simulation: Mathematics, Cognitive Sciences, Physics, Computer Graphics, etc. The reason for this large interest is that crowd simulation raise fascinating challenges.

At first, crowd can be first seen as a complex system: numerous local interactions occur between its elements and results into macroscopic emergent phenomena. Interactions are of various nature and are undergoing various factors as well. Physical factors are crucial as a crowd gathers by definition numerous moving people with a certain level of density. But sociological, cultural and psychological factors are important as well, since crowd behavior is deeply changed from country to country, or depending on the considered situations. On the computational point of view, crowd push traditional simulation algorithms to their limit. An element of a crowd is subject to interact with any other element belonging the same crowd, a naive simulation algorithm has a quadratic complexity. Specific strategies are set to face such a difficulty: level-of-detail techniques enable scaling large crowd simulation and reach real-time solutions.

MimeTIC is an international key contributor in the domain of crowd simulation. Our approach is specific and based on three axis. First, our modeling approach is founded on human movement science: we conducted challenging experiment on the motion of groups. Second: we developed high-performance solutions for crowd simulation. Third, we develop solutions for realistic navigation in virtual world to enable interaction with crowds in Virtual Reality.

## 4.4. Motion Sensing

Recording human activity is a key point of many applications and fundamental works. Numerous sensors and systems have been proposed to measure positions, angles or accelerations of the user's body parts. Whatever the system is, one of the main is to be able to automatically recognize and analyze the user's performance according to poor and noisy signals. Human activity and motion are subject to variability: intra-variability due to space and time variations of a given motion, but also inter-variability due to different styles and anthropometric dimensions. MimeTIC has addressed the above problems in two main directions.

Firstly, we have studied how to recognize and quantify motions performed by a user when using accurate systems such as Vicon (product of Oxford Metrics) or Optitrack (product of Natural Point) motion capture systems. These systems provide large vectors of accurate information. Due to the size of the state vector (all the degrees of freedom) the challenge is to find the compact information (named features) that enables the automatic system to recognize the performance of the user. Whatever the method is used, finding these relevant features that are not sensitive to intra-individual and inter-individual variability is a challenge. Some researchers have proposed to manually edit these features (such as a Boolean value stating if the arm is moving forward or backward) so that the expertise of the designer is directly linked with the success ratio. Many proposals for generic features have been proposed, such as using Laban notation which was introduced to encode dancing motions. Other approaches tend to use machine learning to automatically extract these features. However most of the proposed approaches were used to seek a database for motions which properties correspond to the features of the user's performance (named motion retrieval approaches). This does not ensure the retrieval of the exact performance of the user but a set of motions with similar properties.

Secondly, we wish to find alternatives to the above approach which is based on analyzing accurate and complete knowledge on joint angles and positions. Hence new sensors, such as depth-cameras (Kinect, product of Microsoft) provide us with very noisy joint information but also with the surface of the user. Classical approaches would try to fit a skeleton into the surface in order to compute joint angles which, again, lead to large state vectors. An alternative would be to extract relevant information directly from the raw data, such as the surface provided by depth cameras. The key problem is that the nature of these data may be very different

from classical representation of human performance. In MimeTIC, we try to address this problem in specific application domains that require picking specific information, such as gait asymmetry or regularity for clinical analysis of human walking.

## 4.5. VR and Sports

Sport is characterized by complex displacements and motions. These motions are dependent on visual information that the athlete can pick up in his environment, including the opponent's actions. The perception is thus fundamental to the performance. Indeed, a sportive action, as unique, complex and often limited in time, requires a selective gathering of information. This perception is often seen as a prerogative for action, it then takes the role of a passive collector of information. However, as mentioned by Gibson in 1979, the perception-action relationship should not be considered sequential but rather as a coupling: we perceive to act but we must act to perceive. There would thus be laws of coupling between the informational variables available in the environment and the motor responses of a subject. In other words, athletes have the ability to directly perceive the opportunities of action directly from the environment. Whichever school of thought considered, VR offers new perspectives to address these concepts by complementary using real time motion capture of the immersed athlete.

In addition to better understanding sports and interaction between athletes, VR can also be used as a training environment as it can provide complementary tools to coaches. It is indeed possible to add visual or auditory information to better train an athlete. The knowledge found in perceptual experiments can be for example used to highlight the body parts that are important to look at to correctly anticipate the opponent's action.

## 4.6. Interactive Digital Storyrelling

Interactive digital storytelling, including novel forms of edutainment and serious games, provides access to social and human themes through stories which can take various forms and contains opportunities for massively enhancing the possibilities of interactive entertainment, computer games and digital applications. It provides chances for redefining the experience of narrative through interactive simulations of computer-generated story worlds and opens many challenging questions at the overlap between computational narratives, autonomous behaviours, interactive control, content generation and authoring tools.

