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THEME COG

Activity Report

2008

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TAO (Thème Apprentissage et Optimisation) is a joint project inside PCRI, including researchers from INRIA and the LRI team I & A – Inférence et Apprentissage (CNRS and University of Paris Sud), located in Orsay.

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2. Overall Objectives

2.1. Introduction

Data Mining (DM) has been identified as one of the ten main challenges of the 21st century (MIT Technological Review, fev. 2001). The goal is to exploit the massive amounts of data produced in scientific labs, industrial plants, banks, hospitals or supermarkets, in order to extract valid, new and useful regularities. In other words, DM resumes the Machine Learning (ML) goal, finding (partial) models for the complex system underlying the data.

DM and ML problems can be set as optimization problems, thus leading to two possible approaches. Note that this alternative has been characterized by H. Simon (1982) as follows. *In complex real-world situations, optimization becomes approximate optimization since the description of the real-world is radically simplified until reduced to a degree of complication that the decision maker can handle. Satisficing seeks simplification in a somewhat different direction, retaining more of the detail of the real-world situation, but settling for a satisfactory, rather than approximate-best, decision.*

The first approach is to simplify the learning problem to make it tractable by standard statistical or optimization methods. The alternative approach is to preserve as much as possible the genuine complexity of the goals (yielding "interesting" models, accounting for prior knowledge): more flexible optimization approaches are therefore required, such as those offered by Evolutionary Computation.

Symmetrically, optimization techniques are increasingly used in all scientific and technological fields, from optimum design to risk assessment. Evolutionary Computation (EC) techniques, mimicking the Darwinian paradigm of natural evolution, are stochastic population-based dynamical systems that are now widely known for their robustness and flexibility, handling complex search spaces (e.g. mixed, structured, constrained representations) and non-standard optimization goals (e.g. multi-modal, multi-objective, context-sensitive), beyond the reach of standard optimization methods.

The price to pay for such properties of robustness and flexibility is twofold. On one hand, EC is tuned, mostly by trials and errors, using quite a few parameters. On the other hand, EC generates massive amounts of intermediate solutions. It is suggested that the principled exploitation of preliminary runs and intermediate solutions, through Machine Learning and Data Mining techniques, can offer sound ways of adjusting the parameters and finding shortcuts in the trajectories in the search space of the dynamical system.

2.2. Context and overall goal of the project

The overall goals of the project are to model, to predict, to understand, and to control physical or artificial systems. The central claim is that Learning and Optimisation approaches must be used, adapted and integrated in a seamless framework, in order to bridge the gap between the system under study on the one hand, and the expert's goal as to the ideal state/functionality of the system on the other hand.

Specifically, our research context involves the following assumptions:

1. The systems under study range from large-scale engineering systems to physical or chemical phenomenons, including games. Such systems, sometimes referred to as *complex systems*, can hardly be modelled based on first principles due to their size, their heterogeneity and the incomplete information aspects involved in their behaviour.
2. Such systems can be observed; indeed selecting the relevant observations and providing a reasonably appropriate description thereof is part of the problem to be solved. A further assumption is that these observations are sufficient to build a reasonably accurate model of the system under study.
3. The available expertise is sufficient to assess the system state, and any modification thereof, with respect to the desired states/functionalities. The assessment function is usually not a well-behaved function (differentiable, convex, defined on a continuous domain, etc), barring the use of standard optimisation approaches and making Evolutionary Computation a better suited alternative.

In this context, the objectives of TAO are threefold:

1. using Evolutionary Computation (EC) and more generally Stochastic Optimisation to support Machine Learning (ML);
2. using Statistical Machine Learning to support Evolutionary Computation;
3. investigating integrated ML/EC approaches on diversified and real-world applications.

Due to the unavoidable shift of the scientific environement and people interest after 4 years of activity, the detailed implementation of those objectives have been slightly revised since the initial project proposal 4 years ago, and updated lines of research will be described in next section 3.1.

