



RESEARCH CENTER

FIELD

**Perception, Cognition and Interaction**

Activity Report 2016

# Section Application Domains

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## DATA AND KNOWLEDGE REPRESENTATION AND PROCESSING

1. CEDAR Team	5
2. DAHU Project-Team	6
3. EXMO Project-Team	7
4. GRAPHIK Project-Team (section vide)	8
5. LACODAM Team	9
6. LINKS Project-Team	12
7. MAGNET Project-Team	13
8. ORPAILLEUR Project-Team	14
9. SMIS Project-Team	16
10. TYREX Project-Team	17
11. WIMMICS Project-Team	18
12. ZENITH Project-Team	21

## INTERACTION AND VISUALIZATION

13. ALICE Project-Team	23
14. AVIZ Project-Team	24
15. EX-SITU Team	25
16. GRAPHDECO Project-Team (section vide)	26
17. HYBRID Project-Team	27
18. ILDA Project-Team	28
19. IMAGINE Project-Team (section vide)	29
20. MANAO Project-Team	30
21. MAVERICK Project-Team	31
22. MIMETIC Project-Team	32
23. MINT Project-Team (section vide)	36
24. Mjolnir Team	37
25. POTIOC Project-Team	38
26. TITANE Project-Team	39

## LANGUAGE, SPEECH AND AUDIO

27. ALPAGE Project-Team (section vide)	40
28. MULTISPEECH Project-Team	41
29. PANAMA Project-Team	43
30. SEMAGRAMME Project-Team	44

## ROBOTICS AND SMART ENVIRONMENTS

31. CHROMA Team	45
32. DEFROST Team	47
33. FLOWERS Project-Team	49
34. HEPHAISTOS Project-Team	50
35. LAGADIC Project-Team	51
36. LARSEN Team	52
37. PERVERSIVE INTERACTION Team	53

38. RITS Project-Team .....	54
VISION, PERCEPTION AND MULTIMEDIA INTERPRETATION	
39. AYIN Team (section vide) .....	56
40. LINKMEDIA Project-Team .....	57
41. MAGRIT Project-Team .....	58
42. MORPHEO Project-Team .....	59
43. PERCEPTION Project-Team (section vide) .....	60
44. SIROCCO Project-Team .....	61
45. STARS Project-Team .....	63
46. THOTH Project-Team .....	65
47. WILLOW Project-Team .....	66

## **CEDAR Team**

# **4. Application Domains**

## **4.1. Computational Journalism**

Modern journalism increasingly relies on content management technologies in order to represent, store, and query source data and media objects themselves. Writing news articles increasingly requires consulting several sources, interpreting their findings in context, and crossing links between related sources of information. CEDAR research results directly applicable to this area provide techniques and tools for rich Web content warehouse management. This work will be funded by the ANR ContentCheck project, and a Google Award on Even Thread Extraction. We work in collaboration with Le Monde's "Les Décodeurs" team to investigate these topics.

## **4.2. Open Data Intelligence**

The Web is a vast source of information, to which more is added every day either in unstructured form (Web pages) or, increasingly, as partially structured sources of information, in particular as Open Data sets, which can be seen as connected graphs of data, most frequently described in the RDF data format recommended by the W3C. Further, RDF data is also the most appropriate format for representing structured information extracted automatically from Web pages, such as the DBpedia database extracted from Wikipedia or Google's InfoBoxes. We work on this topic within the 4-year project ODIN started in 2014.

## **4.3. Hybrid Data Warehousing**

Increasingly many modern applications need to exploit data from a variety of formats, including relations, text, trees, graphs etc. The recent development of data management systems aimed at "Big Data", including NoSQL platforms, large-scale distributed systems etc. provides enterprise architects with many systems to choose from. This makes it hard to decide which part of the application data to handle in which system, especially given that each system is best at handling a specific kind of data and a certain class of operations. CEDAR investigates principled techniques for distributing an application's data sources across a variety of systems and data models, based on materialized views. We test our ideas in this area within the Datalyse project.

## **DAHU Project-Team**

# **4. Application Domains**

## **4.1. Application Domains**

Databases are pervasive across many application fields. Indeed, most human activities today require some form of data management. In particular, all applications involving the processing of large amounts of data require the use of a database. Increasingly complex Web applications and services also rely on DBMS, and their correctness and robustness is crucial.

We believe that the automated solutions that Dahu aims to develop for verifying such systems will be useful in this context.

## **EXMO Project-Team**

# **4. Application Domains**

## **4.1. Semantic web technologies**

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

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

The vision of a “semantic web” [17] complements the web, with formal knowledge representation spanning across sites. Taking advantage of this semantic web requires the manipulation of various knowledge representation formats. EXMO concerns are thus central to the semantic web implementation. Our work aims at enhancing content understanding, including the intelligibility of communicated knowledge and formal knowledge transformations.

In addition, EXMO considers more specific uses of semantic web technologies in wider contexts.

**GRAPHIK Project-Team (section vide)**



## LACODAM Team

# 4. Application Domains

## 4.1. Introduction

The current period is extremely favorable for teams working in Data Science and Artificial Intelligence, and Lacodam is no exception. We are eager to see our work applied in real world applications, and have thus an important activity in maintaining strong ties with industrial partners concerned with marketing and energy as well as public partners working in health, agriculture and environment.

## 4.2. Industry

We present below our industrial collaborations. Some are well established partnerships, while others are more recent collaborations with local industries that wish to reinforce their Data Science R&D with us (e.g. STMicroelectronics, Energiency, Amossys).

- **Execution trace analysis for SOC debugging (STMicroelectronics).** 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 pattern mining techniques, which he is now pursuing with his colleagues of the Lacodam project-team.
- **Resource consumption analysis for optimizing energy consumption and practices in industrial factories (Energiency).** In order to increase their benefits, companies introduce more and more sensors in their factories. Thus, the resource (electricity, water, etc.) consumption of engines, workshops or factories are recorded in the form of times series or temporal sequences. The person who is in charge of resource consumption optimization needs better software than classical spreadsheets. He/she needs effective decision-aiding tools with statistical and artificial intelligence knowledge. The start-up Energiency aims at designing and offering such pieces of software for analyzing energy consumption. The starting CIFRE PhD thesis of Maël Guillemé aims at proposing new approaches and solutions from the data mining field to tackle this issue.
- **Security (Amossys).** Current networks are faced with an increasing variety of attacks, from the classic « DDoS » that makes a server unusable for a few hours, to advanced attacks that silently infiltrate a network and exfiltrate sensitive information months or even years later. Such intrusions, called APT (Advanced Persistent Threat) are extremely hard to detect, and this will become even harder as most communications will be encrypted. A promising solution is to work on “behavioral analysis”, by discovering patterns based on the metadata of IP-packets. Such patterns can relate to an unusual sequencing of events, or to an unusual communication graph. Finding such complex patterns over a large volume of streaming data requires to revisit existing stream mining algorithms to dramatically improve their throughput, while guaranteeing a manageable false positive rate. We are collaborating on this topic with the Amossys company and the Emsec team of Irista through the co-supervision of a CIFRE PhD (located in the Emsec team). Our goal is to design novel anomaly detection methods that can detect APT, and that scales on real traffic volumes.

- **Market basket data analysis (Intermarché) and multi-channel interaction data analysis (EDF) for better Customer Relationship Management (CRM).** An important application domain of data mining for companies that deal with large numbers of customers is to analyze customer interaction data, either for marketing purposes or to improve the quality of service. We have activities in both settings. In the first case, we collaborate with a major french retailer, Intermarché, in order to detect customer churn by analyzing market basket data. In the second case, we collaborate with the major french power supplier, EDF, to discover actionable patterns for CRM aiming at avoiding reaching undesirable situations from logs of user interactions with the company (web clicks, phone calls, etc.).

### 4.3. Health

- **Care pathways analysis for supporting pharmaco-epidemiological studies.** Pharmaco-epidemiology applies the methodologies developed in general epidemiology to answer to questions about the uses and effects of health products, drugs [20], [19] or medical devices [17], on population. In classical pharmaco-epidemiology studies, people who share common characteristics are recruited to build a dedicated prospective cohort. Then, meaningful data (drug exposures, diseases, etc.) are collected from the cohort within a defined period of time. Finally, a statistical analysis highlights the links (or the lack of links) between drug exposures and outcomes (*e.g.* adverse effects). The main drawback of prospective cohort studies is the time required to collect the data and to integrate it. Indeed, in some cases of health product safety, health authorities have to answer quickly to pharmaco-epidemiology questions.

New approaches of pharmaco-epidemiology consist in using large EHR (Electronic Health Records) databases to investigate the effects and uses (or misuses) of drugs in real conditions. The objective is to benefit from nationwide available data to answer accurately and in a short time pharmaco-epidemiological queries for national public health institutions. Despite the potential availability of the data, their size and complexity make their analysis long and tremendous. The challenge we tackle is the conception of a generic digital toolbox to support the efficient design of a broad range of pharmaco-epidemiology studies from EHR databases.

We propose to use pattern mining algorithm and reasoning techniques to analyse the typical care pathways of specific groups of patients.

To be able to answer the broad range of pharmaco-epidemiological queries from national public health institutions, the PEPS<sup>0</sup> platform exploits, in secondary use, the French health cross-schemes insurance system, called SNIIRAM. The SNIIRAM covers most of the French population with a sliding period of 3 past years. The main characteristics of this data warehouse are described in [18]. Contrary to local hospital EHR or even with other national initiatives, the SNIIRAM data warehouse covers a huge population. It makes possible studies on unfrequent drugs or diseases in real conditions of use. To tackle the volume and the diversity of the SNIIRAM data warehouse, a research program has been established to design an innovative toolbox. This research program is focused first on the modeling of care pathways from the SNIIRAM database and, second, on the design of tools supporting meaningful insights extraction about massive and complex care pathways by clinicians. In such database a care pathway is an individual sequence of drugs exposures, medical procedures and hospitalizations.