Of particular interest for the Mimetic research team, virtual storytelling triggers challenging opportunities in providing effective models for enforcing autonomous behaviours for characters in complex 3D environments. Offering both low-level capacities to characters such as perceiving the environments, interacting with the environment and reacting to changes in the topology, on which to build higher-levels such as modelling abstract representations for efficient reasonning, planning paths and activities, modelling cognitive states and behaviours requires the provision of expressive, multi-level and efficient computational models. Furthermore virtual storytelling requires the seamless control of the balance between the autonomy of characters and the unfolding of the story story through the narrative discourse. Virtual storytelling also raises challenging questions on the conveyance of a narrative through interactive or automated control of the cinematography (how to stage the characters, the lights and the cameras). For example, estimating visibility of key subjects, or performing motion planning for cameras and lights are central issues for which have not received satisfactory answers in the litterature.

## 4.7. VR and Ergonomics

The design of workstations nowadays tends to include assessment steps in a Virtual Environment (VE) to evaluate ergonomic features. This approach is more cost-effective and convenient since working directly on the Digital Mock-Up (DMU) in a VE is preferable to constructing a real physical mock-up in a Real Environment (RE). This is substantiated by thefact that a Virtual Reality (VR) set-up can be easily modified, enabling quick adjustmentsofthe workstation design.Indeed, the aim of integrating ergonomics evaluation tools inVE is to facilitate the design process, enhance the design efficiency, and reduce the costs.

The development of such platforms ask for several improvements in the field of motion analysis and VR: the interactions have to be as fidelistic as possible to properly mimic the motions performed in real environments, the fidelity of the simulator need also to be correctly evaluated, and motion analysis tools have to be able to provide in real-time biomechanics quantities usable by ergonomists to analyse and improve the working conditions.

# MYRIADS Project-Team  (section vide)

<span style="color:red">**PANAMA Project-Team**</span>

# 4. Application Domains

## 4.1. Acoustic scene capture

Acoustic fields carry much information about audio sources (musical instruments, speakers, etc.) and their environment (e.g., church acoustics differ much from office room acoustics). A particular challenge is to capture as much information from a complete 3D+t acoustic field associated with an audio scene, using as few sensors as possible. The feasibility of compressive sensing to address this challenge was shown in certain scenarii, and the actual implementation of this framework will potentially impact practical scenarii such as remote surveillance to detect abnormal events, e.g. for health care of the elderly or public transport surveillance.

## 4.2. Audio signal separation in reverberant environments

Audio signal separation consists in extracting the individual sound of different instruments or speakers that were mixed on a recording. It is now successfully addressed in the academic setting of linear instantaneous mixtures. Yet, real-life recordings, generally associated to reverberant environments, remain an unsolved difficult challenge, especially with many sources and few audio channels. Much of the difficulty comes from the estimation of the unknown room impulse response associated to a matrix of mixing filters, which can be expressed as a dictionary-learning problem. Solutions to this problem have the potential to impact, for example, the music and game industry, through the development of new digital re-mastering techniques and virtual reality tools, but also surveillance and monitoring applications, where localizing audio sources is important.

## 4.3. Multimedia indexing

Audiovisual and multimedia content generate large data streams (audio, video, associated data such as text, etc.). Manipulating large databases of such content requires efficient techniques to: segment the streams into coherent sequences; label them according to words, language, speaker identity, and more generally to the type of content; index them for easy querying and retrieval, etc. As the next generation of online search engines will need to offer content-based means of searching, the need to drastically reduce the computational burden of these tasks is becoming all the more important as we can envision the end of the era of wasteful datacenters that can increase forever their energy consumption. Most of today's techniques to deal with such large audio streams involve extracting features such as Mel Frequency Cepstral Coefficients (MFCC) and learning high-dimensional statistical models such as Gaussian Mixture Models, with several thousand parameters. The exploration of a compressive learning framework is expected to contribute to new techniques to efficiently process such streams and perform segmentation, classification, etc., in the compressed domain. A particular challenge is to understand how this paradigm can help exploiting truly multimedia features, which combine information from different associated streams such as audio and video, for joint audiovisual processing.

## 4.4. Brain source imaging

Epilepsies constitute a common neurological disorder that affects about 1% of the world population. As the epileptic seizure is a dynamic phenomenon, imaging techniques showing static images of the brain (MRI, PET scan) are frequently not the best tools to identify the brain area of interest. Electroencephalography (EEG) is the technique most indicated to capture transient events directly related to the underlying epileptic pathology (like interictal spikes, in particular). EEG convey essential information regarding brain (patho-)physiological activity. In addition, recording techniques of surface signals have the major advantage of being noninvasive. For this reason, an increased use in the context of epilepsy surgery is most wanted. However, to

reach this objective, we have to solve an electromagnetic inverse problem, that is to say to estimate the current generators underlying noisy EEG data. Theoretically, a specific electromagnetic field pattern may be generated by an infinite number of current distributions. The considered inverse problem, called "brain source imaging problem", is then said to be ill-posed.

