



RESEARCH CENTER
Bordeaux - Sud-Ouest

FIELD

Activity Report 2012

Section highlights of the Team

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LFANT Project-Team

2.2. Highlights of the Year

- Vincent Verneuil has defended his PhD thesis on “Cryptographie à base de courbes elliptiques et sécurité de composants embarqués” [12] in June 2012.
- Pierre Lezowski has defended his PhD thesis on “Questions d’Euclidianité ” [11] in December 2012.
- The ERC project ANTICS of Andreas Enge started in January 2012.
- The 2nd Atelier PARI/GP was held in 2012 (after the first installment in 2004), with the aim of creating a yearly event dedicated to the development of the main software product of the LFANT team.

ALEA Project-Team

2.2. Highlights of the Year

The book [33] presents a series of novel results on the design and analysis of new classes of mean field particle models in numerical finance, including particle sensitivity measures, calibration models, and particle option pricing algorithms.

BACCHUS Team

2.2. Highlights of the Year

- Many achievements in rocket science have been made since Apollo, but prediction of the heat flux to the surface of spacecraft remains an imperfect science, and inaccuracies in these predictions can be fatal for the crew or the success of robotic missions. Predicting an accurate heat flux is a particularly complex task, regarding uncertainty on the complex multi-physics phenomena involved in hypersonic flows models as well as on atmospheric properties such as density and temperature. Hence, it is difficult to establish “error bars” on the heat flux prediction. We succeeded the first call for project from ESA concerning uncertainty quantification for aerospace applications. In this project, we are the main investigator concerning the set-up of efficient numerical techniques for UQ.
- In June and July, we joined the NASA Center for Turbulence Research (CTR) Summer Program at Stanford University. We developed a novel method to solve stochastic partial differential equations, in particular hyperbolic equations.
- We have developed an algorithm for the robust construction of curved simplicial meshes in two and three dimensions. Starting from a classical (straight) mesh, we are able to curve the boundary elements then the volumic ones in keeping as much as possible the structure of the initial mesh. In particular, this algorithm does not destroy the boundary layer structures, even for meshes designed for turbulent simulations.
- We have succeeded in having Residual Distribution schemes that are *uniformly* accurate whatever the Peclet number for scalar advection diffusion problems. The schemes have been extended to turbulent flow simulations.
- The native scheduler of the PaStiX solver can be replaced with generic runtimes to address sparse direct factorizations on heterogeneous architectures (clusters of multicore/multigpu). Our results on heterogeneous architectures show we can easily improve the factorization time on a personal computer (1 GPU and several cores), and we have identified leads, both on algorithms and on schedulers, to optimize the performances on larger platforms.

CAGIRE Team (section vide)

CONCHA Project-Team (section vide)

CQFD Project-Team

2.2. Highlights of the Year

CQFD made advances in the practical use of its algorithms with DCNS. In the particular case of submarine command, we have coupled an tracking algorithm with an optimization code in order to compute optimal trajectories using only signals issued from embedded sonars. These results will be developed in an operating simulator.

The CQFD team created in 2012 a new annual national conference for the users of the statistical software R. The "Premières Rencontres R" are conceived as a place to present and share ideas on using the R statistical software. This meeting is designed to be a nationwide event where various topics belong, such as graphical tools, applied statistics, biostatistics, bayesian statistics, bioinformatics, data analysis, modeling, machine learning, high performance computing, etc...

The Rencontres R contained 5 guest lectures, 32 regular talks, 12 Lightning Talks and 6 posters on the following topics :

- new advances in statistics and their implementation with R,
- new R packages,
- applications or original case studies involving the R software (genetics, bioinformatics, environment, psychometrics, social sciences, neuroscience, etc...),
- computer features about the R software (multithreading, graphical tools, binding with other softwares, etc...) ,
- topics about teaching methods with R.

This meeting was intended to everyone interested in R: researchers, teachers, people from industries, students, etc... It was built for both beginners and advanced R users, statisticians and informaticians, as well as wellwishers from every area where R can be useful. More than hundred participants attended this first edition of the conference.

GEOSTAT Project-Team (section vide)

MC2 Project-Team (section vide)

REALOPT Project-Team

2.2. Highlights of the Year

Our scientific output is marked by strong publications in prestigious journals such as *Discrete Mathematics*, *Mathematical Programming*, *EURO Journal on Computational Optimization*, *INFORMS Journal on Computing*, and *Operations Research*, for instance, with contributions ranging from theoretical and methodological to numerical and applied industrial problem solving. This is completed by conference invitations in China, Chili and Canada and proceedings in selective conferences.

