RESEARCH CENTER
Lille - Nord Europe

FIELD

Activity Report 2013

Section Application Domains

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ATEAMS Project-Team (section vide)

DREAMPAL Team

4. Application Domains

4.1. Reflective Camera Networks

HiPEAC vision 2011-2012:

> *"reconfiguration, customization and runtime adaptation techniques will facilitate switching between tasks during the deployment of smart camera networks"*

A Smart Camera (SC) is a vision system which, in addition to image-capturing capabilities, is able to extract application-specific information from the captured images and to automatically make intelligent decisions based on them. Dynamicity is inherent in SCs: processing may change depending on the specific observations they make and on the context. For example, an SC may use a low-quality face recognition IP while observing an office during the day, but switch to a high-quality one if it detects an intrusion during the night. Moreover, image processing requires high-performance computing, which is achieved by using parallelism. Thus, the integration of dynamic reconfiguration and parallelism, which is addressed by our project, is naturally present in SCs. Previous work in the DaRT team has already explored efficient uses of FPGAs in an SC network deployed in a retail store. A new proposal concerns embedded reflective camera in the Smart Cities multidisciplinary project developed on the University Lille 1 campus.

4.2. Set-top Boxes

Television sets and set-top-boxes are forming a symbiotic connection, which relies on common standards and protocols such as DLNA, Web standards, Web 2.0, H264, HEVC... As a result, the hardware platform on which applications run is becoming less important: commonly used ISAs like x86 are not mandatory any more. Dedicated pieces of hardware could efficiently provide specific services according to user requests. End-users expect platforms supporting many services with maximum performance, but do not require all of them at the same time. Dynamic reconfiguration is here too a good compromise, and it is efficient enough to support high performance algorithms like H264 or HEVC. It could also provide a ground for supporting on-the-fly codec switching. This may occur because the broadcaster decides to change the encoding of its video signal for safety reasons. Nowadays this operation is performed by a software because changing a hard codec still means flashing the set-top boxes to update it. Dreampal has started a collaboration with Kalray (http://www.kalray.eu) to develop a massively parallel language (without dynamic reconfiguration facilities, for now) on their MPSoC. H264 will be tested on this chip and on special FPGA boards with dedicated extensions for multimedia applications like the Xilinx Zynq.

4.3. Safe and Intelligent Transportation

Safety issues are today a key differentiator in the transportation industrial sector. The supervision and the detection of dangerous situations is a key technological challenge for future transportation systems at the infrastructure and vehicle levels. As an example, various obstacles can be detected on the road or in a Level Crossing (LC) using embedded systems. The proposed system will be based on stereo-vision technology (high definition cameras) and embedded reconfigurable computing and can be integrated either in vehicles or in the rail network. Also, Dreampal has started a collaboration with INDUCT (http://induct-technology.com/) to develop reconfigurable parallel architecture for the detection and the identification of obstacles in the frame of the NAVIA (autonomous electrical vehicle) project. This application will be implemented on Xilinx Zynq-based boards equipped with video processing features.

DOLPHIN Project-Team

4. Application Domains

4.1. Academic Benchmark Problems

- ρMNK-landscapes [34] constitute a problem-independent model used for constructing multiobjective multimodal landscapes with objective correlation. They extend single-objective NK-landscapes [90] and multiobjective NK-landscapes with independent objective functions [85]. The four parameters defining a ρMNK-landscape are: (i) the size of (binary string) solutions N, (ii) the variable correlation $K < N$, (iii) the number of objective functions M, and (iv) the correlation coefficient ρ. A number of problem instances and an instance generator are available at the following URL: http://mocobench.sf.net/.
- The Unconstrained Binary Quadratic Programming (UBQP) problem is known to be a unified modeling and solution framework for many combinatorial optimization problems [91]. Given a collection of n items such that each pair of items is associated with a profit value that can be positive, negative or zero, UBQP seeks a subset of items that maximizes the sum of their paired values. In [29], we proposed an extension of the single-objective UBQP to the multiobjective case (mUBQP), where multiple objectives are to be optimized simultaneously. We showed that the mUBQP problem is both NP-hard and intractable. Some problem instances with different characteristics and an instance generator are also available at the following URL: http://mocobench.sf.net/.