### 4.4. Agriculture and environment

- **Dairy farming.** The use and analysis of data acquired in dairy farming is a challenge both for data science and for animal science. Its goal is to improve farming conditions (health, welfare and environment) as well as farmers' income. Nowadays, animals are monitored by multiple sensors giving a wealth of heterogeneous data (ex: temperature, weight, milk composition...).

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<sup>0</sup>PEPS: Pharmaco-Epidémiologie et Produits de Santé – Pharmacoepidemiology of health products

Current techniques used by animal scientists focus mostly on mono-sensor approaches. The dynamic combination of several sensors could provide new services and information useful for dairy farming. A PhD thesis will begin soon to study such combinations of sensors and to investigate data mining methods, especially pattern mining algorithms. The challenge is to design new algorithms taking into account the data heterogeneity, coming both from their nature and the different time scales involved, and to produce patterns that are actually useful for dairy farming. This thesis will be an original and important contribution to the new challenge of the IoT (Internet of Things) and will interest domain actors to find new added value to a global data analysis. The PhD thesis will take place in an interdisciplinary setting bringing together computer scientists from Inria and animal scientists from INRA, both located in Rennes.

Similar problems are investigated with the veterinary department of the University of Calgary in the context of cattle monitoring from multiple sensors placed on calves for the early detection of diseases.

- **Optimizing the nutrition of individual sow.** Another direction for further research is to combine data flow with prediction models in order to learn nutrition strategies. We are currently starting a project with INRA on the nutritional requirements and the optimal diet to be supplied to individual lactating sow. The research issue will be to develop decision algorithms for the determination of the optimal ration (amount and composition) to be fed to a given sow, on a given day, considering all the information available (real-time observation data flow and historical data). Issues concern the design of an incremental learning algorithm that will compute the animal profile and how to determine the best feeding plan. Efficiency issues of developed algorithms will also be considered since the proposed software should work in real-time on the automated feeder.
- **Ecosystem modeling and management.** Ongoing research on ecosystem management includes modelling of ecosystems and anthropogenic pressures, with a special concern on the representation of socio-economical factors that impact human decisions. A main research issue is how to represent these factors and how to integrate their impact on the ecosystem simulation model. This work is an ongoing cooperation with ecologists from the Marine Spatial Ecology of Queensland University, Australia and from Agrocampus Ouest.

## **LINKS Project-Team**

# **4. Application Domains**

## **4.1. Linked Data Integration**

There are many contexts in which integrating linked data is interesting. We advocate here one possible scenario, namely that of integrating business linked data to feed what is called Business Intelligence. The latter consists of a set of theories and methodologies that transform raw data into meaningful and useful information for business purposes (from Wikipedia). In the past decade, most of the enterprise data was proprietary, thus residing within the enterprise repository, along with the knowledge derived from that data. Today's enterprises and businessmen need to face the problem of information explosion, due to the Internet's ability to rapidly convey large amounts of information throughout the world via end-user applications and tools. Although linked data collections exist by bridging the gap between enterprise data and external resources, they are not sufficient to support the various tasks of Business Intelligence. To make a concrete example, concepts in an enterprise repository need to be matched with concepts in Wikipedia and this can be done via pointers or equalities. However, more complex logical statements (i.e. mappings) need to be conceived to map a portion of a local database to a portion of an RDF graph, such as a subgraph in Wikipedia or in a social network, e.g. LinkedIn. Such mappings would then enrich the amount of knowledge shared within the enterprise and let more complex queries be evaluated. As an example, businessmen with the aid of business intelligence tools need to make complex sentimental analysis on the potential clients and for such a reason, such tools must be able to pose complex queries, that exploit the previous logical mappings to guide their analysis. Moreover, the external resources may be rapidly evolving thus leading to revisit the current state of business intelligence within the enterprise.

## **4.2. Data Cleaning**

The second example of application of our proposal concerns scientists who want to quickly inspect relevant literature and datasets. In such a case, local knowledge that comes from a local repository of publications belonging to a research institute (e.g. HAL) need to be integrated with other Web-based repositories, such as DBLP, Google Scholar, ResearchGate and even Wikipedia. Indeed, the local repository may be incomplete or contain semantic ambiguities, such as mistaken or missing conference venues, mistaken long names for the publication venues and journals, missing explanation of research keywords, and opaque keywords. We envision a publication management system that exploits both links between database elements, namely pointers to external resources and logical links. The latter can be complex relationships between local portions of data and remote resources, encoded as schema mappings. There are different tasks that such a scenario could entail such as (i) cleaning the errors with links to correct data e.g. via mappings from HAL to DBLP for the publications errors, and via mappings from HAL to Wikipedia for opaque keywords, (ii) thoroughly enrich the list of publications of a given research institute, and (iii) support complex queries on the corrected data combined with logical mappings.

## **4.3. Real Time Complex Event Processing**

Complex event processing serves for monitoring nested word streams in real time. Complex event streams are gaining popularity with social networks such as with Facebook and Twitter, and thus should be supported by distributed databases on the Web. Since this is not yet the case, there remains much space for future industrial transfer related to Links' second axis on dynamic linked data.

## **MAGNET Project-Team**

### **4. Application Domains**

#### **4.1. Targeted Applications**

Our main targeted applications are browsing, monitoring, recommending and mining in information networks. The learning tasks considered in the project such as node clustering, node and link classification and link prediction are likely to yield important improvements in these applications. Application domains cover social networks for cultural data and e-commerce, and biomedical informatics.

## ORPAILLEUR Project-Team

# 4. Application Domains

## 4.1. Life Sciences: Biology, Chemistry and Medicine

**Participants:** Adrien Coulet, Nicolas Jay, Joël Legrand, Jean Lieber, Pierre Monnin, Amedeo Napoli, Chedy Raïssi, Mohsen Sayed, Malika Smaïl-Tabbone, Yannick Toussaint, Mickaël Zehren.

**Keywords:** knowledge discovery in life sciences, bioinformatics, biology, chemistry, medicine, pharmacogenomics

One major application domain which is currently investigated by the Orpailleur team is related to life sciences, with particular emphasis on biology, medicine, and chemistry. The understanding of biological systems provides complex problems for computer scientists, and the developed solutions bring new research ideas or possibilities for biologists and for computer scientists as well. Indeed, the interactions between researchers in biology and researchers in computer science improve not only knowledge about systems in biology, chemistry, and medicine, but knowledge about computer science as well.

Knowledge discovery is gaining more and more interest and importance in life sciences for mining either homogeneous databases such as protein sequences and structures, or heterogeneous databases for discovering interactions between genes and environment, or between genetic and phenotypic data, especially for public health and pharmacogenomics domains. The latter case appears to be one main challenge in knowledge discovery in biology and involves knowledge discovery from complex data depending on domain knowledge.

On the same line as biological data, chemical data are presenting important challenges w.r.t. knowledge discovery, for example for mining collections of molecular structures and collections of chemical reactions in organic chemistry. The mining of such collections is an important task for various reasons among which the challenge of graph mining and the industrial needs (especially in drug design, pharmacology and toxicology). Molecules and chemical reactions are complex data that can be modeled as undirected labeled graphs. Graph mining methods may play an important role in this framework and Formal Concept Analysis can also be used in an efficient and well-founded way [86]. Graph mining in the framework of FCA is a very important task on which we are working, whose results can be transferred to text mining as well.

We are working on knowledge management in medicine and analysis of patient trajectories. The Kasimir research project is about decision support and knowledge management for the treatment of cancer. This is a multidisciplinary research project in which researchers in computer science (Orpailleur) and experts in oncology are participating. For a given cancer localization, a treatment is based on a protocol, which is applied in 70% of the cases and provides a treatment. The 30% remaining cases are “out of the protocol”, e.g. contraindication, treatment impossibility, etc. and the protocol should be adapted, based on discussions among specialists. This adaptation process is modeled in Kasimir thanks to CBR, where semantic web technologies are used and adapted for several years.

The analysis of patient trajectories, i.e. the “path” of a patient during illness (chronic illnesses and cancer), can be considered as an analysis of sequences. It is important to understand such sequential data and sequence mining methods should be adapted for addressing the complex nature of medical events. We are interested in the analysis of trajectories at different levels of granularity and w.r.t. external domain ontologies. In addition, it is also important to be able to compare and classify trajectories according to their content. Then we are also interested in the definition of similarity measures able to take into account the complex nature of trajectories and that can be efficiently implemented for allowing quick and reliable classifications.

PractiKPharma (Practice-based evidences for actioning Knowledge in Pharmacogenomics) is a starting research project about the validation of state-of-the-art knowledge in pharmacogenomics by mining “Electronic Health Records” (EHRs) [55]. Pharmacogenomics is a field studying how genomic variations impact drug responses. Most of the state of the art in the field is only available in biomedical literature, with various levels of validation. Accordingly we propose firstly, to extract pharmacogenomic knowledge units from the literature and secondly, to confirm or moderate these units by mining EHRs. Comparing knowledge units extracted from the literature with facts extracted from EHRs is not a trivial task for several reasons, among which (i) the literature is in English, whereas EHRs are in French, (ii) EHRs represent observations at the patient level whereas the literature is generalizing sets of patients...