Our methodology of combining an extended formulation approach with Dantzig-Wolfe decomposition and column generation, that is now published [21], is a great illustration of our team's threefold objective: it is a theoretically proved method, playing the complementary between exact optimization techniques, and leading to an computational edge in application solving. This methodology is a key tool for currently ongoing collaboration with EDF and Russian partners on railway applications.

The Samba project with our associated team in Brasil is picking up a new pace, with good progress on primal heuristics [27] [30] and stabilization techniques [23] [25] [29] [32]. In the coming year, short term visits will be completed by a one-month stay of Professor Uchoa, and a one-year-stay of his PhD student.

The composition of the team is going through rapid evolution: Gautier Stauffer, our Inria Chair, has been promoted as a Professor in Grenoble; Andrew Miller has returned to the US. Both positions have been re-published in our thematic. We are currently building tighter links with CEPAGE by building closer work relations with Olivier Beaumont, Lionel Eyraud-Dubois, and Paul Renaud-Goud who share our methodologies, while emphasizing our expertise in the application domain of cloud computing.

The team has been integrated in the LaBEX CPU. The complete team participates in the WP5 "Network and Service Optimization". At the same time, there is a participation in the WP6 "Codes, Cryptologie, Algorithmique Arithmétique" with the proper methodology of the team.

CARMEN Team

2.2. Highlights of the Year

- S. Labarthe was awarded the poster price for the theoretical and applied aspects of his work on atrial modeling by to distinct communities:
 - poster award by the medical community after at the « printemps de la cardiologie 2012 »;
 - poster award by the applied mathematics community at the CANUM 2012.
- N. Zemzemi: best poster presentation award at the international conference Computing in Cardiology 2012 (CINC'2012), [25].

MAGIQUE-3D Project-Team (section vide)

MAGNOME Project-Team (section vide)

MNEMOSYNE Team

2.2. Highlights of the Year

As a good illustration of our thematic shift from models of visuomotor functions to applications to neurodegenerative diseases, this recent publication in PNAS [1] proposes that the Degus, a rodent from Chile used for the design of models of the retina, is also an animal model for the Alzheimer disease.

CEPAGE Project-Team

2.3. Highlights of the Year

- A long paper has been presented at the STOC'12 Conference: I. Abraham, S. Chechik and C. Gavoille. *Fully Dynamic Approximate Distance Oracles for Planar Graphs via Forbidden-Set Distance Labels* in 44th Annual ACM Symposium on Theory of Computing (STOC), pp. 1199-1217, New York, May 2012.
- Ralf Klasing was the Conference Chair of the *11th International Symposium on Experimental Algorithms (SEA 2012)*, Bordeaux, France, June 7-9, 2012.
- The members of CEPAGE have been involved in the following program committees: SODA 2013, IPDPS 2013, DISC 2012, ISAAC 2012, ICDCN 2012, IPDPS 2012 FOMC 2012, ADHOC-NOW 2012, IWOCA 2012, SEA 2012, ALGOTEL 2012, FUN2012.

HIEPACS Project-Team

2.2. Highlights of the Year

- With the Lawrence Berkeley National Laboratory (LBNL) and Stanford an associate team has been initiated, which name is FASTLA http://people.bordeaux.inria.fr/coulaud/projets/FastLA_Website/index.html. In this collaborative research initiative we propose to study, design and implement hierarchical parallel scalable numerical techniques to address two challenging numerical kernels involved in many intensive simulation codes: namely, the N-body interaction calculations and the solution of large sparse linear systems.
- In the framework of the EADS-ASTRIUM/Inria/Conseil Régional Aquitaine agreement officially signed on March 29th, HiePACS hosts Guillaume Sylvand, EADS-IW senior engineer, who has a strong expertise in large scale parallel simulation and is an expert of parallel fast multipole techniques. Guillaume Sylvand already plays an active role in the scientific activities and will enable to strength the interaction between the academic applied and industrial research and will contribute to shrink the gap between the two.

PHOENIX Project-Team

2.2. Highlights of the Year

- Our first user experiments in the domain of digital assistance:
 - Experimental evaluation of a digital assistance for school inclusion of autistic children (first deployment in the *Gérard Philippe* College in Pessac from September 2012),
 - Need analysis and pre-evaluation of DiaSuiteBox with 80 elderly persons, in collaboration with the UDCCAS Gironde (Union Départementale des Centres Communaux d'Action Sociale) managing elderly care and the “Université du Temps Libre” in Bordeaux,
 - Experimental evaluation of a cognitive assistance for supporting the autonomy of persons with intellectual disabilities, in collaboration with the TSA Chair of UQTR (Université du Québec à Trois-Rivières).