<span style="color:red">**SAGE Project-Team**</span>

# 4. Application Domains

## 4.1. Geophysics

The team has chosen a particular domain of application, which is geophysics. In this domain, many problems require solving large scale systems of equations, arising from the discretization of coupled models. Emphasis is put on hydrogeology, but the team also investigates geodesy, heat and mass transfer in soil, and granular materials. One of the objectives is to use high performance computing in order to tackle 3D large scale computational domains with complex physical models.

## 4.2. Hydrogeology

This is joint work with Geosciences Rennes at OSUR, Pprime at University of Poitiers and CDCSP at University of Lyon. It is also done in the context of the group Momas and previous Andra grants.

Many environmental studies rely on modelling geo-chemical and hydrodynamic processes. Some issues concern water resources, aquifer contamination, underground waste disposal, clean-up of former waste deposits, acid mine drainage remediation. Other issues, also related to energy, concern geothermy, unconventional gas, enhanced oil recovery, underground storage of $CO_2$, underground storage of nuclear waste.

Simulation of contaminant transport in groundwater is a highly complex problem, governed by coupled linear or nonlinear PDAEs. Moreover, due to the lack of experimental data, stochastic models are used for dealing with heterogeneity. The main objective of the team is to design and to implement efficient and robust numerical models, including Uncertainty Quantification methods.

Recent research showed that rock solid masses are in general fractured and that fluids can percolate through networks of inter-connected fractures. Fractured media are by nature very heterogeneous and multi-scale, so that homogenisation approaches are not relevant. The team develops a numerical model for fluid flow and contaminant transport in three-dimensional porous fractured media.

An important output is the parallel scientific platform H2OLab, running on clusters, grids and machines available in supercomputing centers.

<p align="center"><span style="color:red"><b>SERPICO Project-Team</b></span></p>

# 4. Application Domains

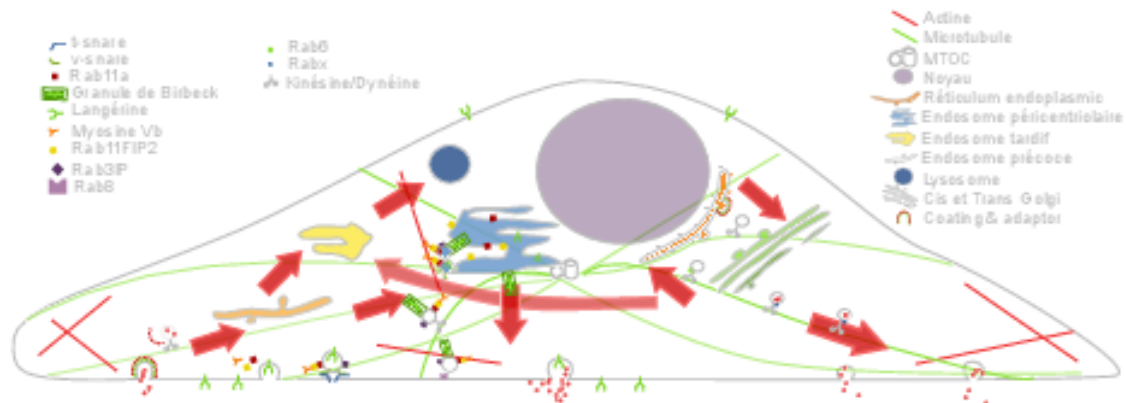## 4.1. Biological pilot models: Birbeck granule and Melanosome biogenesis



*Figure 1. Cargo Langerin Trafficking controlled by Rab11A/Rab11FIP2/MyoVb platform.*

In the past recent years, research carried at UMR 144 CNRS-Institut Curie ("Space Time imaging of Endomembranes and organelles Dynamics" (STED) team) contributed to a better understanding of the intracellular compartimentation of specialized model cells such as melanocytes and Langerhans cells, the components and structural events involved in the biogenesis of their specialized organelles: melanosomes and Birbeck granules, respectively. These studies have started to highlight: i) multiple sorting and structural events involved in the biogenesis of these organelles; ii) complexity of the endo-melanosomal network of these highly specialized cells; iii) complex molecular architecture organizing and coordinating their dynamics; iv) intracellular transport steps affected in genetic diseases, among which the Hermansky Pudlak syndrome (HPS) or involved in viral infection (HIV and Langerin in Langerhans cells).