4.2. Transportation and logistics

- **Scheduling problems:** The flow-shop scheduling problem is one of the most well-known problems from scheduling. However, most of the works in the literature use a single-objective formulation. In general, the minimized objective is the total completion time (makespan). Many other criteria may be used to schedule tasks on different machines: maximum tardiness, total tardiness, mean job flowtime, number of delayed jobs, maximum job flowtime, etc. In the DOLPHIN project, a bi-criteria model, which consists in minimizing the makespan and the total tardiness, is studied. Multiple combinations of two objective functions have also been investigated. At last, a three-objective flow-shop problem, minimizing in addition the maximum tardiness, is also studied. It allows us to develop and test multi-objective (and not only bi-objective) exact methods.
- **Routing problems:** The vehicle routing problem (VRP) is a well-known problem and it has been studied since the end of the fifties. It has a lot of practical applications in many industrial areas (ex. transportation, logistics, etc). Existing studies of the VRP are almost all concerned with the minimization of the total distance only. The model studied in the DOLPHIN project introduces a second objective, whose purpose is to balance the length of the tours. This new criterion is expressed as the minimization of the difference between the length of the longest tour and the length of the shortest tour. As far as we know, this model is one of the pioneer works in the literature. One of our current goals, related to an Inria ADT project, is to a propose VRP library called VRP-solve that is able to cope with a multiple objective and a large number of constraints. This code will be used in future industrial collaborations, and already includes algorithms to use GIS.
- **Packing problems:** In logistic and transportation fields, packing problems may be a major issue in the delivery process. They arise when one wants to minimize the size of a warehouse or a cargo, the number of boxes, or the number of vehicles used to deliver a batch of items. These problems have been the subjects of many papers, but only few of them study multi-objective cases, and to our knowledge, never from an exact point of view. Such a case occurs for example when some pairs of items cannot be packed in the same bin. The DOLPHIN project is currently studying the problem in its one-dimensional version. We plan to generalize our approach to two and three dimensional problems, and to more other conflict constraints, with the notion of *distance* between items.

4.3. Bioinformatics and Health care

Bioinformatic research is a great challenge for our society and numerous research entities of different specialities (biology, medical or information technology) are collaborating on specific themes.

4.3.1. Genomic and post-genomic studies

Previous studies of the DOLPHIN project mainly deal with genomic and postgenomic applications. These have been realized in collaboration with academic and industrial partners (IBL: Biology Institute of Lille; IPL: Pasteur Institute of Lille; IT-Omics firm).

First, genomic studies aim at analyzing genetic factors which may explain multi-factorial diseases such as diabetes, obesity or cardiovascular diseases. The scientific goal was to formulate hypotheses describing associations that may have any influence on diseases under study.

Secondly, in the context of post-genomic, a very large amount of data are obtained thanks to advanced technologies and have to be analyzed. Hence, one of the goals of the project was to develop analysis methods in order to discover knowledge in data coming from biological experiments.

These problems can be modeled as classical data mining tasks (Association rules, feature selection). As the combinatoric of such problems is very high and the quality criteria not unique, we proposed to model these problems as multi-objective combinatorial optimization problems. Evolutionary approaches have been adopted in order to cope with large scale problems.

Nowadays the technology is still going fast and the amount of data increases rapidly. Within the collaboration, started in 2010, with Genes Diffusion, specialized in genetics and animal reproduction for bovine, swine, equine and rabbit species, we study combinations of Single Nucleotide Polymorphisms (SNP) that can explain some phenotypic characteristics. Therefore feature selection for regression is addressed using metaheuristics.

4.3.2. Optimization for health care

The collaboration (PhD thesis 2010-2013) with the Alicante company, a major actor in the hospital decision making, deals with knowledge extraction by optimization methods for improving the process of inclusion in clinical trials. Indeed, conducting a clinical trial, allowing for example to measure the effectiveness of a treatment, involves selecting a set of patients likely to participate to this test. Currently existing selection processes are far from optimal, and many potential patients are not considered. The objective of this collaboration consists in helping the practitioner to quickly determine if a patient is interesting for a clinical trial or not. Exploring different data sources (from a hospital information system, patient data...), a set of decision rules have to be generated. For this, approaches from multi-objective combinatorial optimization are implemented, requiring extensive work to model the problem, to define criteria optimization and to design specific optimization methods.

MODAL Project-Team

4. Application Domains

4.1. Domain

Potential application areas of statistical modeling for heterogeneous data are extensive but some particular areas are identified. For historical reasons and considering the background of the team members, MODAL is mainly focused on biological applications where new challenges in high throughput technologies are opened. In addition, other secondary applications areas are considered in industry, retail, credit scoring and astronomy. Several contacts and collaborations are already established with some partners in these application areas and are described in Sections 7 and 8.

NON-A Project-Team

4. Application Domains

4.1. Networked robots

Both economically and scientifically, cooperation in robot swarms represents an important issue since it concerns many service applications (health, handicap, urban transports...) and can increase the potential of sensor networks [4]. It involves several challenges such as:
- Because autonomy is a key for being able to increase the network size, maximize the autonomy of the robots in their different tasks of localization, motion, communication;
- Aiming at making 1+1 be more than 2, extend the global potential of the swarm by introducing collaboration (exchanging information with other robots) and cooperation (acting with other robots);
- Include time and energy saving considerations at the design stage.

The self deployment of autonomous groups of mobile robots in an unknown environment (including different kinds of static or moving obstacles) involves localization, path planning and robust control problems. Both the control and signal aspects of our researches are oriented to solve some problems coming from – or taking advantage of – such collaboration frameworks. To mention a few:
- Localization using as few as possible landmarks and exteroceptive information by means of derivative estimates;
- Image-based sensing algorithms inspired by our multidimensional estimation techniques;
- Detection and adaptation to sudden loss of communication, time-varying topology, or communication delays;
- Robust, autonomous, energy-aware controllers based on either model-free or model-based techniques.