## 4.2. Cooking

**Participants:** Emmanuelle Gaillard, Jean Lieber, Emmanuel Nauer.

**Keywords:** cooking, knowledge engineering, case-based reasoning, semantic web

123 The origin of the Taaable project is the Computer Cooking Contest (CCC). A contestant to CCC is a system that answers queries about recipes, using a recipe base; if no recipe exactly matches the query, then the system adapts another recipe. Taaable is a case-based reasoning system based on various technologies from semantic web, knowledge discovery, knowledge representation and reasoning. From a research viewpoint the system enables to test scientific results and to study the complementarity of various research trends in an application domain which is simple to understand and which raises complex issues at the same time.

## 4.3. Agronomy

**Participants:** Sébastien Da Silva, Florence Le Ber, Jean-François Mari.

**Keywords:** simulation in agronomy, graph model in agronomy

Research in agronomy was conducted in the framework of an Inria-INRA collaboration, taking place in the INRA research network PAYOTE about landscape modeling. In this framework, Sébastien da Silva prepared and defended a PhD thesis [74] in September 2014, supervised by Claire Lavigne (DR in ecology, INRA Avignon) and Florence Le Ber. The research work was related to the characterization and the simulation of hedgerow structures in agricultural landscapes, based on Hilbert-Peano curves and Markov models [48].

Moreover, an on-going research work about the representation of peasant knowledge is involved within a collaboration with IRD in Madagascar [81]. Sketches drawn by peasants were transformed into graphs and compared thanks to Formal Concept Analysis.

## 4.4. Digital Humanities

**Participant:** Jean Lieber.

**Keywords:** digital humanities, semantic web, SPARQL, approximate search, case-based reasoning

Recent contacts with the digital humanity community occurred with a group of researchers working in history and philosophy of science and technologies (located in Brest, Montpellier and Nancy). They want to benefit from semantic Web technologies in order to provide better accesses to their text corpora. A paper based on this starting collaboration was published [69], about exact and approximate search in RDFS-annotated text corpora based on the SPARQL technology and on case-based reasoning principles.

## **SMIS Project-Team**

# **4. Application Domains**

## **4.1. Application Domains**

Our work addresses varied application domains. Typically, data management techniques on chip are required each time data-driven applications have to be embedded in ultra-light computing devices. This situation occurs for example in healthcare applications where medical folders are embedded into smart tokens (e.g., smart cards, secured USB keys), in telephony applications where personal data (address book, agenda, etc.) is embedded into cellular phones, in sensor networks where sensors log raw measurements and perform local computation on them, in smart-home applications where a collection of smart appliances gather information about the occupants to provide them a personalized service, and more generally in most applications related to ambient intelligence.

Safeguarding data confidentiality has become a primary concern for citizens, administrations and companies, broadening the application domains of our work on access control policies definition and enforcement. The threat on data confidentiality is manifold: external and internal attacks on the data at rest, on the data on transit, on the data hosted in untrusted environments (e.g., Database Service Providers, Web-hosting companies) and subject to illegal usage, insidious gathering of personal data in an ambient intelligence surrounding. Hence, new access control models and security mechanisms are required to accurately declare and safely control who is granted access to which data and for which purpose.

While the application domain mentioned above is rather large, two applications are today more specifically targeted by the SMIS team. The first one deals with privacy preservation in EHR (Electronic Health Record) systems and PCEHR (Personally Controlled EHR) [3]. We are developing technologies tackling this issue and experiment them in the field. The second application area deals with privacy preservation in the context of personal Cloud, that is personal data hosted in dedicated servers staying under the holder's control (e.g., in a personal internet box or in a home automation box).



## **TYREX Project-Team**

### **4. Application Domains**

#### **4.1. Web Programming Technologies**

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

#### **4.2. Multimedia and Augmented Environments**

The term Augmented Environments refers collectively to ubiquitous computing, context-aware computing, and intelligent environments. The goal of our research on these environments is to introduce personal Augmented Reality (AR) devices, taking advantage of their embedded sensors. We believe that personal AR devices such as mobile phones or tablets will play a central role in augmented environments. These environments offer the possibility of using ubiquitous computation, communication, and sensing to enable the presentation of context-sensitive information and services to the user. AR applications often rely on 3D content and employ specialized hardware and computer vision techniques for both tracking and scene reconstruction and exploration. Our approach tries to seek a balance between these traditional AR contexts and what has come to be known as mobile AR browsing. It first acknowledges that mobile augmented environment browsing does not require that 3D content be the primary means of authoring. It provides instead a method for HTML5 and audio content to be authored, positioned in the surrounding environments and manipulated as freely as in modern web browsers. The applications we develop to guide and validate our concepts are pedestrian navigation techniques and applications for cultural heritage visits. Features found in augmented environments are demanding for the other activities in the team. They require all kinds of multimedia information, that they have to combine. This information has to be processed efficiently and safely, often in real time, and it also, for a significant part, has to be created by human users.

## **WIMMICS Project-Team**

# **4. Application Domains**

## **4.1. Social Semantic Web**

A number of evolutions have changed the face of information systems in the past decade but the advent of the Web is unquestionably a major one and it is here to stay. From an initial wide-spread perception of a public documentary system, the Web as an object turned into a social virtual space and, as a technology, grew as an application design paradigm (services, data formats, query languages, scripting, interfaces, reasoning, etc.). The universal deployment and support of its standards led the Web to take over nearly all of our information systems. As the Web continues to evolve, our information systems are evolving with it.

Today in organizations, not only almost every internal information system is a Web application, but these applications also more and more often interact with external Web applications. The complexity and coupling of these Web-based information systems call for specification methods and engineering tools. From capturing the needs of users to deploying a usable solution, there are many steps involving computer science specialists and non-specialists.

We defend the idea of relying on Semantic Web formalisms to capture and reason on the models of these information systems supporting the design, evolution, interoperability and reuse of the models and their data as well as the workflows and the processing.

## **4.2. Linked Data on the Web and on Intranets**

With billions of triples online (see Linked Open Data initiative), the Semantic Web is providing and linking open data at a growing pace and publishing and interlinking the semantics of their schemas. Information systems can now tap into and contribute to this Web of data, pulling and integrating data on demand. Many organisations also started to use this approach on their intranets leading to what is called linked enterprise data.

A first application domain for us is the publication and linking of data and their schemas through Web architectures. Our results provide software platforms to publish and query data and their schemas, to enrich these data in particular by reasoning on their schemas, to control their access and licenses, to assist the workflows that exploit them, to support the use of distributed datasets, to assist the browsing and visualization of data, etc.

Examples of collaboration and applied projects include: SMILK Joint Laboratory, Corese, DBpedia.fr.

## **4.3. Assisting Web-based Epistemic Communities**

In parallel to linked open data on the Web, social Web applications also spread virally (e.g. Facebook growing toward 1.5 billion users) first giving the Web back its status of a social read-write media and then putting it back on track to its full potential of a virtual place where to act, react and interact. In addition, many organizations are now considering deploying social Web applications internally to foster community building, expert cartography, business intelligence, technological watch and knowledge sharing in general.

By reasoning on the Linked Data and the semantics of the schemas used to represent social structures and Web resources, we provide applications supporting communities of practice and interest and fostering their interactions in many different contexts (e-learning, business intelligence, technical watch, etc.).

We use typed graphs to capture and mix: social networks with the kinds of relationships and the descriptions of the persons; compositions of Web services with types of inputs and outputs; links between documents with their genre and topics; hierarchies of classes, thesauri, ontologies and folksonomies; recorded traces and suggested navigation courses; submitted queries and detected frequent patterns; timelines and workflows; etc.

Our results assist epistemic communities in their daily activities such as biologists exchanging results, business intelligence and technological watch networks informing companies, engineers interacting on a project, conference attendees, students following the same course, tourists visiting a region, mobile experts on the field, etc. Examples of collaboration and applied projects: EduMICS, OCKTOPUS, Vigiglobe, Educlever, Gayatech.

#### **4.4. Linked Data for a Web of diversity**

We intend to build on our results on explanations (provenance, traceability, justifications) and to continue our work on opinions and arguments mining toward the global analysis of controversies and online debates. One result would be to provide new search results encompassing the diversity of viewpoints and providing indicators supporting opinion and decision making and ultimately a Web of trust. Trust indicators may require collaborations with teams specialized in data certification, cryptography, signature, security services and protocols, etc. and this will raise the specific problem of interaction design for security and privacy. In addition, from the point of view of the content, this requires to foster the publication and coexistence of heterogeneous data with different points of views and conceptualizations of the world. We intend to pursue the extension of formalisms to allow different representations of the world to co-exist and be linked and we will pay special attention to the cultural domain and the digital humanities. Examples of collaboration and applied projects: Zoomathia, Seempad, SMILK,

#### **4.5. Artificial Web intelligence**

We intend to build on our experience in artificial intelligence (knowledge representation, reasoning) and distributed artificial intelligence (multi-agent systems - MAS) to enrich formalisms and propose alternative types of reasoning (graph-based operations, reasoning with uncertainty, inductive reasoning, non-monotonic, etc.) and alternative architectures for linked data with adequate changes and extensions required by the open nature of the Web. There is a clear renewed interest in AI for the Web in general and for Web intelligence in particular. Moreover distributed AI and MAS provide both new architectures and new simulation platforms for the Web. At the macro level, the evolution accelerated with HTML5 toward Web pages as full applications and direct Page2Page communication between browser clearly is a new area for MAS and P2P architectures. Interesting scenarios include the support to a strong decentralization of the Web and its resilience to degraded technical conditions (downscaling the Web), allowing pages to connect in a decentralized way, forming a neutral space, and possibly going offline and online again in erratic ways. At the micro level one can imagine the place RDF and SPARQL could take as data model and programming model in the virtual machines of these new Web pages and, of course, in the Web servers. RDF is also used to serialize and encapsulate other languages and becomes a pivot language in linking very different applications and aspects of applications. Example of collaboration and applied projects: MoreWAIS, Corese, Vigiglobe collaboration.