These experiments are supervised by Hélène Sauzéon, a researcher in Cognitive Science member of the PHOENIX project-team, on leave from the University of Bordeaux 2 since September 2012.

- The DiaSuiteBox project has been accepted to the startup accelerator program “Le Camping” in Toulouse. This program allows 6 startup projects to be mentored by experienced entrepreneurs during 6 months.
- Five articles accepted in top-ranked journals (IEEE Transactions on Software Engineering, Visual Languages and Computing, 2 Software Practice and Experience, and Science of Computer Programming).

RUNTIME Project-Team

2.2. Highlights of the Year

- The hwloc software [5.2](#) is used for node topology discovery and process binding by the most popular MPI implementations, including MPICH2 and OPEN MPI and all their derivatives such as Intel MPI.
- The StarPU software [5.7](#) is used for dynamic scheduling by the state-of-the art dense linear algebra library, Magma v1.1 <http://icl.cs.utk.edu/magma/> .

FLOWERS Project-Team

2.2. Highlights of the Year

2.2.1. *Ergo-Robots: Large-scale life-long learning robot experiment*

The FLOWERS team, in collaboration with University Bordeaux I/Labri, has participated as a central actor of the exhibition “Mathematics: A Beautiful Elsewhere” at Fondation Cartier pour l’Art Contemporain in Paris. This installation, called “Ergo-Robots/FLOWERS Fields” was made in collaboration with artist David Lynch and mathematician Mikhail Gromov (IHES, France), and shows computational models of curiosity-driven learning, human-robot interaction as well as self-organization of linguistic conventions. This exhibition, at the crossroads of science and art, allowed to disseminate our work towards the general public, explaining concepts related to learning mechanisms in humans and robots to a large audience (80000 visitors). This was also an opportunity for experimenting and improving our technologies for life-long robot learning experimentation. For one of the first times in the world outside the laboratory, we demonstrated how it is possible to achieve experimentation with learning robots quasi-continuously for 5 months. This opens novel stimulating scientific perspectives in the field of developmental robotics. This experimentation was presented through large audience radios, magazines and newspapers (France Inter, France Culture, RFI, Sciences et Avenir, Tangente, Financial Times, Daily Telegraph, Libération, ...).

More information available at: <http://flowers.inria.fr/ergo-robots.php> and <http://fondation.cartier.com/>.

2.2.2. *MACSi: Integrated system for curiosity-driven visual object discovery on ICub robot*

In the frame of the MACSi ANR project conducted together with ISIR (UPMC - Paris) a complete cognitive architecture for humanoid robots interacting with objects and caregivers in a developmental robotics scenario has been integrated on the iCub robot [43]. The architecture is foundational to the MACSi project and to several research axis of FLOWERS: it is designed to support experiments to make a humanoid robot gradually enlarge its repertoire of known objects and skills combining autonomous learning, social guidance and intrinsic motivation. This complex learning process requires the capability to learn affordances, i.e. the capacity for the robot to predict which actions are possible on scene elements. Several papers presenting the general framework for achieving these goals, focusing on the elementary action, perception and interaction modules have been published. This architecture is an important milestone of the project, enabling future experiments on object learning and recognition, object categorization and interaction between autonomous exploration and social guidance.

2.2.3. *Algorithmic architecture for learning inverse models in high-dimensional robots*

Through the design of the SAGG-RIAC algorithmic architecture, and its publication in a major robotics journal [22], we have produced a highly-efficient system for intrinsically motivated goal exploration mechanism which allows active learning of inverse models in high-dimensional redundant robots. Based on active goal babbling, this allows a robot to efficiently and actively learn distributions of parameterized motor skills/policies that solve a corresponding distribution of parameterized tasks/goals. We have conducted experiments with high-dimensional continuous sensorimotor spaces in three different robotic setups: 1) learning the inverse kinematics in a highly-redundant robotic arm, 2) learning omnidirectional locomotion with motor primitives in a quadruped robot, 3) an arm learning to control a fishing rod with a flexible wire. We showed that 1) exploration in the task space can be a lot faster than exploration in the actuator space for learning inverse models in redundant robots; 2) selecting goals maximizing competence progress creates developmental trajectories driving the robot to progressively focus on tasks of increasing complexity and is statistically significantly more efficient than selecting tasks randomly, as well as more efficient than different standard active motor babbling methods; 3) this architecture allows the robot to actively discover which parts of its task space it can learn to reach and which part it cannot.