Several algorithms have already been applied to the control of formations of mobile robots: an illustrative platform is currently developed at EuraTechnologie center within the framework of *Non-A*[5]. They are now being extended to medical devices (such as wheelchairs) within the European project *SYSIASS* (see http://www.sysiass.eu), in collaboration with partners from hospital settings.

Another future application concerns Wireless Sensor and Robot Networks (WSRN, Fig. 2), dedicated to the surveillance of zones, to the exploration of hostile areas, or to the supervision of large scale sensor networks. The main idea here is to integrate mobile nodes (the mobile robots) within the sensor network, allowing to overcome a sensor defection, to maintain the connectivity of the network, or to extend the coverage area during a random deployment. This involves consideration about mobile actuators within a mobile network of sensors and control networks (wireless) with strong constraints on the possibilities of communication in a noisy and non-homogeneous environment. This work is made in close collaboration with the Inria project-team *POPS* (Lille), which brings its expertise in terms of sensor networks. It takes place in the framework of the Inria ADT *SENSAS* and represents our contribution to the LABEX proposal *ICON*.

4.2. Nano/macro machining

Nano machining:

[4]Integrating wireless sensor networks and multi-robot systems increases the potential of the sensors: robots, in comparison, are resource-rich and can be involved in taking decisions and performing appropriate actions on themselves on sensors and/or the environment.

[5]"RobotCity" was exhibited for the first time during the opening ceremony held on April 6th, 2011

../../../../projets/non-a/IMG/WSRN.png

Figure 2. An illustration of collaboration in a Wireless Sensor and Robot Network.

Recent research investigations have reported the development of a number of process chains that are complementary to those used for batch manufacturing of Micro Electro Mechanical Systems (MEMS) and, at the same time, broaden the application domain of products incorporating micro and nano scale features. Such alternative process chains combine micro and nano structuring technologies for master making with replication techniques for high volume production such as injection moulding and roll-to-roll imprinting. In association with the Manufacturing Engineering Center of Cardiff, Arts et Metiers ParisTech center of Lille develops a new process chain for the fabrication of components with nano scale features. In particular, AFM probe-based nano mechanical machining is employed as an alternative master making technology to commonly used lithography-based processes (Fig. 3). Previous experimental studies demonstrated the potential of this approach for thermoplastic materials. Such a manufacturing route also represents an attractive prototyping solution to test the functionalities of components with nano scale features prior to their mass fabrication and, thus, to reduce the development time and cost of nano technology-enabled products. Application of our control and estimation techniques improves the trajectory tracking accuracy and the speed of the machining tools.

../../../../projets/non-a/IMG/nano-logo.png

../../../../projets/non-a/IMG/nano-pos

Figure 3. Left: A machined nano structure: 16μm ×8μm × some nm. Right: Nano-positioning system available at Arts et Métiers ParisTech Lille (75 μm range of motion).

Machining with industrial robots:

Industrials are enthusiastic to replace machine-tools with industrial robots: compared to machine-tools, industrial articulated robots are very cheaper, more flexible, and exhibit more important workspaces. They can carry out machining applications like prototyping, cleaning and pre-machining of cast parts, as well as end-machining of middle tolerance parts. Such applications require high accuracy in the positioning and path tracking. Unfortunately, industrial robots have a low stiffness and are not that accurate [6] and they deserve an increased quality of control.

We deal with the modelling and the on-line identification of flexible-joint robot models. This can be used both for dynamic simulation and model-based control of industrial robots. We address the problem of real-time identification of the parameters involved in the dynamic linear model of an industrial robot axis. This

[6] Industrial robots were designed to realize repeatable tasks. The robot repeatability ranges typically from 0.03 to 0.1mm, but the accuracy is often measured to be within several millimetres. Due to their serial structure, articulated robot has lower stiffness (less than 1 N/mm) than classical machine-tools (greater than 50 N/mm). These poor accuracy and stiffness are caused by many factors, such as geometric parameter errors (manufacturing tolerances), wear of parts and components replacement, as well as flexibility of links and gear trains, gear backlashes, encoder resolution errors and thermal effects.

is possible thanks to a special sensor developed by Arts et Métiers, subject to an EADS project within the FUI (Fonds Unique Interministériel). Control algorithms for other machining actuators such as active magnet bearings are also under study. Within the framework of LAGIS, we also consider the remote control of industrial robots (via internet of Wi-Fi links, for instance), which sets numerous problems in relation with the communication delays.

4.3. Multicell chopper

On the basis of benchmarks developed at ECS-lab (ENSEA Cergy), we intend to work on the control and observation of serial and parallel multicell choppers, as well as more usual power converters. These power electronic systems associated with their respective loads are typical hybrid dynamical systems and many industrial and/or theoretical challenging problems occur. For example, in the industrial problem of power supply for a supercomputer, the parallel multicell chopper appears as a new solution particularly with respect to the power efficiency. Nevertheless, the observation and control of such hybrid dynamical systems is a difficult task, where non asymptotic estimation and control can be useful.