#### **4.6. Human-Data Interaction (HDI) on the Web**

We need more interaction design tools and methods for linked data access and contribution. We intend to extend our work on exploratory search coupling it with visual analytics to assist sense making. It could be a continuation of the Gephi extension we built targeting more support for non expert to access and analyze data on a topic or issue of their choice. More generally speaking SPARQL is inappropriate for common users and we need to support a larger variety of interaction means with linked data. We also believe linked data and natural language processing (NLP) have to be strongly integrated to support natural language based interactions. Linked Open Data (LOD) for NLP, NLP for LOD and Natural Dialog Processing for querying, extracting and asserting data on the Web is a priority to democratize its use. Micro accesses and micro contributions are important to ensure public participation and also call for customized interfaces and thus for methods and tools to generate these interfaces. In addition, the user profiles are being enriched now with new data about the user such as his current mental and physical state, the emotion he just expressed or his cognitive performances. Taking into account this information to improve the interactions, change the behavior of the system and adapt the interface is a promising direction. And these human-data interaction means should

also be available for “small data”, helping the user to manage her personal information and to link it to public one or collective one maintaining her personal and private perspective as a personal Web of data. Finally, the continuous knowledge extractions, updates and flows add the additional problem of representing, storing, querying and interacting with dynamic data. Examples of collaboration and applied projects: QAKIS, Sychonext collaboration, ALOOF, DiscoveryHub, Wasabi, MoreWAIS.

**Web-augmented interactions with the world:** The Web continues to augment our perception and interaction with reality. In particular, Linked Open Data enable new augmented reality applications by providing data sources on almost any topic. The current enthusiasm for the Web of Things, where every object has a corresponding Web resource, requires evolutions of our vision and use of the Web architecture. This vision requires new techniques as the ones mentioned above to support local search and contextual access to local resources but also new methods and tools to design Web-based human devices interactions. These new usages are placing new requirements on the Web Architecture in general and on the semantic Web models and algorithms in particular to handle new types of linked data. They should support implicit requests considering the user context as a permanent query. They should also simplify our interactions with devices around us jointly using our personal preferences and public common knowledge to focus the interaction on the vital minimum that cannot be derived in another way. For instance the access to the Web of data for a robot can completely change the quality of the interactions it can offer. Again these interactions and the data they require raise problems of security and privacy. Examples of collaboration and applied projects: ALOOF, AZKAR, MoreWAIS.

## ZENITH Project-Team

# 4. Application Domains

## 4.1. Data-intensive Scientific Applications

The application domains covered by Zenith are very wide and diverse, as they concern data-intensive scientific applications, i.e., most scientific applications. Since the interaction with scientists is crucial to identify and tackle data management problems, we are dealing primarily with application domains for which Montpellier has an excellent track record, i.e., agronomy, environmental science, life science, with scientific partners like INRA, IRD and CIRAD. However, we are also addressing other scientific domains (e.g. astronomy, oil extraction) through our international collaborations (e.g. in Brazil).

Let us briefly illustrate some representative examples of scientific applications on which we have been working on.

- **Management of astronomical catalogs.** An example of data-intensive scientific applications is the management of astronomical catalogs generated by the Dark Energy Survey (DES) project on which we are collaborating with researchers from Brazil. In this project, huge tables with billions of tuples and hundreds of attributes (corresponding to dimensions, mainly double precision real numbers) store the collected sky data. Data are appended to the catalog database as new observations are performed and the resulting database size is estimated to reach 100TB very soon. Scientists around the globe can query the database with queries that may contain a considerable number of attributes. The volume of data that this application holds poses important challenges for data management. In particular, efficient solutions are needed to partition and distribute the data in several servers. An efficient partitioning scheme should try to minimize the number of fragments accessed in the execution of a query, thus reducing the overhead associated to handle the distributed execution.
- **Personal health data analysis and privacy** Today, it is possible to acquire data on many domains related to personal data. For instance, one can collect data on her daily activities, habits or health. It is also possible to measure performance in sports. This can be done thanks to sensors, communicating devices or even connected glasses. Such data, once acquired, can lead to valuable knowledge for these domains. For people having a specific disease, it might be important to know if they belong to a specific category that needs particular care. For an individual, it can be interesting to find a category that corresponds to her performances in a specific sport and then adapt her training with an adequate program. Meanwhile, for privacy reasons, people will be reluctant to share their personal data and make them public. Therefore, it is important to provide them solutions that can extract such knowledge from everybody's data, while guaranteeing that their private data won't be disclosed to anyone.
- **Botanical data sharing.** Botanical data is highly decentralized and heterogeneous. Each actor has its own expertise domain, hosts its own data, and describes them in a specific format. Furthermore, botanical data is complex. A single plant's observation might include many structured and unstructured tags, several images of different organs, some empirical measurements and a few other contextual data (time, location, author, etc.). A noticeable consequence is that simply identifying plant species is often a very difficult task; even for the botanists themselves (the so-called taxonomic gap). Botanical data sharing should thus speed up the integration of raw observation data, while providing users an easy and efficient access to integrated data. This requires to deal with social-based data integration and sharing, massive data analysis and scalable content-based information retrieval. We address this application in the context of the French initiative PI@ntNet, with CIRAD and IRD.
- **Biology data integration and analysis.**

Biology and its applications, from medicine to agronomy and ecology, are now producing massive data, which is revolutionizing the way life scientists work. For instance, using plant phenotyping platforms such as PhenoDyn at INRA Montpellier, quantitative genetic methods allow to identify genes involved in phenotypic variation in response to environmental conditions. These methods produce large amounts of data at different time intervals (minutes to days), at different sites and at different scales ranging from small tissue samples until the entire plant. Analyzing such big data creates new challenges for data management and data integration.

These application examples illustrate the diversity of requirements and issues which we are addressing with our scientific application partners. To further validate our solutions and extend the scope of our results, we also want to foster industrial collaborations, even in non scientific applications, provided that they exhibit similar challenges.

## **ALICE Project-Team**

### **4. Application Domains**

#### **4.1. Geometric Tools for Simulating Physics with a Computer**

Numerical simulation is the main targeted application domain for the geometry processing tools that we develop. Our mesh generation tools are tested and evaluated in the frame of our cooperation with the Gocad consortium, with applications in oil exploration and geomechanics, through co-advised Ph.D. thesis (Arnaud Botella, Julien Renaudeau). We think that the hex-dominant meshes that we generate have geometrical properties that make them suitable for some finite element analyses. We work on evaluating and measuring their impact with simple problems (heat equation, linear elasticity) and then practical applications (unfolding geological layer), with the Ph.D. thesis of Maxence Reberol.

In numerical simulation, developing discrete formulations that satisfy the conservation laws (conservation of mass, conservation of energy, conservation of momentum) is important to ensure that the numerical simulation faithfully reflects the behavior of the physics. There are interesting relations with optimal transport theory, as explained by Benamou and Brenier who developed a numerical algorithm for optimal transport that uses a fluid dynamics formulation [17]. Conversely, some dynamics can be approximated by a series of optimal transport problems, as in the Jordan-Kinderlehrer-Otto scheme [20] and in recent works by Mérigot. We started developing efficient geometric algorithms and optimisation methods that may serve as the basis for implementing these numerical methods in 3D. We started discussions / cooperation projects with Quentin Mérigot (MOKAPLAN project).

#### **4.2. Fabrication**

Our work around fabrication and additive manufacturing finds applications in different fields. Our algorithms for fast geometric computations on solids (boolean operations, morphological operations) are useful to model a variety of shapes, from mechanical engineering parts to prosthetics for medical applications.

Our by-example techniques allow for simpler modeling and processing of very intricate geometries and therefore also find applications in art and design, for unusual shapes that would be very difficult to obtain otherwise. Extensions of these techniques also find applications for reproducing naturally occurring microstructures from a scanned sampled.

## **AVIZ Project-Team**

# **4. Application Domains**

## **4.1. Domains**

Research in visual analytics can profit from the challenges and requirements of real-world datasets. Aviz develops active collaboration with users from a range of application domains, making sure it can support their specific needs. By studying similar problems in different domains, we can begin to generalize our results and have confidence that our solutions will work for a variety of applications.

We apply our techniques to important medical applications domains such as bioinformatics and brain studies. In particular, we are interested in helping neuroscientists make sense of evolving functional networks, in the form of weighted and/or dynamic graphs.

Other application domains include:

- Digital Humanities in general, with the Cendari European project with historians from most European countries, the project “Interactive Network Visualization” with Microsoft Research-Inria Joint Centre on Graph Visualization, and with our work on Word-Scale Visualizations;
- Many traditional scientific research fields such as astronomy, fluid dynamics, structural biology, and neurosciences;
- Scientific illustration that can benefit from illustrative visualization techniques for scientific data;
- Personal visualization and visual analytics in which we develop solutions for the general audience.



## **EX-SITU Team**

### **4. Application Domains**

#### **4.1. Creative industries**

We work closely with creative professionals in the arts and in design, including music composers, musicians, and sound engineers; painters and illustrators; dancers and choreographers; theater groups; graphic and industrial designers; and architects.

#### **4.2. Scientific research**

We work with creative professionals in the sciences and engineering, including neuroscientists and doctors; programmers and statisticians; chemists and astrophysicists; and researchers in fluid mechanics.