In this context, the central aim of SERPICO is to understand how the different machineries of molecular components involved are interconnected and coordinated to generate such specialized structures. We need to address the following topics:

1. developing new bioimaging approaches to observe and statistically analyze such coordinated dynamics in live material;

2. correlating this statistically relevant spatiotemporal organization of protein networks with the biological architectures and at the ultrastructural level;

3. modeling intracellular transport of those reference biological complex systems and proposing new experimental plans in an iterative and virtuous circle;

4. managing and analyzing the workflow of image data obtained along different multidimensional microscopy modalities.

These studies are essential to unravel the complexity of the endomembrane system and how different machineries evolve together (e.g. see Fig. 1 ). They help to control cell organization and function at different scales through an integrative workflow of methodological and technological developments.

At long term, these studies will shed light on the cellular and molecular mechanisms underlying antigen presentation, viral infection or defense mechanisms, skin pigmentation, the pathogenesis of hereditary genetic disorders (lysosomal diseases, immune disorders) and on the mechanisms underlying cell transformation. Our methodological goal is also to link dynamics information obtained through diffraction limited light microscopy, eventually at a time regime compatible with live cell imaging. The overview of ultrastructural organization will be achieved by complementary electron microscopical methods. Image visualization and quantitative analysis are of course important and essential issues in this context.

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

# 4. Application Domains

## 4.1. Introduction

The application domains addressed by the project are:

- Compression with advanced functionalities of various image modalities (including multi-view, medical images such as MRI, CT, WSI, or satellite images);
- Networked multimedia applications via their various needs in terms of image and 2D and 3D video compression, or in terms of network adaptation (e.g., resilience to channel noise);
- Content editing and post-production.

## 4.2. Compression with advanced functionalities

Compression of images and of 2D video (including High Definition and Ultra High Definition) remains a widely-sought capability for a large number of applications. This is particularly true for mobile applications, as the need for wireless transmission capacity will significantly increase during the years to come. Hence, efficient compression tools are required to satisfy the trend towards mobile access to larger image resolutions and higher quality. A new impulse to research in video compression is also brought by the emergence of new formats beyond High Definition TV (HDTV) towards high dynamic range (higher bit depth, extended colorimetric space), super-resolution, formats for immersive displays allowing panoramic viewing and 3DTV.

Different video data formats and technologies are envisaged for interactive and immersive 3D video applications using omni-directional videos, stereoscopic or multi-view videos. The "omni-directional video" set-up refers to 360-degree view from one single viewpoint or spherical video. Stereoscopic video is composed of two-view videos, the right and left images of the scene which, when combined, can recreate the depth aspect of the scene. A multi-view video refers to multiple video sequences captured by multiple video cameras and possibly by depth cameras. Associated with a view synthesis method, a multi-view video allows the generation of virtual views of the scene from any viewpoint. This property can be used in a large diversity of applications, including Three-Dimensional TV (3DTV), and Free Viewpoint Video (FTV). The notion of "free viewpoint video" refers to the possibility for the user to choose an arbitrary viewpoint and/or view direction within a visual scene, creating an immersive environment. Multi-view video generates a huge amount of redundant data which need to be compressed for storage and transmission. In parallel, the advent of a variety of heterogeneous delivery infrastructures has given momentum to extensive work on optimizing the end-to-end delivery QoS (Quality of Service). This encompasses compression capability but also capability for adapting the compressed streams to varying network conditions. The scalability of the video content compressed representation and its robustness to transmission impairments are thus important features for seamless adaptation to varying network conditions and to terminal capabilities.

## 4.3. Networked visual applications

*3D and Free Viewpoint TV:* The emergence of multi-view auto-stereoscopic displays has spurred a recent interest for broadcast or Internet delivery of 3D video to the home. Multiview video, with the help of depth information on the scene, allows scene rendering on immersive stereo or auto-stereoscopic displays for 3DTV applications. It also allows visualizing the scene from any viewpoint, for scene navigation and free-viewpoint TV (FTV) applications. However, the large volumes of data associated to multi-view video plus depth content raise new challenges in terms of compression and communication.

*Internet and mobile video:* Broadband fixed (ADSL, ADSL2+) and mobile access networks with different radio access technologies (RAT) (e.g. 3G/4G, GERAN, UTRAN, DVB-H), have enabled not only IPTV and Internet TV but also the emergence of mobile TV and mobile devices with internet capability. A major challenge for next internet TV or internet video remains to be able to deliver the increasing variety of media (including more and more bandwidth demanding media) with a sufficient end-to-end QoS (Quality of Service) and QoE (Quality of Experience).