SequeL Project-Team

4. Application Domains

4.1. In Short

SEQUEL aims at solving problems of prediction, as well as problems of optimal and adaptive control. As such, the application domains are very numerous.

The application domains have been organized as follows:

- adaptive control,
- signal processing and functional prediction,
- medical applications,
- web mining,
- computer games.

4.2. Adaptive Control

Adaptive control is an important application of the research being done in SEQUEL. Reinforcement learning (RL) precisely aims at controling the behavior of systems and may be used in situations with more or less information available. Of course, the more information, the better, in which case methods of (approximate) dynamic programming may be used [40]. But, reinforcement learning may also handle situations where the dynamics of the system is unknown, situations where the system is partially observable, and non stationary situations. Indeed, in these cases, the behavior is learned by interacting with the environment and thus naturally adapts to the changes of the environment. Furthermore, the adaptive system may also take advantage of expert knowledge when available.

Clearly, the spectrum of potential applications is very wide: as far as an agent (a human, a robot, a virtual agent) has to take a decision, in particular in cases where he lacks some information to take the decision, this enters the scope of our activities. To exemplify the potential applications, let us cite:

- game softwares: in the 1990's, RL has been the basis of a very successful Backgammon program, TD-Gammon [46] that learned to play at an expert level by basically playing a very large amount of games against itself. Today, various games are studied with RL techniques.
- many optimization problems that are closely related to operation research, but taking into account the uncertainty, and the stochasticity of the environment: see the job-shop scheduling, or the cellular phone frequency allocation problems, resource allocation in general [40]
- we can also foresee that some progress may be made by using RL to design adaptive conversational agents, or system-level as well as application-level operating systems that adapt to their users habits.

  More generally, these ideas fall into what adaptive control may bring to human beings, in making their life simpler, by being embedded in an environment that is made to help them, an idea phrased as "ambient intelligence".
- The sensor management problem consists in determining the best way to task several sensors when each sensor has many modes and search patterns. In the detection/tracking applications, the tasks assigned to a sensor management system are for instance:
  - detect targets,
  - track the targets in the case of a moving target and/or a smart target (a smart target can change its behavior when it detects that it is under analysis),
  - combine all the detections in order to track each moving target,
  - dynamically allocate the sensors in order to achieve the previous three tasks in an optimal way. The allocation of sensors, and their modes, thus defines the action space of the underlying Markov decision problem.

In the more general situation, some sensors may be localized at the same place while others are dispatched over a given volume. Tasking a sensor may include, at each moment, such choices as where to point and/or what mode to use. Tasking a group of sensors includes the tasking of each individual sensor but also the choice of collaborating sensors subgroups. Of course, the sensor management problem is related to an objective. In general, sensors must balance complex trade-offs between achieving mission goals such as detecting new targets, tracking existing targets, and identifying existing targets. The word "target" is used here in its most general meaning, and the potential applications are not restricted to military applications. Whatever the underlying application, the sensor management problem consists in choosing at each time an action within the set of available actions.

- sequential decision processes are also very well-known in economy. They may be used as a decision aid tool, to help in the design of social helps, or the implementation of plants (see [44], [43] for such applications).

4.3. Signal Processing

Applications of sequential learning in the field of signal processing are also very numerous. A signal is naturally sequential as it flows. It usually comes from the recording of the output of sensors but the recording of any sequence of numbers may be considered as a signal like the stock-exchange rates evolution with respect to time and/or place, the number of consumers at a mall entrance or the number of connections to a web site. Signal processing has several objectives: predict , estimate, remove noise, characterize or classify. The signal is often considered as sequential: we want to predict, estimate or classify a value (or a feature) at time t knowing the past values of the parameter of interest or past values of data related to this parameter. This is typically the case in estimation processes arising in dynamical systems.

Signals may be processed in several ways. One of the best–known way is the time-frequency analysis in which the frequencies of each signal are analyzed with respect to time. This concept has been generalized to the time-scale analysis obtained by a wavelet transform. Both analysis are based on the projection of the original signal onto a well-chosen function basis. Signal processing is also closely related to the probability field as the uncertainty inherent to many signals leads to consider them as stochastic processes: the Bayesian framework is actually one of the main frameworks within which signals are processed for many purposes. It is worth noting that Bayesian analysis can be used jointly with a time-frequency or a wavelet analysis. However, alternatives like belief functions came up these last years. Belief functions were introduced by Demspter few decades ago and have been successfully used in the few past years in fields where probability had, during many years, no alternatives like in classification. Belief functions can be viewed as a generalization of probabilities which can capture both imprecision and uncertainty. Belief functions are also closely related to data fusion.

4.4. Medical Applications

One of the initial motivations of the multi-arm bandit theory stems from clinical trials when one researches the effects of different treatments while maximizing the improvement of the patients' health states.

Medical health-care and in particular patient-management is up today one of the most important applications of the sequential decision making. This is because the treatment of the more complex health problems is typically sequential: A physician repeatedly observes the current state of the patient and makes the decision in order to improve the health condition as measured for example by *qualys* (quality adjusted life years).