2.3. Highlights

In 2008, TAO aimed at modelling, predicting, and ultimately controllling physical or artificial systems through seamless integration of statistical Machine Learning (ML) and Optimization approaches. Systems under study range from large-scale engineering systems to physical or chemical phenomenons, including robotics and games, with emphasis on incomplete information, dynamic environments, and ill-posed optimization problems.

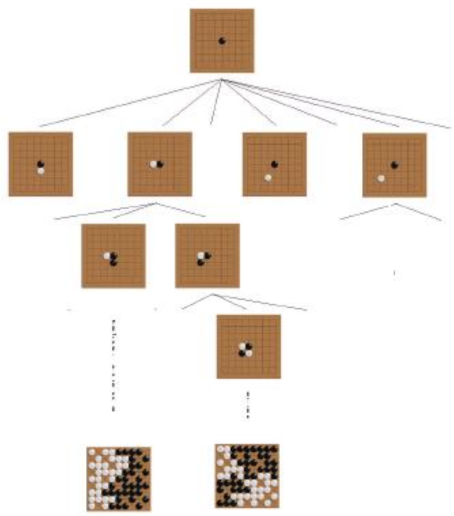

Figure 1. Tree-structured Multi-armed Bandits, the MoGo algorithm

One major breakthrough of TAO regarding optimal control in uncertain environments was illustrated by the MoGo program, first ever Computer-Go program to win a professional human player (more in section 6.5). This achievement, acknowledged a “notable success of AI” by *The Economist* (jan. 2007) is based on original tree-structured extensions of Multi-Armed Bandit algorithms (Fig. 1). Its parallelization was undertaken in collaboration with the Parall team and Bull; collaborations with Microsoft started in 2008. Notably, the approach involves little specific domain knowledge; it directly tackles optimal policy learning under uncertain/incomplete information. This work has been widely disseminated to the general public: IA-Go Challenge in Paris in March; Gold medal Olympiads 2008.

Other fundamental results regard the adaptation of statistical learning theory tools to evolutionary optimization. Specifically, Monte Carlo Markov Chains were used for proving the convergence of Evolution Strategies (ES) and analysing their convergence rate. Other results regard the optimization of computationally expensive functions or the use of quasi-random algorithms. The robustness of ES compared to standard, Newton-based approaches in convex settings *with high condition number* has been demonstrated experimentally.

Figure 2. Optimal Design, The Seroussi Contest

EC-based applications in Numerical Engineering require the design of representations enforcing stability, compacity, and versatility; various search spaces have been considered, ranging from developmental representations to Echo State Networks. Architectural applications in collaboration with EZCT, opened promising avenues for research (exhibitions at the Beaubourg Museum of Modern Art; primed contribution to the Seroussi contest, Fig. 2).

TAO also actively participated in the pioneering of ML-based Autonomic Computing, a major field of applications for both learning and optimization. This research theme benefitted from the arrival and expertise of Balász Kégl in 2007, strengthening the link between LRI and Laboratoire de l'Accélérateur Linéaire. In collaboration with the Enabling Grid for E-SciencE project (EGEE, FP6 and FP7, 2004-2010), a Grid Observatory (http://www.grid-observatory.org/) acted to gather and publish traces of grid activity, permitting the behavioural modelling of the grid with its self-management as ultimate goal. Independently, active relational learning has been applied to the generation of test cases for structural statistical software testing (coll. ForTeSe, LRI). Finally, a joint initiative (Microsoft-INRIA) is concerned with automatic parameter tuning.

During the year 2008, TAO has confirmed its position as a key research group in Evolutionary Computation (invited talks at GPTP'08, IEEE CIS'2008, 8th ISEA in June 2009; editor in chief of MIT Press *Evolutionary Computation* journal) and in Machine Learning (steering committee of PASCAL and PASCAL-2 NoEs, 2003-2013). It has expanded its activities to Data Mining (KDUbiq CA; invited talk at IEEE Forum on DM) and Complex Systems (chair of ANR SYSCOMM Evaluation Committee). TAO activities have also been recognized as a source of applicative breakthroughs (OMD RNTL; MoGo; coll. with EZCT nominated for Seroussi contest). Following earlier recommendations, TAO 's robotics activities are now supported by an active collaboration with hardware roboticists (SYMBRION IP).