*Mobile video retrieval:* The Internet has changed the ways of interacting with content. The user is shifting its media consumption from a passive to a more interactive mode, from linear broadcast (TV) to on demand content (YouTubes, iTunes, VoD), and to user-generated, searching for relevant, personalized content. New mobility and ubiquitous usage has also emerged. The increased power of mobile devices is making content search and retrieval applications using mobile phones possible. Quick access to content in mobile environments with restricted bandwidth resources will benefit from rate-efficient feature extraction and description.

*Wireless multi-camera vision systems:* Our activities on scene modelling, on rate-efficient feature description, distributed coding and compressed sensing should also lead to algorithmic building blocks relevant for wireless multi-camera vision systems, for applications such as visual surveillance and security.

## 4.4. Medical Imaging (CT, MRI, Virtual Microscopy)

The use of medical imaging has greatly increased in recent years, especially with *magnetic resonance images (MRI) and computed tomography (CT)*. In the medical sector, lossless compression schemes are in general used to avoid any signal degradation which could mask a pathology and hence disturb the medical diagnosis. Nevertheless, some discussions are on-going to use near-lossless coding of medical images, coupled with a detection and segmentation of region-of interest (ROIs) guided by a modeling stage of the image sensor, by a precise knowledge of the medical imaging modalities and by the diagnosis and expertise of practitioners. New application domains using these new approaches of telemedicine will surely increase in the future. The second aspect deals with the legal need of biomedical images storage. The legacy rules of such archives are changing and it could be interesting to propose adaptive compression strategies, i.e to explore reversible lossy-to-lossless coding algorithms and new storage modalities which use, in a first stage, the lossless representation and continuously introduce controlled lossy degradations for the next stages of archives. Finally, it seems promising to explore new representation and coding approaches for 3D biological tissue imaging captured by *3D virtual microscopy*. These fields of interest and scientific application domains commonly generate terabytes of data. Lossless schemes but also lossy approaches have to be explored and optimized, and interactive tools supporting scalable and interactive access to large-sized images such as these virtual microscopy slides need to be developed.

## 4.5. Editing and post-production

Video editing and post-production are critical aspects in the audio-visual production process. Increased ways of "consuming" video content also highlight the need for content repurposing as well as for higher interaction and editing capabilities. Content captured at very high resolutions may need to be repurposed in order to be adapted to the requirements of actual users, to the transmission channel or to the terminal. Content repurposing encompasses format conversion (retargeting), content summarization, and content editing. This processing requires powerful methods for extracting condensed video representations as well as powerful inpainting techniques. By providing advanced models, advanced video processing and image analysis tools, more visual effects, with more realism become possible. Other applications such as video annotation/retrieval, video restoration/stabilization, augmented reality, can also benefit from the proposed research.

<span style="color:red">**SUMO Project-Team**</span>

# 4. Application Domains

## 4.1. Telecommunication network management

The domain of autonomic network management, will remain an important playground for SUMO. It covers a wide variety of problems, ranging from distributed (optimal) control to distributed diagnosis, optimization, reconfiguration, provisioning, etc. We have a long experience in model-based diagnosis, in particular distributed (active) diagnosis, and have recently proposed promising techniques for self-modeling. It consists in building the model of the managed network on the fly, guided by the needs of the diagnosis algorithm. This approach allows one to deal with potentially huge models, that are only described by their construction grammar, and discovered at runtime. Another important research direction concerns the management of "multi-resolution" models, that can be considered at different granularity levels. This feature is central to network design, but has no appropriate modeling formalism nor management approaches. This is a typical investigation field for abstraction techniques. Technology is ahead of theory in this domain since networks are already driven or programmed through management policies, that assign high level objectives to an abstract view of the network, leaving open the question of their optimal implementation. As a last topic of investigation, today management issues are no longer isolated within one operator, but range accross several of them, up to the supported services, which brings game theory aspects into the picture.

## 4.2. Control of data centers

Data centers are another example of a large scale reconfigurable and distributed system: they are composed of thousands of servers on which Virtual Machines (VM) can be (de)activated, migrated, etc. depending on the requests of the customers, on the load of the servers and on the power consumption. Autonomic management functionalities already exist to deploy and configure applications in such a distributed environment. They can also monitor the environment and react to events such as failures or overloads and reconfigure applications and/or infrastructures accordingly and autonomously. To supervise these systems, Autonomic Managers (AM) can be deployed in order to apply administration policies of specific aspects to the different entities of a data center (servers, VM, web services, power supply, etc). These AMs may be implemented in different layers: the hardware level, the operating system level or the middleware level. Therefore several control loops may coexists, and they have to take globally consistent decisions to manage the trade-off between availability, performance, scalability, security and energy consumption. This leads to multi-criteria optimization and control problems in order to automatically derive controllers in charge of the coordination of the different AMs. We are relatively new on this topic, that will require more technical investment from us. But we are driven to it by both the convergence of IT and networking, by virtualization techniques that reach networks (see the growing research effort about network operating systems), and by the call for more automation in the management of clouds. We believe our experience in network management can help. Some members of SUMO are already involved in the ANR Ctrl-Green, which addresses the controller coordination problem. We are also in contact with the Myriads team, which research interests moved from OS for grids/clouds to autonomic methods. This is supported as well by the activities of b<>com, the local IRT, where some projects in cloud management and in networking may start joint activities.