Moreover, machine learning methods may be used for at least two means in neuroscience:

1. as in any other (experimental) scientific domain, the machine learning methods relying heavily on statistics, they may be used to analyse experimental data,
2. dealing with induction learning, that is the ability to generalize from facts which is an ability that is considered to be one of the basic components of "intelligence", machine learning may be considered as a model of learning in living beings. In particular, the temporal difference methods for reinforcement learning have strong ties with various concepts of psychology (Thorndike's law of effect, and the Rescorla-Wagner law to name the two most well-known).

4.5. Web Mining

We work on the news/ad recommendation. These online learning algorithms reached a critical importance over the last few years due to these major applications. After designing a new algorithm, it is critical to be able to evaluate it without having to plug it into the real application in order to protect user experiences or/and the company's revenue. To do this, people used to build simulators of user behaviors and try to achieve good performances against it. However designing such a simulator is probably much more difficult than designing the algorithm itself! An other common way to evaluate is to not consider the exploration/exploitation dilemma (also known as “Cold Start” for recommender systems). Lately data-driven methods have been developed. We are working on building automatic replay methodology with some theoretical guarantees. This work also exhibits strong link with the choice of the number of contexts to use with recommender systems wrt your audience.

An other point is that web sites must forecast Web page views in order to plan computer resource allocation and estimate upcoming revenue and advertising growth. In this work, we focus on extracting trends and seasonal patterns from page view series. We investigate Holt-Winters/ARIMA like procedures and some regularized models for making short-term prediction (3-6 weeks) wrt to logged data of several big media websites. We work on some news event related webpages and we feel that kind of time series deserves a particular attention. Self-similarity is found to exist at multiple time scales of network traffic, and can be exploited for prediction. In particular, it is found that Web page views exhibit strong impulsive changes occasionally. The impulses cause large prediction errors long after their occurrences and can sometimes be predicted (*e.g.*, elections, sport events, editorial changes,holidays) in order to improve accuracies. It also seems that some promising model could arise from using global trends shift in the population.

4.6. Games

The problem of artificial intelligence in games consists in choosing actions of players in order to produce artificial opponents. Most games can be formalized as Markov decision problems, so they can be approached with reinforcement learning.

In particular, SEQUEL was a pioneer of Monte Carlo Tree Search, a technique that obtained spectacular successes in the game of Go. Other application domains include the game of poker and the Japanese card game of hanafuda.

SIMPAF Project-Team

4. Application Domains

4.1. Physics

Our applications to physics concern:

- non-equilibrium statistical physics
- cold atoms
- laser propagation
- Maxwell equations

4.1.1. Non-equilibrium statistical physics

Describing, understanding, predicting and controlling the complex physical phenomena occurring in classical or quantum dynamical systems with a large or infinite number of degrees of freedom are important issues for equilibrium and non-equilibrium statistical mechanics and remain an important challenge for mathematical physics. Some of the typical questions are the following. How does a collective dynamics emerge from the interactions of individual entities? How to compute transport coefficients in terms of microscopic quantities and more generally, what is the role of the local (microscopic) dynamics on global transport properties? What are the system ergodic properties and how are asymptotic states, if they exist, approached? What are the dynamical mechanisms for approach to equilibrium in such systems?

4.1.2. Cold atoms

A typical problem we are concerned with is the effect of interactions (modeled by a nonlinearity in the evolution equation) on the localization properties of quantum kicked rotors, experimentally realized in cold-atom experiments.

4.1.3. Laser propagation

We are interested in variants of the NonLinear Schrödinger Equation (NLSE), which govern the evolution of optical fibers, and in particular photonic crystal fibers (PCF). These are key to information and communication technology, and form an unmatchable platform to explore complex nonlinear phenomena.

4.1.4. Maxwell equations

A posteriori error estimators developed for the Maxwell equations are very useful tools for practical computations. They are implemented in the software "Carmel-3D" (see the softwares section). This numerical code is used in order to study some original applications, like electrical machines or specific actuators. It is also devoted to nondestructive control by the use of Foucault currents, to the simulation of devices using magnetic fluids or of induced currents in human bodies.

4.2. Continuum mechanics

Our applications to continuum mechanics concern:

- the numerical simulation of viscous flows
- the mathematical and numerical derivation of rubber elasticity from polymer physics

4.2.1. Numerical simulation of viscous flows

We are concerned with systems of PDEs describing the evolution of mixture flows. The fluid is described by the density, the velocity and the pressure. These quantities obey mass and momentum conservation. On the one hand, when we deal with the 2D variable density incompressible Navier-Stokes equations, we aim to study some instabilities phenomena such as the Raileigh-Taylor instability. On the other hand, diffuse interface models have gained renewed interest for the last few years in fluid mechanics applications. From a physical viewpoint, they allow to describe some phase transition phenomena. If the Fick's law relates the divergence of the velocity field to derivatives of the density, one obtain the so called Kazhikhov-Smagulov model. Here, the density of the mixture is naturally highly non homogeneous, and the constitutive law accounts for diffusion effects between the constituents of the mixture. Furthermore, a surface tension force can be added to the momentum equation introducing a specific stress tensor, proposed for the first time by Korteweg. The first phenomena that we try to reproduce are the powder-snow avalanches, but we can also model flows where species (like salt or pollutant) are dissolved in a compressible or incompressible fluid. Other similar hydrodynamic models arise in combustion theory.