3. Scientific Foundations

3.1. Scientific Foundations

3.1.1. Introduction

This section describes Tao's main research directions, first presented during Tao's evaluation in November 2007. Four strategic issues had been identified at the crossroad of Machine Learning and Evolutionary Computation:

Where What is the search space and how to search it.
Representations, Navigation Operators and Trade-offs.

What What is the goal and how to assess the solutions.
Optimal Decision under Uncertainty.

How.1 How to bridge the gap between algorithms and computing architectures ?
Hardware-aware software and Autonomic Computing.

How.2 How to bridge the gap between algorithms and users?
Crossing the chasm.

Six Special Interest Groups (SIGs) have been defined in Tao, investigating the above complementary issues from different perspectives. The comparatively small size of Tao SIGs enables in-depth and lively discussions; the fact that all Tao members belong to several SIGs, on the basis of their personal interests, enforces the strong and informal collaboration of the groups, and the fast information dissemination.

3.1.2. Representations and Properties

The choice of the solution space is known to be the crux of both Machine Learning (model selection) and Evolutionary Computation (genotypic-phenotypic mapping).

The first research axis in Tao thus concerns the definition of an adequate representation, or search space H, together with that of adequate navigation operators. H and its operators must enforce flexible trade-offs between expressivity and compacity on the one hand, and stability and versatility on the other hand.

The first trade-off corresponds to the fact that H should simultaneously include sufficiently complex solutions $-$ i.e. good-enough solutions for the problem at hand $-$ and offer a short description for these solutions, thus making it feasible to find them.

The second tradeoff is actually related to the navigation in H; while most modifications of a given solution should only marginally modify its behaviour (stability), some modifications should lead to radically different behaviours (versatility). Both properties are required for efficient optimization in complex search spaces; stability, also referred to as "strong causality principle"[1] is needed for optimization to do better than random walk; versatility potentially speeds up optimization through creating short-cuts in the search space.

This research direction is investigated in the Complex System SIG (section 6.2) about developmental representations for Design and sequential representations for Temporal Planning, in the Reservoir Computing SIG (section 6.6) for large Neural Network Topologies, and in the Continuous Optimization SIG, studying some adaptive representation.

3.1.3. Optimal decision under uncertainty

Benefitting from the expertise acquired when designing and developing MoGo, Tao investigates several extensions of the Multi-Armed Bandit (MAB) framework and the Monte-Carlo tree search. Some main issues raised by optimal decision under uncertainty are the following:

- Regret minimization and any-time behaviour.
  The any-time issue is tightly related to the scalability of Optimal Decision under Uncertainty; typically, MAB was found better suited than standard Reinforcement Learning to large-scale problems as its criterion (the regret minimization) is more amenable to fast approximations.
- Dynamic environments (non stationary reward functions).
  The issue of dynamic environments was first raised through the Online Trading of Exploration vs Exploitation Challenge[2]; it is relevant to e.g. online parameter tuning (see section 6.3).
- Use of side information / Multi-variate MAB

[1] I. Rechenberg: *Evolutionstrategie: Optimierung Technisher Systeme nach Prinzipien des Biologischen Evolution*. Fromman-Hozlboog Verlag, Stuttgart, 1973.

The use of side information by MAB is meant to exploit prior knowledge and/or complementary information about the reward. Typically in MoGo, the end of the game can be described at different levels of precision (e.g., win/lose, difference in the number of stones); estimating the local reward estimate depending on the available side information aims at a better robustness.

- Bounded rationality.
  The bounded rationality issue considers the case where the action space is large relatively to the time horizon, meaning that only a sample of the possible actions can be considered in the imparted time.
- Multi-objective optimization.
  Many applications actually involve antagonistic criteria; for instance autonomous robot controllers might simultaneously want to explore the robot environment, while preserving the robot integrity. The challenge raised by Multi-objective MAB is to find the "Pareto-front" policies for a moderately increased computational cost compared to the standard mono-objective approach.