## 4.3. Web services and distributed active documents

Data centric systems are already deployed, and our goal is not to design new languages, architectures, or standards for them, but rather to propose techniques for the verification and monitoring of the existing systems. A bottleneck is the complexity and heterogeneity of web-based systems, that make them difficult to model and analyze. However, one can still hope for some lightweight verification or monitoring techniques for some specific aspects, for example to check the absence of conflict of interest in a transaction system, to verify

(off line) and maintain (on line) the QoS, to prevent security breaches, etc. Safety aspects of WS are little addressed; any progress in that area would be useful. Besides, modeling issues are central for some applications of data centric systems. Collaborative work environments with shared active documents can be found in many domains ranging from banking, maintenance of critical systems, webstores... We consider that models for data driven systems can find applications in most of these application areas. Our approach will be to favor purely declarative approaches for the specification of such collaborative environments. We have contacts with Centre Pasteur in Yaoundé on the design of diseases monitoring systems in developing countries. Diseases monitoring systems can be seen as a collaborative edition work, where each actor in the system reports and aggregates information about cases he or she is aware of. This collaboration is an opportunity to confront our models to real situations and real users needs. Formally modeling such a large distributed system can be seen as a way to ensure its correctness. We also envision to promote this approach as a support for maintenance operations in complex environments (train transportation, aeronautics,...). We believe this framework can be useful both for the specification of distributed maintenance procedures, for circulating information and sharing processes across teams, but also for the analysis of the correctness of procedures, possibly for their optimization or redesign, and finally to automatically elaborate logs of maintenance operations. We are in contact with several major companies on these topics, for the maintenance application side. Other industrial contacts need to be built: we have preliminary contact with IBM (leader in business artifacts), and would like to establish relations with SAP (leader in service architectures).

<span style="color:red">**TACOMA Team**</span>

# 4. Application Domains

## 4.1. Pervasive applications in Smart Home

A smart home is a residence equipped with information-and-communication-technology (ICT) devices conceived to collaborate in order to anticipate and respond to the needs of the occupants, working to promote their comfort, convenience, security and entertainment while preserving their natural interaction with the environment.

The idea of using the Ubiquitous Computing paradigm in the smart home domain is not new. However, the state-of-the-art solutions only partially adhere to its principles. Often the adopted approach consists in a heavy deployment of sensor nodes, which continuously send a lot of data to a central elaboration unit, in charge of the difficult task of extrapolating meaningful information using complex techniques. This is a *logical approach*. TACOMA proposed instead the adoption of a *physical approach*, in which the information is spread in the environment, carried by the entities themselves, and the elaboration is directly executed by these entities "inside" the physical space. This allows performing meaningful exchanges of data that will thereafter need a less complicate processing compared to the current solutions. The result is a smart home that can, in an easier and better way, integrate the context in its functioning and thus seamlessly deliver more useful and effective user services. Our contribution aims at implementing the physical approach in a domestic environment, showing a solution for improving both comfort and energy savings.

## 4.2. Metamorphic House

The motivation for metamorphic houses is that many countries, including France, are going through socio-demographic evolutions, like growth of life expectancy and consequent increase in the number of elderly people, urbanization and resource scarcity. Households experience financial restrictions, while housing costs increase with the raise of real estate and energy prices [5].

Important questions arise concerning the future of housing policies and ways of living. We observe novel initiatives like participative housing and developing behaviors, including house-sharing, teleworking and longer stay of children in parents' homes.

To tackle the challenges raised by these emerging phenomena, future homes will have to be modular, upgradeable, comfortable, sparing of resources. They should be integrated in the urban context and exchange information with other homes, contribute to reducing the distances to be covered daily and respect the characteristics of the territory where they are located.

To reach these goals, metamorphic domestic environments will modify their shape and behavior to support activities and changes in life cycle of occupants, increase comfort and optimize the use of resources. Thanks to Information and Communication Technologies (ICT) and adaptive building elements, the same physical spaces will be transformed for different uses, giving inhabitants the illusion of living in bigger, more adapted and more comfortable places.