Flow control strategies using passive or active devices are crucial tools in order to save energy in transports (especially for cars, trucks or planes), or to avoid the fatigue of some materials arising in a vast amount of applications. Nowadays, shape optimization needs to be completed by other original means, such as porous media located on the profiles, as well as vortex generator jets in order to drive active control.

4.2.2. From polymer physics to rubber elasticity

Our aim is to rigorously derive nonlinear elasticity theory from polymer physics. The starting point is the statistical physics description of polymer-chains. Under some proper rescaling, this discrete model converges to continuum nonlinear elasticity models in the sense of Gamma-convergence. The long-term goal of our approach is to derive practical constitutive laws for rubbers (to be used in nonlinear elasticity softwares) from the discrete model.

4.3. Corrosion models

4.3.1. Corrosion modelling of iron based alloy in nuclear waste repository

The concept for long term storage of high-level radioactive waste in France under study is based on an underground repository. The waste shall be confined in a glass matrix and then placed into cylindrical steel canisters. These containers shall be placed into micro-tunnels in the highly impermeable Callovo-Oxfordian claystone layer at a depth of several hundred meters. At the request of the French nuclear waste management agency ANDRA, investigations are conducted to optimize and finalize this repository concept with the aim to ensure its long-term safety and its reversibility. The long-term safety assessment of the geological repository has to take into account the degradation of the carbon steel used for the waste overpacks and the cell disposal liners, which are in contact with the claystone formation. This degradation is mainly caused by generalized corrosion processes which form a passive layer on the metal surface consisting of a dense oxide inner layer and a porous hydroxide outer layer in contact with the groundwater in the pore space of the claystones. The processes take place under anaerobic conditions, since the groundwater is anoxic.

As a tool to investigate the corrosion processes at the surface of the carbon steel canisters, the Diffusion Poisson Coupled Model (DPCM) for corrosion has been developed by Bataillon *et al.* [32]. The numerical approximation of this corrosion model and some associated models by accurate and efficient methods is challenging. Theoretical study of the models (existence of solutions, long time behavior) is also worthy of interest.

4.3.2. Corrosion modeling of Ni-base alloys in Pressurized Water Reactor primary water

The understanding of the oxidation behavior of Ni-base alloys in Pressurized Water Reactor (PWR) primary water is of major importance due to the cations released due to corrosion of the steam generators which is a source of the radioactivity of the primary circuit. Moreover, the oxidation process is the reason of the initiation of intergranular stress corrosion cracking in some alloys. A numerical model, called EKINOX (Estimation KINetics OXydation), has been developed at CEA [33] in order to simulate the oxide scale growth.This model should be able to calculate the evolutions of concentration profiles of the species and of their point defects in the oxide and in the substrate. Numerical experiments have shown the limits of this existing numerical model, especially the need of very small time steps for the computations ; a macroscopic model has been developed and numerical methods proposed for its simulation.

BONSAI Project-Team

4. Application Domains

4.1. Sequence processing for Next Generation Sequencing

As said in the introduction of this document, biological sequence analysis is a foundation subject for the team. In the last years, sequencing techniques experienced remarkable advances with NGS, that allow for fast and low-cost acquisition of huge amounts of sequence data, and outperforms conventional sequencing methods. These technologies can apply to genomics, with DNA sequencing, as well as to transcriptomics, with RNA sequencing allowing to gene expression analysis. They promise to address a broad range of applications including: Comparative genomics, individual genomics, high-throughput SNP detection, identifying small RNAs, identifying mutant genes in disease pathways, profiling transcriptomes for organisms where little information is available, researching lowly expressed genes, studying the biodiversity in metagenomics. From a computational point of view, NGS gives rise to new problems and gives new insight on old problems by revisiting them: Accurate and efficient remapping, pre-assembling, fast and accurate search of non exact but quality labelled reads, functional annotation of reads, ...

4.2. Noncoding RNA

Our expertise in sequence analysis also applies to noncodingRNA analysis. Noncoding RNA genes play a key role in many cellular processes. First examples were given by microRNAs (miRNAs) that were initially found to regulate development in *C. elegans*, or small nucleolar RNAs (snoRNAs) that guide chemical modifications of other RNAs in mammals. Hundreds of miRNAs are estimated to be present in the human genome, and computational analysis suggests that more than 20% of human genes are regulated by miRNAs. To go further in this direction, the 2007 ENCODE Pilot Project provides convincing evidence that the Human genome is pervasively transcribed, and that a large part of this transcriptional output does not appear to encode proteins. All those observations open a universe of “RNA dark matter” that must be explored. From a combinatorial point of view, noncoding RNAs are complex objects. They are single stranded nucleic acids sequences that can fold forming long-range base pairings. This implies that RNA structures are usually modelled by complex combinatorial objects, such as ordered labeled trees, graphs or arc-annotated sequences.