**GRAPHDECO Project-Team (section vide)**

## **HYBRID Project-Team**

# **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.

## ILDA Project-Team

# 4. Application Domains

## 4.1. Mission-critical systems

Mission-critical contexts of use include emergency response & management, and critical infrastructure operations, such as public transportation systems, communications and power distribution networks, or the operations of large scientific instruments such as particle accelerators and astronomical observatories. Central to these contexts of work is the notion of situation awareness [27], i.e., how workers perceive and understand elements of the environment with respect to time and space, such as maps and geolocated data feeds from the field, and how they form mental models that help them predict future states of those elements. One of the main challenges is how to best assist subject-matter experts in constructing correct mental models and making informed decisions, often under time pressure. This can be achieved by providing them with, or helping them efficiently identify and correlate, relevant and timely information extracted from large amounts of raw data, taking into account the often cooperative nature of their work and the need for task coordination. With this application area, our goal is to investigate novel ways of interacting with computing systems that improve collaborative data analysis capabilities and decision support assistance in a mission-critical, often time-constrained, work context.

Relevant publications by team members this year: [22], [24].

## 4.2. Exploratory analysis of scientific data

Many scientific disciplines are increasingly data-driven, including astronomy, molecular biology, particle physics, or neuroanatomy. While making the right decision under time pressure is often less of a critical issue when analyzing scientific data, at least not on the same temporal scale as truly time-critical systems, scientists are still faced with large-to-huge amounts of data. No matter their origin (experiments, remote observations, large-scale simulations), these data are difficult to understand and analyze in depth because of their sheer size and complexity. Challenges include how to help scientists freely-yet-efficiently explore their data, keep a trace of the multiple data processing paths they considered to verify their hypotheses and make it easy to backtrack, and how to relate observations made on different parts of the data and insights gained at different moments during the exploration process. With this application area, our goal is to investigate how data-centric interactive systems can improve collaborative scientific data exploration, where users' goals are more open-ended, and where roles, collaboration and coordination patterns [46] differ from those observed in mission-critical contexts of work.

Relevant publications by team members this year: [7].

**IMAGINE Project-Team (section vide)**

## MANAO Project-Team

# 4. Application Domains

## 4.1. Physical Systems

Given our close relationships with researchers in optics, one novelty of our approach is to extend the range of possible observers to physical sensors in order to work on domains such as simulation, mixed reality, and testing. Capturing, processing, and visualizing complex data is now more and more accessible to everyone, leading to the possible convergence of real and virtual worlds through visual signals. This signal is traditionally captured by cameras. It is now possible to augment them by projecting (e.g., the infrared laser of Microsoft Kinect) and capturing (e.g., GPS localization) other signals that are outside the visible range. This supplemental information replaces values traditionally extracted from standard images and thus lowers down requirements in computational power. Since the captured images are the result of the interactions between light, shape, and matter, the approaches and the improved knowledge from *MANAO* help in designing interactive acquisition and rendering technologies that are required to merge the real and the virtual worlds. With the resulting unified systems (optical and digital), transfer of pertinent information is favored and inefficient conversion is likely avoided, leading to new uses in interactive computer graphics applications, like **augmented reality**, **displays** and **computational photography**.

## 4.2. Interactive Visualization and Modeling

This direction includes domains such as **scientific illustration and visualization**, **artistic or plausible rendering**, and **3D modeling**. In all these cases, the observer, a human, takes part in the process, justifying once more our focus on real-time methods. When targeting average users, characteristics as well as limitations of the human visual system should be taken into account: in particular, it is known that some configurations of light, shape, and matter have masking and facilitation effects on visual perception. For specialized applications (such as archeology), the expertise of the final user and the constraints for 3D user interfaces lead to new uses and dedicated solutions for models and algorithms.

## **MAVERICK Project-Team**

# **4. Application Domains**

## **4.1. Application Domains**

The natural application domain for our research is the production of digital images, for example for movies and special effects, virtual prototyping, video games...

Our research have also been applied to tools for generating and editing images and textures, for example generating textures for maps.

Our current application domains are:

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

## **MIMETIC Project-Team**

### **4. Application Domains**

#### **4.1. Autonomous Characters**

Autonomous characters are becoming more and more popular as 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. In order to obtain a better understanding of human motion, MimeTIC addresses three main situations: everyday motions of a lambda subject, locomotion of pathological subjects and sports gestures.

In the first situation, MimeTIC is interested in studying how subjects maintain their balance in highly dynamic conditions. Until now, balance have 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 largely contributed to gaining a better understanding of collision avoidance between pedestrians. This topic includes the research of the parameters that are interactively controlled and the study of each one's role within this interaction.

The second situation focuses on locomotion of pathological subjects. When patients cannot walk efficiently, in particular those suffering from central nervous system affections, it becomes very useful for practitioners to benefit from an objective evaluation of their capacities. To facilitate such evaluations, we have developed two complementary indices, one based on kinematics and the other one on muscle 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: a) the tennis serve, where the goal was to understand the contribution of each segment of the body on the speed of the ball and b) 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 example, for collision avoidance.

### **4.3. Interactions between walkers**

Modeling and simulating the interactions between walkers is a very active, complex and competitive domain, interesting various disciplines such as Mathematics, Cognitive Sciences, Physics, Computer Graphics, etc. Interactions between walkers are by definition at the very core of our society since they represent the basic synergies of our daily life. When walking in the street, we take information about our surrounding environment in order to interact with people, move without collision, alone or in a group, intercept, meet or escape to somebody. Large groups of walkers can be first seen as a complex system: numerous local interactions occur between its elements and result into macroscopic emergent phenomena. Interactions are of various nature (e.g., collision avoidance, following) and are undergoing various factors as well. Physical factors are crucial as a group gathers by definition numerous moving people with a certain level of density. But sociological, cultural and psychological factors are important as well, since people's behavior is deeply changed from country to country, or depending on the considered situations. On the computational point of view, simulating the movements of large groups of walkers (i.e., crowds) pushes traditional simulation algorithms to their limit. As an element of a crowd is subject to interact with any other element belonging the same crowd, a naïve 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 understanding and simulating interactions between walkers, in particular for virtual crowds. Our approach is specific and based on three axes. First, our modeling approach is based on human movement science: we conduct challenging experiments focusing on the perception as well as on the motion involved in local interactions between walkers both using real and virtual set-ups. Second: we develop 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 of Human Activity**

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 problems 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 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. 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 interactions 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 Storytelling**

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 reasoning, 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 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 literature.

## **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 the fact that a Virtual Reality (VR) set-up can be easily modified, enabling quick adjustments of the workstation design. Indeed, the aim of integrating ergonomics evaluation tools in VEs is to facilitate the design process, enhance the design efficiency, and reduce the costs.

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

**MINT Project-Team (section vide)**

## **Mjolnir Team**

# **4. Application Domains**

## **4.1. Application Domains**

Mjolnir works on fundamental aspects of Human-Computer Interaction that can be applied to diverse application domains. Our 2016 research concerned desktop and touch-based interfaces with notable applications to social network analysis, genetics research, 3D environments, as well as 3D films and Virtual Reality stories.

## **POTIOC Project-Team**

### **4. Application Domains**

#### **4.1. Education, popularization of science, art, entertainment**

Our project aims at providing rich interaction experiences between users and the digital world, in particular for non-expert users. The final goal is to stimulate understanding, learning, communication and creation. Our scope of applications encompasses

- education
- popularization of science
- art
- entertainment

See "Objective 3: Exploring new applications and usages" (3.4) for a detailed description.

## **TITANE Project-Team**

# **4. Application Domains**

## **4.1. Applications**

In addition to tackling enduring scientific challenges, our research on geometric modeling and processing is motivated by applications to computational engineering, reverse engineering, digital mapping and urban planning. The main deliverable of our research will be algorithms with theoretical foundations. Ultimately we wish to contribute making geometry modeling and processing routine for practitioners who deal with real-world data. Our contributions may also be used as a sound basis for future software and technology developments.

Our first ambition for technology transfer is to consolidate the components of our research experiments in the form of new software components for the CGAL (Computational Geometry Algorithms Library) library. Through CGAL we wish to contribute to the “standard geometric toolbox”, so as to provide a generic answer to application needs instead of fragmenting our contributions. We already cooperate with the Inria spin-off company Geometry Factory, which commercializes CGAL, maintains it and provide technical support.

Our second ambition is to increase the research momentum of companies through advising Cifre Ph.D. theses and postdoctoral fellows on topics that match our research program.

**ALPAGE Project-Team (section vide)**



## **MULTISPEECH Project-Team**

# **4. Application Domains**

## **4.1. Introduction**

Approaches and models developed in the MULTISPEECH project are intended to be used for facilitating oral communication in various situations through enhancements of the communication channels, either directly via automatic speech recognition or speech production technologies, or indirectly, thanks to computer assisted language learning. Applications also include the usage of speech technologies for helping people in handicapped situations or for improving their autonomy. Foreseen application domains are related to computer assisted learning, health and autonomy (more precisely aided communication and monitoring), annotation and processing of spoken documents, and multimodal computer interaction.

## **4.2. Computer Assisted Learning**

Although speaking seems quite natural, learning foreign languages, or learning the mother tongue for people with language deficiencies, represents critical cognitive stages. Hence, many scientific activities have been devoted to these issues either from a production or a perception point of view. The general guiding principle with respect to computer assisted mother or foreign language learning is to combine modalities or to augment speech to make learning easier. Based upon a comparison of the learner's production to a reference, automatic diagnoses of the learner's production can be considered, as well as perceptual feedback relying on an automatic transformation of the learner's voice. The diagnosis step strongly relies on the studies on categorization of sounds and prosody in the mother tongue and in the second language. Furthermore, reliable diagnosis on each individual utterance is still a challenge, and elaboration of advanced automatic feedback requires a temporally accurate segmentation of speech utterances into phones and this explains why accurate segmentation of native and non-native speech is an important topic in the field of acoustic speech modeling.