## 4.3. Pervasive applications in uncontrolled environnements

Some limitations of existing RFID technology become challenging: unlike standard RFID application scenarios, pervasive computing often involves uncontrolled environment for RFID, where tags and reader have to operate in much more difficult situations that those usually encountered or expected for classical RFID systems.

RFID technology is to avoid missing tags when reading multiple objects, as reading reliability is affected by various effects such shadowing or wave power absorption by some materials. The usual applications of RFID operate in a controlled environment in order to reduce the risk of missing tags while scanning objects.

In pervasive computing applications, a controlled reading environment is extremely difficult to achieve, as one of the principle is to enhance existing processes "in situ", unlike the controlled conditions that can be found in industrial processes. Consider for example a logistic application, where RFID tags could be used on items inside a package in order to check for its integrity along the shipping process. Tags would likely be placed randomly on items inside the package, and reading conditions would be variable depending on where the package is checked.

RFID operation in uncontrolled environments is challenging because RFID performance is affected by multiple parameters, in particular:

- Objects materials (on which tags are attached to),

- Materials in the surrounding environment,

- RFID frequency spectrum,

- Antenna nature and placement with respect to the tags.

In controlled environment, the difficulty to read tags can be limited by using the appropriate parameters to maximize the RFID performance for the application. But in many cases, it is needed to read large number of objects of various nature, arranged randomly in a given area or container. Most pervasive computing applications fall in this context. At the software level, RFID inventory reliability issue is usually addressed by anti-collisions mechanisms and redundancy mechanisms. Anti-collisions protocols limit the risk of data corruption when multiples tags have to reply to an inventory request. Redundancy is often implemented in RFID readers by aggregating the results of multiple inventory requests over a time frame, to give the tags multiple opportunities to reply. While useful, these strategies cannot ensure that a given inventory is valid or not (in other words, one or more tags may be missing without being noticed).

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

# 4. Application Domains

## 4.1. Introduction

Constraint programming deals with the resolution of decision problems by means of rational, logical and computational techniques. Above all, constraint programming is founded on a clear distinction between, on the one hand the description of the constraints intervening in a problem, and on the other hand the techniques used for the resolution. The ability of constraint programming to handle in a flexible way heterogeneous constraints has raised the commercial interest for this paradigm in the early nighties. Among his fields of predilection, one finds traditional applications such as computer aided decision-making, scheduling, planning, placement, logistics or finance, as well as applications such as electronic circuits design (simulation, checking and test), DNA sequencing and phylogeny in biology, configuration of manufacturing products or web sites, formal verification of code.

## 4.2. Panorama

In 2014 the TASC team was involved in the following application domains:

- *Replanning* in industrial timetabling problems in a Labcom project with Eurodécision.
- *Planning and replanning* in Data Centres taking into account energy consumption in the EPOC (Energy Proportional and Opportunistic Computing system) project.
- *Packing complex shapes* in the context of a warehouse (NetWMS2 project).
- Building decision support system for *city development planning with evaluation of energy impacts* (SUSTAINS project).
- *Optimizing electricity production* in the context of the Gaspard Monge call program for Optimisation and Operation Research. We extract global constraints from daily energy production temporal series issued from all productions plants of EDF.

<span style="color:red">**TEA Project-Team**</span>

# 4. Application Domains

## 4.1. Application Domains

From our continuous collaboration with major academic and industrial partners through projects TOPCASED, OPENEMBEDD, SPACIFY, CESAR, OPEES, P and CORAIL, our experience has primarily focused on the aerospace domain. The topics of time and architecture of team TEA extend to both avionics and automotive, as demonstrated from this section to section 8. Yet, the research focus on time in team TEA is central in any aspect of, cyber-physical, embedded system design in automotive, music synthesis, signal processing, software radio, circuit and system on a chip design; many application domains which, should more collaborators join the team, would definitely be worth investigating.

Nonetheless, the application domains of our two direct collaborations with industry, avionics with Thales and automotive Toyota, are perfectly in line with the research objectives of team TEA and will allow us to quickly stream our theoretical results onto software and standards, which we will continue to distribute in open-source.

Multi-scale, multi-aspect time modelling, analysis and software synthesis will greatly contribute to architecture modelling in these domains, with applications to optimised (distributed, parallel, multi-core) code generation for avionics (our project with Thales avionics, section 8) as well as modelling standards, real-time simulation and virtual integration in automotive (our project with Toyota, section 8).

Together with the importance of open-source software, one of these project, the FUI Project P, demonstrated that a centralised model for system design could not just be a domain-specific programming language, such as discrete Simulink data-flows or a synchronous language. Synchronous languages implement a fixed model of time using logical clocks that are abstraction of time as sensed by software. They correspond to a fixed viewpoint in system design, and in a fixed hardware location in the system, which is not adequate to our purpose and must be extended.