4.3. Genome structures

Our third application domain is concerned with the structural organization of genomes. Genome rearrangements are able to change genome architecture by modifying the order of genes or genomic fragments. The first studies were based on linkage maps and mathematical models fifteen year old mathematical models. But the usage of computational tools was still limited due to the lack of data. The increasing availability of complete and partial genomes now offers an unprecedented opportunity to analyse genome rearrangements in a systematic way and gives rise to a wide spectrum of problems: Taking into account several kinds of evolutionary events, looking for evolutionary paths conserving common structure of genomes, dealing with duplicated content, being able to analyse large sets of genomes even at the intraspecific level, computing ancestral genomes and paths transforming these genomes into several descendant genomes.

4.4. Nonribosomal peptides

Lastly, the team has been developing for several years a tight collaboration with Probiogem lab on nonribosomal peptides, and has became a leader on that topic. Nonribosomal peptide synthesis produces small peptides not going through the central dogma. As the name suggests, this synthesis uses neither messenger RNA nor ribosome but huge enzymatic complexes called nonribosomal peptide synthetases (NRPSs). This alternative pathway is found typically in bacteria and fungi. It has been described for the first time in the 70’s [14]. For the last decade, the interest in nonribosomal peptides and their synthetases has considerably increased, as witnessed by the growing number of publications in this field. These peptides are or can be used in many biotechnological and pharmaceutical applications (e.g. anti-tumors, antibiotics, immuno-modulators).

SHACRA Project-Team

4. Application Domains

4.1. Medical Simulation

Some of the scientific challenges described previously can be seen in a general context (such as solving constraints between different types of objects, parallel computing for interactive simulations, etc.) but often it is necessary to define a clinical context for the problem. This is required in particular for defining the appropriate assumptions in various stages of the biophysical modeling. It is also necessary to validate the results. This clinical context is a combination of two elements: the procedure we attempt to simulate and the objective of the simulation: training, planning or per-operative guidance. Several simulators applications are being developped in the team for instance Interventional Cerebro- and Cardio- vascular Radiology, Minimally-invasive ear surgery, Deep-Brain Stimulation planning...

It is important also to note that developing these applications raises many challenges and as such this step should be seen as an integral part of our research. It is also through the development of these applications that we can communicate with physicians, and validate our results. SOFA will be used as a backbone for the integration of our research into clinical applications.

4.2. Robotics

Contrary to rigid robots, the number of degrees of freedom (dof) of soft robots is infinite. On the one hand, a great advantage is to multiply the actuators and actuating shapes in the structure to expand the size of the workspace. In the other hand, these actuators are coupled together by the deformation of the robot which makes the control very tricky. Moreover, if colliding their direct environment, the robots may deform and also deform the environment, which complicates even more the control.

This project would build on our recent results, that use a real-time implementation of the finite element method to compute adequately the control of the structure. The present results allow to compute, in real-time, an inverse model of the robot (i.e. provide the displacements of the actuator that creates a desired motion of the end effector of the robot) for a few number of actuators and with simple interactions with its environment. However, the design of the robots, as well as the type of actuator used are far from optimal. The goal of this work is to improve the control methods especially when the robot is in interaction with its environment (by investigating feedback control strategies and by increasing the number of actuators that can be piloted) and to investigate new applications of these devices in medicine (especially for surgical robotics but not only...) and HCI (game, entertainment, art...).

ADAM Project-Team

4. Application Domains

4.1. Introduction

The ADAM project-team targets the software engineering of adaptive service-oriented applications and middleware. The application domain covered by ADAM is broad and spans from distribution applications to middleware. In all these cases, adaptability is the property which is sought: applications and middleware must be adaptable to new execution contexts, they must react to changes in the environment and they must be able to discover and integrate new services.

The ADAM project-team produces software and middleware building blocks. This explains why the application domain is broad, yet targeting applications where adaptability is the key requirement. This includes electronic commerce, embedded systems, health care information systems, and terrestrial transport information systems. These domains are in direct relation with our currently funded activities. They act as testbeds for the solutions that we propose in terms of middleware services, middleware platforms, runtime kernels, component libraries, languages design or domain modeling.

4.2. Electronic Commerce

Applications in the domain of electronic commerce are by essence distributed. They involve many different participants with heterogeneous information systems which cannot be changed. The challenge is then to provide an adaptation layer to be able to compose and let these systems interoperate. In the context of the ANR TLog SCOrWare, the ICT SOA4All and the FUI CAPPUCINO projects, our activities in this domain aim at supporting service-oriented architectures. We want to have adaptive architectures that can be composed and orchestrated seamlessly. In this domain, the business relationship with customers is vital and many different usage scenarios must be supported. Customers are roaming, and the services must be kept operational across different devices. This puts some constraints on the server tier where technical services must be adapted to manage, for instance, long lasting transactions. The application server infrastructure must then provide a support for adapting technical services.