## **4.3. Aided Communication and Monitoring**

A foreseen application aims at improving the autonomy of elderly or disabled people, and fit with smartroom applications. In a first step, source separation techniques could be tuned and should help for locating and monitoring people through the detection of sound events inside apartments. In a longer perspective, adapting speech recognition technologies to the voice of elderly people should also be useful for such applications, but this requires the recording of adequate databases. Sound monitoring in other application fields (security, environmental monitoring) could also be envisaged.

## **4.4. Annotation and Processing of Spoken Documents and Audio Archives**

A first type of annotation consists in transcribing a spoken document in order to get the corresponding sequences of words, with possibly some complementary information, such as the structure (punctuation) or the modality (affirmation/question) of the utterances to make the reading and understanding easier. Typical applications of the automatic transcription of radio or TV shows, or of any other spoken document, include making possible their access by deaf people, as well as by text-based indexing tools.

A second type of annotation is related to speech-text alignment, which aims at determining the starting and ending times of the words, and possibly of the sounds (phonemes). This is of interest in several cases as for example, for annotating speech corpora for linguistic studies, and for synchronizing lip movements with speech sounds, for example for avatar-based communications. Although good results are currently achieved on clean data, automatic speech-text alignment needs to be improved for properly processing noisy spontaneous speech data and needs to be extended to handle overlapping speech.

Large audio archives are important for some communities of users, e.g., linguists, ethnologists or researchers in digital humanities in general. In France, a notorious example is the "Archives du CNRS — Musée de l'homme", gathering about 50,000 recordings dating back to the early 1900s. When dealing with very old recordings, the practitioner is often faced with the problem of noise. This stems from the fact that a lot of interesting material from a scientific point of view is very old or has been recorded in very adverse noisy conditions, so that the resulting audio is poor. The work on source separation can lead to the design of semi-automatic denoising and enhancement features, that would allow these researchers to significantly enhance their investigation capabilities, even without expert knowledge in sound engineering.

Finally, there is also a need for speech signal processing techniques in the field of multimedia content creation and rendering. Relevant techniques include speech and music separation, speech equalization, prosody modification, and speaker conversion.

## **4.5. Multimodal Computer Interactions**

Speech synthesis has tremendous applications in facilitating communication in a human-machine interaction context to make machines more accessible. For example, it started to be widely common to use acoustic speech synthesis in smartphones to make possible the uttering of all the information. This is valuable in particular in the case of handicap, as for blind people. Audiovisual speech synthesis, when used in an application such as a talking head, i.e., virtual 3D animated face synchronized with acoustic speech, is beneficial in particular for hard-of-hearing individuals. This requires an audiovisual synthesis that is intelligible, both acoustically and visually. A talking head could be an intermediate between two persons communicating remotely when their video information is not available, and can also be used in language learning applications as vocabulary tutoring or pronunciation training tool. Expressive acoustic synthesis is of interest for the reading of a story, such as audiobook, to facilitate the access to literature (for instance for blind people or illiterate people).

## **PANAMA Project-Team**

# **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.

## SEMAGRAMME Project-Team

# 4. Application Domains

## 4.1. Deep semantic analysis

Our applicative domains concern natural language processing applications that rely on a deep semantic analysis. For instance, one may cite the following ones:

- textual entailment and inference,
- dialogue systems,
- semantic-oriented query systems,
- content analysis of unstructured documents,
- text transformation and automatic summarization,
- (semi) automatic knowledge acquisition.

It seems clear, nowadays, that the need for semantics is ubiquitous. Nevertheless, according to the present state of the art, there are only a few applications for which a deep semantic analysis results in a real improvement over non semantic-based techniques. This is due to the fact that most current application chains are such that their weakest links are not located at the semantic level.

## 4.2. Text Transformation

Text transformation is an application domain featuring two important sub-fields of computational linguistics:

- parsing, from surface form to abstract representation,
- generation, from abstract representation to surface form.

Text simplification or automatic summarization belong to that domain.

We aim at using the framework of Abstract Categorical Grammars we develop to this end. It is indeed a reversible framework that allows both parsing and generation. Its underlying mathematical structure of  $\lambda$ -calculus makes it fit with our type-theoretic approach to discourse dynamics modeling. The ANR project Polymnie (see section [7.2.1.1](#)) is especially dedicated to this aim.

## CHROMA Team

# 4. Application Domains

## 4.1. Introduction

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



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

## 4.2. Future cars and transportation systems

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

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

<sup>0</sup> Advanced Driver Assistance Systems

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

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

### 4.3. Services robotics

Service robotics is an application domain quickly emerging, and more and more industrial companies (e.g., IS-Robotics, Samsung, LG) are now commercializing service and intervention robotics products such as vacuum cleaner robots, drones for civil or military applications, entertainment robots ... One of the main challenges is to propose robots which are sufficiently robust and autonomous, easily usable by non-specialists, and marked at a reasonable cost. We are involved in developing observation and surveillance systems, by using ground robots (Turtlebot fleet) or aerial ones (ANR VIMAD<sup>0</sup>), see Fig. 4.

A more recent challenge for the coming decade is to develop robotized systems for assisting elderly and/or disabled people. In the continuity of our work in the IPL PAL<sup>0</sup>, we aim to propose smart technologies to assist electric wheelchair users in their displacements (see Figure 2 for illustration). We address the problem of assisting the user for joining a group of people and navigating in crowded environments, in cooperation with Inria Lagadic team (Rennes).

Another emerging application to assist people is telepresence robot. In 2016 we started the TENSIVE project, funded by the Region, with the team of G. Bailly from GIPSA Lab (Grenoble) and with the Awabot and Hoomano companies (in Lyon). The project aims to improve the driving of such robots by providing a social and autonomous navigation (PhD of R. Cambuzat). Moreover, the project is supported by INSA-CITI Lab. through the acquisition of a Pepper robot (see Fig. 4).

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<sup>0</sup>Institut de Recherche Technologique

<sup>0</sup>ENABLE-S3: European Initiative to Enable Validation for Highly Automated Safe and Secure Systems.

<sup>0</sup>Service Expérimentation et Développement

<sup>0</sup>Navigation autonome des drones aériens avec la fusion des données visuelles et inertielles, lead by A. Martinelli, Chroma.

<sup>0</sup>Personnally assisted Living

## DEFROST Team

# 4. Application Domains

## 4.1. Industry

Robotics in the manufacturing industry is already highly diffused and is one of the ways put forward to maintain the level of competitiveness of companies based in France and to avoid relocation in cheap labor countries. Yet, in France, it is considered that the level of robotization is insufficient compared to Germany for instance. One of the challenge is the high investment cost for buying robotic arms. In the recent years, it has led the development of « generic » and « flexible » (but rigid) robotic solution that can be produced in series. But their applicability to specific tasks is still challenging or too costly. With the development of 3D printing, we can imagine the development of a complete opposite strategy: a « task-specific » design of robots. Given a task that need to be performed by a deformable robot: we would optimize the shape of its structure to create the set of desired motion . An second important aspect is the reduction of the manufacturing cost: It is often anticipated that the cost of deformable robots will be low compared to classical rigid robotics. The robot could be built on one piece using rapid prototyping or 3D printers and be more adapted for collaborative work with operators. This remains to be « proved », but it could open new perspectives in robotic applications. A last remarkable property of soft robots is their adaptability to fragile or tortuous environment. For some particular industry (chemistry, food industry...) this could also be an advantage compared to existing rigid solutions. For instance, the german company <http://www.festo.com>/Festo, key player in the industrial robots field, is experiencing with deformable trunk robot and we are working on their accurate control.

## 4.2. Personal and service robotics

The personal and service robotics are considered as an important source of economic expansion in the coming years. The potential applications are numerous and particularly include the challenge of finding robotic solutions for active and healthy aging at home. We plan to develop functional orthosis for which it is better not to have a rigid exoskeleton that are particularly not comfortable. These orthosis will be ideally personalised for each patient and built using rapid prototyping. On this topic, the place of our team will be to provide algorithms for controlling the robots. We will find some partners to build these robots that would fall in the category of « wearable robots ». With this thematic we also connect with a strong pole of excellence of the region on intelligent textile Up-Text.

## 4.3. Entertainment industry and arts

Robots have a long history with entertainment and arts where animatronics have been used since years for cinematographic shootings, theater, amusement parc and performing arts. These animatronics are either radio-controlled by a team of professionals or using recorded movements. Our FEM-inversed approach to control soft robots may simplify animatronic control and thus impact this field. We are currently working on implementing demonstration of a deformable animatronic puppets in which motion tracking systems are used and the gestures and movements directly control the puppet. We are also collaborating with the art school Le Fresnoy based at Tourcoing, in particular with the artist Jonathan Pepe (see figure 1 ).



*Figure 1. Our team has worked with the artist Jonathan Pepe on this art work that will be presented at the museum Le palais de Tokyo in 2017.*



## FLOWERS Project-Team

# 4. Application Domains

## 4.1. Application Domains

**Cognitive Sciences** The computational modelling of life-long learning and development mechanisms achieved in the team centrally targets to contribute to our understanding of the processes of sensorimotor, cognitive and social development in humans. In particular, it provides a methodological basis to analyze the dynamics of the interaction across learning and inference processes, embodiment and the social environment, allowing to formalize precise hypotheses and later on test them in experimental paradigms with animals and humans. A paradigmatic example of this activity is the Neurocuriosity project achieved in collaboration with the cognitive neuroscience lab of Jacqueline Gottlieb, where theoretical models of the mechanisms of information seeking, active learning and spontaneous exploration have been developed in coordination with experimental evidence and investigation, see <https://flowers.inria.fr/neurocuriosityproject/>.