2.2.4. Formalization of several links between intrinsic motivation architectures and statistical machine learning

We incorporated several key concepts of intrinsically motivated developmental learning, especially measures of learning progress for curiosity-driven exploration, in several standard machine learning formalisms. First, we introduced and formalized a general class of learning problems for which a developmental learning strategy is optimal [47]. This class of learning problems characterizes problems where the issue of life-long multitask learning under bounded resources is crucial. Within this formalization, we related the SAGG-RIAC architecture [22] with multi-armed bandits formalisms [47] allowing to study the properties of problems where there several discrete choices to make to accelerate learning. Third, we also included empirical measures of learning progress in standard reinforcement learning problem allowing to automatically choose the best exploration strategy [42] and to extend Rmax approaches, for exploration in model-based RL, to non-stationary problems [46].

2.2.5. Bridging black-box optimization and RL for skill learning in robots

In this year, we have made substantial advances in understanding of the relationship between black-box optimization and reinforcement learning for direct policy search, and the application of such methods to robotics manipulation, as well as their use for modelling human behavior. The key discovery has been that black-box optimization and reinforcement learning have converged towards a same set of algorithmic properties, such as parameter perturbation and reward-weighted averaging, allowing for a direct comparison and integration of such algorithms (see “Relationship between Black-Box Optimization and Reinforcement Learning” below). On the one hand, this has enabled us to exploit principles from black-box optimization, such as covariance matrix adaptation, in the context of reinforcement learning. The resulting algorithm (PI^2 -CMAES) enables adaptive exploration and life-long learning in robots [63], and in reaching experiments leads to proximo-distal maturation as an emergent property [60] (see “Emergent Proximo-Distal Maturation through Adaptive Exploration” below). On the other hand, it has allowed us to demonstrate that black-box optimization outperforms reinforcement learning for a particular class of policies [69]. This is an important result, as these types of policies are typically used for robotic skill learning. Therefore, more efficient and robust black-box optimization algorithms may be applied to learning with such policies, *without* compromising convergence speed and cost of the final solution.

2.2.6. Algorithm for learning sequences of motion primitives

As for applications, we have also extended policy improvement algorithms to work with sequences of motion primitives, enabling 11-DOF manipulation robots to learn how to grasp under uncertainty through fine manipulation, and perform extended pick-and-place tasks [31] (see “Reinforcement Learning with Sequences of Motion Primitives for Robust Manipulation” below). We have also shown that learning variable impedance control is able to mimic the behavior of humans when exposed to force fields (see “Model-free Reinforcement Learning of Impedance Control in Stochastic Environments” below).

2.2.7. Algorithms for autonomous dimensionality reduction

In 2012, we have made significant progress in incremental online learning algorithms capable of finding latent variables in high-dimensional sensory spaces, by either using the principle of multimodal correspondence[24] or weak, self-generated supervision[40]. These advances will be key in further extending the applicability of key artificial curiosity algorithms for learning with high-dimensional sensory spaces.

The following paper obtained the Best Paper Award in the category “Computational Models of Cognitive Development” at the IEEE ICDL-Epirob international conference: [53]

BEST PAPERS AWARDS :

[53] **ICDL-Epirob - International Conference on Development and Learning, Epirob**. C. MOULIN-FRIER, P.-Y. OUDEYER.

MANAO Team

2.1. Highlights of the Year

The main event of this year is the creation of the team *MANAO*. This is a big step for defining a new research domain, at the frontier of optical science and computer graphics.

The second highlight is shared with our partners of the ANR SeARCH project (see Section 6.2.1). The results of our collaborative work on the Alexandria lighthouse was one of the key event of the exhibition dedicated to lighthouses at the "musée de la marine" in Paris (cf. Figure 1). These results were possible thanks to the new visualization and re-assembly tools developed in our team, using data from the new acquisition process developed by our partners Archéovision and CEALex.



Figure 1. Participation to the "PHARE" exhibition at Musée de la marine in Paris. With our partners of the ANR SeARCH project, we have reproduced and provided a first-time-seen reconstructed statue of Isis (left) which was standing in front of the Alexandria lighthouse (1/5 scale).

This year was also very successful in terms of publications. We managed to publish 6 papers in major journals and conferences (2 at TOG/SIGGRAPH [16], [21], 2 at IEEE TVCG [17], [19] and finally 2 at Computer Graphics Forum [15], [18]). They cover the whole range of our project, from material properties [19] to geometry analysis [15], [18], shading analysis [21], content creation [16] and, augmented reality [17]. These publications have received a lot of attention as proved by the two interviews [24], [25] and the 3rd best paper award at the national conference on computer graphics [22].

POTIOC Team (section vide)