4.3. Embedded Systems

Embedded systems form a domain where adaptation is a key requirement. The design and the implementation of modern embedded software uses advanced software engineering techniques such model-driven development or software component frameworks. In this domain, we have been involved in several projects, such as the ANR TLog Flex-eWare, and the FUI MIND projects. Several challenges must be addressed here. For example, when a model-driven developed application is adapted, designers have to ensure that the models and the operational level are kept synchronized. The co-evolution of these two levels is one of the challenges that we are addressing. A second challenge is related to software components that need to be customized in order to fit the requirements imposed by constrained environments. It is, for example, a matter of providing component frameworks that can accommodate various granularities of services.

4.4. Health Care Information Systems

Health care information systems form a third application domain in which the ADAM project-team is involved, for instance through demonstrators which have been implemented in the context of the ANR TLog FAROS project. The challenge here is to provide a distributed infrastructure where information will be available to medical staff wherever they are. This imposes to be able to provide this information on many different devices (from high resolution screens to embedded devices on the scene of an accident), while ensuring the privacy of the medical data of a patient (several level of data access must be granted depending on the categories of medical staff). Given the vital role of such an information system, we want to provide guarantees that the services will be highly available and trustworthy. We envision to provide a service-oriented architecture which will be extended to support software contracts and multi-scale environments.

4.5. Information Systems for Terrestrial Transport

Information systems for terrestrial transport are also a domain that we are relying on. Applications are here characterized by frequent disconnections, poor quality network links, and high mobility. We want to provide an infrastructure where the technical services, and among others the communication services, can be adapted to support new requirements. One of the paths that we propose to investigate is to include such a scenario in the general context of the adaptiveness of component frameworks.

FUN Project-Team (section vide)

RMOD Project-Team

4. Application Domains

4.1. Programming Languages and Tools

Many of the results of RMoD are improving programming languages or development tools for such languages.

As such the application domain of these results is as varied as the use of programming languages in general. Pharo, the language that RMoD develops, is used for a very broad range of applications. From pure research experiments to real world industrial use (the Pharo Consortium has over 10 company members).

Examples are web applications, server backends for mobile applications or even graphical tools and embedded applications.

4.2. Software Reengineering

Moose is a language-independent environment for reverse- and re-engineering complex software systems. Moose provides a set of services including a common meta-model, metrics evaluation and visualization. As such Moose is used for analysing software systems to support understanding and continous development as well as software quality analysis.

LINKS Team

3. Application Domains

3.1. Context

Links are important for web users, who try to locate relevant information. They typically want to pose their queries locally and obtain the answers from both local and remote repositories. With the concept of linked data collections, today's web users are provided with a virtual collection of data and explicit links. One of the goal of our project is to enrich the collection of data and links with more expressive mappings between local relations and external resources. The latter are not available in the current Web and would lead to better take advantage of the diversity and heterogeneity of information. The answer to a user query needs to exploit both explicit links, such as pointers to external resources or semantic correspondences to those and logical links to external repositories, represented as schema mappings. Therefore, the second goal is to evaluate local queries across such mappings and thus exploit the semantic knowledge of external resources. However, we argue that the benefits of links are not limited to casual users. In this paragraph, we briefly discuss two applications in which linked data collections need to be enriched and queried.

Collective Intelligence. Collective knowledge is a shared or group intelligence that emerges from the collaboration of individuals (from Wikipedia). There are many contexts in which such a concept is readily applicable. We advocate here one possible scenario, namely that of Business Intelligence. 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 collective 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 collective intelligence.

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 explicit links, namely pointers to external resources and logical links, i.e. more complex relationships between local portions of data and remote resources. 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.

MAGNET Team

4. Application Domains

4.1. Overview

Our main targeted applications are browsing, monitoring and mining in information networks. Such discovered structures would also be beneficial to predicting links between users and texts which is at the core of recommender systems. All 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.

MINT Project-Team

4. Application Domains

4.1. Next-generation desktop systems

The term *desktop system* refers here to the combination of a window system handling low-level graphics and input with a window manager and a set of applications that share a distinctive look and feel. It applies not only to desktop PCs but also to any other device or combination of devices supporting graphical interaction with multiple applications. Interaction with these systems currently rely on a small number of interaction primitives such as text input, pointing and activation as well as a few other basic gestures. This limited set of primitives is one reason the systems are simple to use. There is, however, a cost. Most simple combinations being already used, few remain to trigger and control innovative techniques that could facilitate task switching or data management, for example. Desktop systems are in dire need of additional interaction primitives, including gestural ones.

4.2. Ambient Intelligence

Ambient intelligence (AmI) refers to the concept of being surrounded by intelligent systems embedded in everyday objects [35]. Envisioned AmI environments are aware of human presence, adapt to users' needs and are capable of responding to indications of desire and possibly engaging in intelligent dialogue. Ambient Intelligence should be unobtrusive: interaction should be relaxing and enjoyable and should not involve a steep learning curve. Gestural interaction is definitely relevant in this context.

4.3. Serious Games

Serious game refers to techniques extensively used in computer games, that are being used for other purposes than gaming. Fields such as learning, use of Virtual Reality for rehabilitation, 3D interactive worlds for retail, art-therapy, are specific context with which the MINT group has scientific connection, and industrial contacts. This field of application is a good opportunity for us to test and transfer our scientific knowledge and results.