**Personal and lifelong learning robotics** Many indicators show that the arrival of personal robots in homes and everyday life will be a major fact of the 21st century. These robots will range from purely entertainment or educative applications to social companions that many argue will be of crucial help in our society. Yet, to realize this vision, important obstacles need to be overcome: these robots will have to evolve in unpredictable homes and learn new skills in a lifelong manner while interacting with non-engineer humans after they left factories, which is out of reach of current technology. In this context, the refoundation of intelligent systems that developmental robotics is exploring opens potentially novel horizons to solve these problems. In particular, this application domain requires advances in artificial intelligence that go beyond the current state-of-the-art in fields like deep learning. Currently these techniques require tremendous amounts of data in order to function properly, and they are severely limited in terms of incremental and transfer learning. One of our goals is to drastically reduce the amount of data required in order for this very potent field to work. We try to achieve this by making neural networks aware of their knowledge, i.e. we introduce the concept of uncertainty, and use it as part of intrinsically motivated multitask learning architectures, and combined with techniques of learning by imitation.

**Human-Robot Collaboration.** Robots play a vital role for industry and ensure the efficient and competitive production of a wide range of goods. They replace humans in many tasks which otherwise would be too difficult, too dangerous, or too expensive to perform. However, the new needs and desires of the society call for manufacturing system centered around personalized products and small series productions. Human-robot collaboration could widen the use of robot in this new situations if robots become cheaper, easier to program and safe to interact with. The most relevant systems for such applications would follow an expert worker and works with (some) autonomy, but being always under supervision of the human and acts based on its task models.

**Environment perception in intelligent vehicles.** When working in simulated traffic environments, elements of FLOWERS research can be applied to the autonomous acquisition of increasingly abstract representations of both traffic objects and traffic scenes. In particular, the object classes of vehicles and pedestrians are of interest when considering detection tasks in safety systems, as well as scene categories ("scene context") that have a strong impact on the occurrence of these object classes. As already indicated by several investigations in the field, results from present-day simulation technology can be transferred to the real world with little impact on performance. Therefore, applications of FLOWERS research that is suitably verified by real-world benchmarks has direct applicability in safety-system products for intelligent vehicles.

**Automated Tutoring Systems.** Optimal teaching and efficient teaching/learning environments can be applied to aid teaching in schools aiming both at increase the achievement levels and the reduce time needed. From a practical perspective, improved models could be saving millions of hours of students' time (and effort) in learning. These models should also predict the achievement levels of students in order to influence teaching practices.

## HEPHAISTOS Project-Team

# 4. Application Domains

## 4.1. Domain 1

While the methods developed in the project can be used for a very broad set of application domains (for example we have an activity in CO2 emission allowances, it is clear that the size of the project does not allow us to address all of them. Hence we have decided to focus our applicative activities on *mechanism theory*, where we focus on *modeling*, *optimal design* and *analysis* of mechanisms. Along the same line our focus is *robotics* and especially *service robotics* which includes rescue robotics, rehabilitation and assistive robots for elderly and handicapped people. Although these topics were new for us when initiating the project we have spent two years determining priorities and guidelines by conducting about 200 interviews with field experts (end-users, praticians, family and caregivers, institutes), establishing strong collaboration with them (e.g. with the CHU of Nice-Cimiez) and putting together an appropriate experimental setup for testing our solutions. A direct consequence of setting up this research framework is a reduction in our publication and contract activities. But this may be considered as an investment as assistance robotics is a long term goal. It must be reminded that we are able to manage a large variety of problems in totally different domains only because interval analysis, game theory and symbolic tools provides us the methodological tools that allow us to address completely a given problem from the formulation and analysis up to the very final step of providing numerical solutions.

## **LAGADIC Project-Team**

# **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.

## LARSEN Team

# 4. Application Domains

## 4.1. Personal Assistance

During the last fifty years, many medical advances as well as the improvement of the quality of life have resulted in a longer life expectancy in industrial societies. The increase in the number of elderly people is a matter of public health because although elderly people can age in good health, old age also causes embrittlement, in particular on the physical plan which can result in a loss of autonomy. That will force us to re-think the current model regarding the care of elderly people.<sup>0</sup> Capacity limits in specialized institutes, along with the preference of elderly people to stay at home as long as possible, explain a growing need for specific services at home.

Ambient intelligence technologies and robotics could contribute to this societal challenge. The spectrum of possible actions in the field of elderly assistance is very large. We will focus on activity monitoring services, mobility or daily activity aids, medical rehabilitation, and social interactions. This will be based on the experimental infrastructure we have build in Nancy (Smart apartment platform) as well as the deep collaboration we have with OHS.<sup>0</sup>

## 4.2. Civil Robotics

Many applications for robotics technology exist within the services provided by national and local government. Typical applications include civil infrastructure services<sup>0</sup> such as: urban maintenance and cleaning; civil security services; emergency services involved in disaster management including search and rescue; environmental services such as surveillance of rivers, air quality, and pollution. These applications may be carried out by a wide variety of robot and operating modality, ranging from single robots or small fleets of homogeneous or heterogeneous robots. Often robot teams will need to cooperate to span a large workspace, for example in urban rubbish collection, and operate in potentially hostile environments, for example in disaster management. These systems are also likely to have extensive interaction with people and their environments.

The skills required for civil robots match those developed in the LARSEN project: operating for a long time in potentially hostile environment, potentially with small fleets of robots, and potentially in interaction with people.

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<sup>0</sup>See the Robotics 2020 Multi-Annual Roadmap [51], section 2.7.

<sup>0</sup>OHS (*Office d'Hygiène Sociale*) is an association managing several rehabilitation or retirement home structures.

<sup>0</sup>See the Robotics 2020 Multi-Annual Roadmap [51], section 2.5.

## **PERSVASIVE INTERACTION Team**

### **4. Application Domains**

#### **4.1. Smart Energy Systems**

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

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

#### **4.2. E-Textile**

Participant: Sabine Coquillart

Partner: LIMSI

Collaboration with the HAPCO team from LIMSI on e-textiles.

#### **4.3. Interaction with Pervasive Media**

Participants: Sabine Coquillart, Jingtao Chen

Partners: Inria GRA, GIPSA, G-SCOP

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

#### **4.4. Bayesian Reasoning**

Participants: Emmanuel Mazer, Marvin Faix

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

## **RITS Project-Team**

# **4. Application Domains**

## **4.1. Introduction**

While the preceding section focused on methodology, in connection with automated guided vehicles, it should be stressed that the evolution of the problems which we deal with, remains often guided by the technological developments. We enumerate three fields of application, whose relative importance varies with time and which have strong mutual dependencies: driving assistance, cars available in self-service mode and fully automated vehicles (cybercars).

## **4.2. Driving assistance**

Several techniques will soon help drivers. One of the first immediate goal is to improve security by alerting the driver when some potentially dangerous or dangerous situations arise, i.e. collision warning systems or lane tracking could help a bus driver and surrounding vehicle drivers to more efficiently operate their vehicles. Human factors issues could be addressed to control the driver workload based on additional information processing requirements. Another issue is to optimize individual journeys. This means developing software for calculating optimal (for the user or for the community) paths. Nowadays, path planning software is based on a static view of the traffic: efforts have to be done to take the dynamic component in account.

## **4.3. New transportation systems**

The problems related to the abusive use of the individual car in large cities led the populations and the political leaders to support the development of public transport. A demand exists for a transport of people and goods which associates quality of service, environmental protection and access to the greatest number. Thus the tram and the light subways of VAL type recently introduced into several cities in France conquered the populations, in spite of high financial costs. However, these means of mass transportation are only possible on lines on which there is a keen demand. As soon as one moves away from these “lines of desire” or when one deviates from the rush hours, these modes become expensive and offer can thus only be limited in space and time. To give a more flexible offer, it is necessary to plan more individual modes which approach the car as we know it. However, if one wants to enjoy the benefits of the individual car without suffering from their disadvantages, it is necessary to try to match several criteria: availability anywhere and anytime to all, lower air and soils pollution as well as sound levels, reduced ground space occupation, security, low cost. Electric or gas vehicles available in self-service, as in the Praxitèle system, bring a first response to these criteria. To be able to still better meet the needs, it is however necessary to re-examine the design of the vehicles on the following points:

- ease empty car moves to better distribute them;
- better use of information systems inboard and on ground;
- better integrate this system in the global transportation system.

These systems are now operating (i.e. in La Rochelle). The challenge is to bring them to an industrial phase by transferring technologies to these still experimental projects.

#### **4.4. Automated vehicles**

The long term effort of the project is to put automatically guided vehicles (cybercars) on the road. It seems too early to mix cybercars and traditional vehicles, but data processing and automation now make it possible to consider in the relatively short term the development of such vehicles and the adapted infrastructures. RITS aims at using these technologies on experimental platforms (vehicles and infrastructures) to accelerate the technology transfer and to innovate in this field. Other application can be precision docking systems that will allow buses to be automatically maneuvered into a loading zone or maintenance area, allowing easier access for passengers, or more efficient maintenance operations. Transit operating costs will also be reduced through decreased maintenance costs and less damage to the braking and steering systems. Regarding technical topics, several aspects of Cybercars have been developed at RITS this year. First, we have stabilized a generic Cycab architecture involving Inria SynDEx tool and CAN communications. The critical part of the vehicle is using a real-time SynDEx application controlling the actuators via two Motorola's MPC555. Today, we have decided to migrate to the new dsPIC architecture for more efficiency and ease of use. This application has a second feature, it can receive commands from an external source (Asynchronously to this time) on a second CAN bus. This external source can be a PC or a dedicated CPU, we call it high level. To work on the high level, in the past years we have been developing a R&D framework called (Taxi) which used to take control of the vehicle (Cycab and Yamaha) and process data such as gyro, GPS, cameras, wireless communications and so on. Today, in order to rely on a professional and maintained solution, we have chosen to migrate to the RTMaps SDK development platform. Today, all our developments and demonstrations are using this efficient prototyping platform. Thanks to RTMaps we have been able to do all the demonstrations on our cybercars: cycabs, Yamaha AGV and new Cybus platforms. These demonstrations include: reliable SLAMMOT algorithm using 2 to 4 laser sensors simultaneously, automatic line/road following techniques, PDA remote control, multi sensors data fusion, collaborative perception via ad-hoc network. The second main topic is inter-vehicle communications using ad-hoc networks. We have worked with the EVA team for setting and tuning OLSR, a dynamic routing protocol for vehicles communications. Our goal is to develop a vehicle dedicated communication software suite, running on a specialized hardware. It can be linked also with the Taxi Framework for getting data such GPS information's to help the routing algorithm.