In project P, we first tried to define a centralised model for importing discrete-continuous models onto a simplified implementation of SIMULINK: P models. Certified code generators would then be developed from that format. Because this does not encompass all aspects being translated to P, the P meta-model is now being extended to architecture description concepts (of the AADL) in order to become better suited for the purpose of system design. Another example is the development of System Modeller on top of SCADE, which uses the more model-engineering flavoured formalism SysML to try to unambiguously represent architectures around SCADE modules.

An abstract specification formalism, capable of representing time, timing relations, with which heterogeneous models can be abstracted, from which programs can be synthesised, naturally appears better suited for the purpose of virtual prototyping. RT-Builder, developed by TNI, was industrially proven and deployed for that purpose at Peugeot. It served to develop the virtual platform simulating all onboard electronics of PSA cars. This 'hardware in the loop" simulator was used to test equipments supplied by other manufacturers with respect to virtual cars. In the avent of the related automotive standard, RT-Builder then became AUTOSAR-Builder.

RT-Builder is the commercial implementation of Signal, whose industrial transfer with TNI was realised in the 90s by Paul Le Guernic and Albert Benveniste. As its actual industry usage has demonstrated, it is clear that the synchronous multi-clocked, or polychronous MoCC of Signal is an appropriate semantic core for the design of embedded software architectures.

<div align="center">

**VISAGES Project-Team**

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# 4. Application Domains

## 4.1. Neuroimaging

*neuroimaging, clinical neuroscience, multiple sclerosis, multispectral MRI, brain atlas*

One research objective in neuroimaging is the construction of anatomical and functional cerebral maps under normal and pathological conditions.

Many researches are currently performed to find correlations between anatomical structures, essentially sulci and gyri, where neuronal activation takes place, and cerebral functions, as assessed by recordings obtained by the means of various neuroimaging modalities, such as PET (Positron Emission Tomography), fMRI (Functional Magnetic Resonance Imaging), EEG (Electro-EncephaloGraphy) and MEG (Magneto-EncephaloGraphy). Then, a central problem inherent to the formation of such maps is to put together recordings obtained from different modalities and from different subjects. This mapping can be greatly facilitated by the use of MR anatomical brain scans with high spatial resolution that allows a proper visualization of fine anatomical structures (sulci and gyri). Recent improvements in image processing techniques, such as segmentation, registration, delineation of the cortical ribbon, modeling of anatomical structures and multi-modality fusion, make possible this ambitious goal in neuroimaging. This problem is very rich in terms of applications since both clinical and neuroscience applications share similar problems. Since this domain is very generic by nature, our major contributions are directed towards clinical needs even though our work can address some specific aspects related to the neuroscience domain.

## 4.2. Multiple sclerosis

Over the past years, a discrepancy became apparent between clinical Multiple sclerosis (MS) classification describing on the one hand MS according to four different disease courses and, on the other hand, the description of two different disease stages (an early inflammatory and a subsequently neurodegenerative phase). It is to be expected that neuroimaging will play a critical role to define *in vivo* those four different MS lesion patterns. An *in vivo* distinction between the four MS lesion patterns, and also between early and late stages of MS will have an important impact in the future for a better understanding of the natural history of MS and even more for the appropriate selection and monitoring of drug treatment in MS patients. MRI has a low specificity for defining in more detail the pathological changes which could discriminate between the different lesion types. However, it has a high sensitivity to detect focal and also widespread, diffuse pathology of the normal appearing white and gray matter. Our major objective within this application domain is then to define new neuroimaging markers for tracking the evolution of the pathology from high dimensional data (e.g. nD+t MRI). In addition, in order to complement MR neuroimaging data, we ambition to perform also cell labeling neuroimaging (e.g. MRI or PET) and to compare MR and PET data using standard and experimental MR contrast agents and radiolabeled PET tracers for activated microglia (e.g. USPIO or PK 11195). The goal is to define and develop, for routine purposes, cell specific and also quantitative imaging markers for the improved *in vivo* characterization of MS pathology.

## 4.3. Modeling of anatomical and anatomo-functional neurological patterns

The major objective within this application domain is to build anatomical and functional brain atlases in the context of functional mapping and for the study of developmental, neurodegenerative or even psychiatric brain diseases (Multiple sclerosis, Epilepsy, Parkinson, Dysphasia, Depression or even Alzheimer). This is a very competitive research domain; our contribution is based on our previous works in this field, and by continuing our local and wider collaborations.

An additional objective within this application domain is to find new descriptors to study the brain anatomy and/or function (e.g. variation of brain perfusion, evolution in shape and size of an anatomical structure in relation with pathology or functional patterns, computation of asymmetries ...). This is also a very critical research domain, especially for many developmental or neurodegenerative brain diseases.