**AYIN Team (section vide)**



## **LINKMEDIA Project-Team**

### **4. Application Domains**

#### **4.1. Asset management in the entertainment 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 consequently ever growing number of innovative applications 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.

## **MAGRIT Project-Team**

### **4. Application Domains**

#### **4.1. Augmented reality**

We have a significant experience in AR that allowed good progress in building usable, reliable and robust AR systems. Our contributions cover the entire process of AR: matching, pose initialization, 3D tracking, in-situ modeling, handling interaction between real and virtual objects....

#### **4.2. Medical Imaging**

For 15 years, we have been working in close collaboration with University Hospital of Nancy and GE Healthcare in interventional neuroradiology. Our common aim is to develop a multimodality framework to help therapeutic decisions and interventional gestures. Contributions of the team focus on the developments of AR tools for neuro-navigation as well as the development of simulation tools for training or planning. Laparoscopic surgery is another field of interest with the development of methods for tracking deformable organs based on bio-mechanical models. Some of these projects are developed in collaboration with the MIMESIS project team.

#### **4.3. Experimental mechanics**

In experimental solid mechanics, an important problem is to characterize properties of specimen subject to mechanical constraints, which makes it necessary to measure tiny strains. Contactless measurement techniques have emerged in the last few years and are spreading quickly. They are mainly based on images of the surface of the specimen on which a regular grid or a random speckle has been deposited. We are engaged since June 2012 in a transdisciplinary collaboration with Institut Pascal (Clermont-Ferrand Université). The aim is to characterize the metrological performances of these techniques limited by, e.g., the sensor noise, and to improve them by several dedicated image processing tools.

## **MORPHEO Project-Team**

# **4. Application Domains**

## **4.1. 4D modeling**

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

## **4.2. Shape Analysis**

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

## **4.3. Human Motion Analysis**

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

## **4.4. Interaction**

The ability to build models of humans in real time allows to develop interactive applications where users interact with virtual worlds. The recent evolutions of HMDs, e.g. Oculus Rift, HTC Vibe and Microsoft Hololens, offer now efficient solutions to visualize virtual worlds, which dramatically increases the need for new contents as well as new interactive and immersive solutions. Challenging issues in this domain include the development of real time applications for interactivity and the design of new interactive applications such as virtual fitting rooms.

**PERCEPTION Project-Team (section vide)**

## SIROCCO Project-Team

# 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 taking into account 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 of emerging imaging modalities

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. 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.

## STARS Project-Team

# 4. Application Domains

## 4.1. Introduction

While in our research the focus is to develop techniques, models and platforms that are generic and reusable, we also make effort in the development of real applications. The motivation is twofold. The first is to validate the new ideas and approaches we introduce. The second is to demonstrate how to build working systems for real applications of various domains based on the techniques and tools developed. Indeed, Stars focuses on two main domains: **video analytic** and **healthcare monitoring**.

## 4.2. Video Analytics

Our experience in video analytic [6], [1], [8] (also referred to as visual surveillance) is a strong basis which ensures both a precise view of the research topics to develop and a network of industrial partners ranging from end-users, integrators and software editors to provide data, objectives, evaluation and funding.

For instance, the Keeneo start-up was created in July 2005 for the industrialization and exploitation of Orion and Pulsar results in video analytic (VSIP library, which was a previous version of SUP). Keeneo has been bought by Digital Barriers in August 2011 and is now independent from Inria. However, Stars continues to maintain a close cooperation with Keeneo for impact analysis of SUP and for exploitation of new results.

Moreover new challenges are arising from the visual surveillance community. For instance, people detection and tracking in a crowded environment are still open issues despite the high competition on these topics. Also detecting abnormal activities may require to discover rare events from very large video data bases often characterized by noise or incomplete data.

## 4.3. Healthcare Monitoring

Since 2011, we have initiated a strategic partnership (called CobTek) with Nice hospital [63], [91] (CHU Nice, Prof P. Robert) to start ambitious research activities dedicated to healthcare monitoring and to assistive technologies. These new studies address the analysis of more complex spatio-temporal activities (e.g. complex interactions, long term activities).

### 4.3.1. Research

To achieve this objective, several topics need to be tackled. These topics can be summarized within two points: finer activity description and longitudinal experimentation. Finer activity description is needed for instance, to discriminate the activities (e.g. sitting, walking, eating) of Alzheimer patients from the ones of healthy older people. It is essential to be able to pre-diagnose dementia and to provide a better and more specialized care. Longer analysis is required when people monitoring aims at measuring the evolution of patient behavioral disorders. Setting up such long experimentation with dementia people has never been tried before but is necessary to have real-world validation. This is one of the challenge of the European FP7 project Dem@Care where several patient homes should be monitored over several months.

For this domain, a goal for Stars is to allow people with dementia to continue living in a self-sufficient manner in their own homes or residential centers, away from a hospital, as well as to allow clinicians and caregivers remotely provide effective care and management. For all this to become possible, comprehensive monitoring of the daily life of the person with dementia is deemed necessary, since caregivers and clinicians will need a comprehensive view of the person's daily activities, behavioral patterns, lifestyle, as well as changes in them, indicating the progression of their condition.

### **4.3.2. Ethical and Acceptability Issues**

The development and ultimate use of novel assistive technologies by a vulnerable user group such as individuals with dementia, and the assessment methodologies planned by Stars are not free of ethical, or even legal concerns, even if many studies have shown how these Information and Communication Technologies (ICT) can be useful and well accepted by older people with or without impairments. Thus one goal of Stars team is to design the right technologies that can provide the appropriate information to the medical carers while preserving people privacy. Moreover, Stars will pay particular attention to ethical, acceptability, legal and privacy concerns that may arise, addressing them in a professional way following the corresponding established EU and national laws and regulations, especially when outside France. Now, Stars can benefit from the support of the COERLE (Comité Opérationnel d'Evaluation des Risques Légaux et Ethiques) to help it to respect ethical policies in its applications.

As presented in 3.1 , Stars aims at designing cognitive vision systems with perceptual capabilities to monitor efficiently people activities. As a matter of fact, vision sensors can be seen as intrusive ones, even if no images are acquired or transmitted (only meta-data describing activities need to be collected). Therefore new communication paradigms and other sensors (e.g. accelerometers, RFID, and new sensors to come in the future) are also envisaged to provide the most appropriate services to the observed people, while preserving their privacy. To better understand ethical issues, Stars members are already involved in several ethical organizations. For instance, F. Brémond has been a member of the ODEGAM - "Commission Ethique et Droit" (a local association in Nice area for ethical issues related to older people) from 2010 to 2011 and a member of the French scientific council for the national seminar on "La maladie d'Alzheimer et les nouvelles technologies - Enjeux éthiques et questions de société" in 2011. This council has in particular proposed a chart and guidelines for conducting researches with dementia patients.

For addressing the acceptability issues, focus groups and HMI (Human Machine Interaction) experts, will be consulted on the most adequate range of mechanisms to interact and display information to older people.



## **THOTH Project-Team**

# **4. Application Domains**

## **4.1. Visual applications**

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

- Semantic-level image and video access is highly relevant for visual search on the Web, in professional archives and personal collections.
- Visual data organization is applicable to organizing family photo and video albums as well as to large-scale information retrieval.
- Visual object recognition has potential applications ranging from surveillance, service robotics for assistance in day-to-day activities as well as the medical domain.
- Action recognition is highly relevant to visual surveillance, assisted driving and video access.
- Real-time scene understanding is relevant for human interaction through devices such as HoloLens, Oculus Rift.

## **WILLOW Project-Team**

# **4. Application Domains**

## **4.1. Introduction**

We believe that foundational modeling work should be grounded in applications. This includes (but is not restricted to) the following high-impact domains.

## **4.2. Quantitative image analysis in science and humanities**

We plan to apply our 3D object and scene modeling and analysis technology to image-based modeling of human skeletons and artifacts in anthropology, and large-scale site indexing, modeling, and retrieval in archaeology and cultural heritage preservation. Most existing work in this domain concentrates on image-based rendering, that is, the synthesis of good-looking pictures of artifacts and digs. We plan to focus instead on quantitative applications. We are engaged in a project involving the archaeology laboratory at ENS and focusing on image-based artifact modeling and decorative pattern retrieval in Pompeii. Application of our 3D reconstruction technology is now being explored in the field of cultural heritage and archeology by the start-up Iconem, founded by Y. Ubelmann, a Willow collaborator.

## **4.3. Video Annotation, Interpretation, and Retrieval**

Both specific and category-level object and scene recognition can be used to annotate, augment, index, and retrieve video segments in the audiovisual domain. The Video Google system developed by Sivic and Zisserman (2005) for retrieving shots containing specific objects is an early success in that area. A sample application, suggested by discussions with Institut National de l'Audiovisuel (INA) staff, is to match set photographs with actual shots in film and video archives, despite the fact that detailed timetables and/or annotations are typically not available for either medium. Automatically annotating the shots is of course also relevant for archives that may record hundreds of thousands of hours of video. Some of these applications will be pursued in our MSR-Inria project.