This research direction is chiefly investigated by the Optimal Decision Making SIG (section 6.5), in interaction with the Complex System and the Crossing the Chasm SIGs (sections 6.2 and 6.3).

3.1.4. Hardware-Software Bridges

Historically, the apparition of parallel architectures only marginally affected the art of programing; the main focus has been on how to rewrite sequential algorithms to make them parallelism-compliant. The use of distributed architectures however calls for a radically different programming spirit, seamlessly integrating computation, communication and assessment.

The main issues thus become i) to aggregate the local information with the information transmitted by the other nodes (computation); ii) to abstract the local information in order to transmit it to the other nodes (communication); iii) possibly, to model and assess the other nodes, aimed at modulating the way the transmitted information is exploited, Message passing algorithms such as Page Rank or Affinity Propagation[3] are prototypical examples of distributed algorithms; the analysis is shifted, from the algorithm termination and computational complexity, to its convergence and approximation properties.
Symmetrically, the ever increasing resources of modern computing systems, as well as their computational load entail a like increase on the administrator workload, in charge of monitoring the grid status and maintaining the job running process. The huge need for scalable administration tools paved the way toward Autonomic Computing[4]. Autonomic Computing (AC) Systems are meant to feature self-configuring, self-healing, self-protecting and self-optimizing skills[5]. A pre-requisite for Autonomic Computing is to provide an empirical model of the (complex) computational system at hand, applying Machine Learning on the running traces of the system.

This research direction is investigated in the Complex System SIG (section 6.2) and in the Autonomic Computing SIG (section 6.1).

3.1.5. Crossing the chasm

This fourth strategic priority, referring to the influential Moore's book[6], is motivated by the fact that many outstandingly efficient algorithms never make it out of research labs. One reason for it is the difference between editor's and programmer's view of algorithms. In the perspective of software editors, an algorithm is best viewed as a single "Go" button. The programmer's perspective is radically different: as he/she sees that

[2] The OTEE Challenge, funded by Touch Clarity Ltd and organized by the PASCAL Network of Excellence, models the selection of news to be displayed by a Web site as a multi-armed bandit, where the user's interests are prone to sudden changes; the OTEE Challenge was won by the TAO team in 2006.

[3] Frey, B., Dueck, D.: Clustering by passing messages between data points. In: Science. Volume 315. (2007) 972–976.

[4] J. O. Kephart and D. M. Chess, "The vision of autonomic computing," *Computer*, vol. 36, pp. 41–50, 2003.

[5] I. Rish, M. Brodie, and S. M. et al, "Adaptive diagnosis in distributed dystems," *IEEE Transactions on Neural Networks (special issue on Adaptive Learning Systems in Communication Networks)*, vol. 16, pp. 1088–1109, 2005.

[6] Moore, G.A.: Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customer. Collins Business Essentials (1991).

various functionalities can be ented on the same algorithmic core, the number of options steadily increases (with the consequence that users usually master less than 10% of the available functionalities). Independently, the programmer gradually acquires some idea of the flexibility needed to handle different application domains; this flexibility is most usually achieved through defining parameters and tuning them. Parameter tuning thus becomes a barrier to the efficient use of new algorithms.

This research direction is chiefly investigated by the Crossing the Chasm SIG (section 6.3) and also by the Continuous Optimization SIG (section 6.4).

4. Application Domains

4.1. Application Domains

The mainstream applications of TAO are, since its creation, engineering applications, autonomous robot control, and medical applications. Furthermore, the two new fields of applications that have appeared more recently within TAO, due to the arrival of new staff on the project, are now flourishing, namely Autonomic Computing and the study of Complex Social Systems

Software Robotics is still an active application domain, as withnessed by Cedric Hartland's on-going PhD, and the recently starting SYMBION european IP, section 6.2.

Several applications involving **Numerical Engineering** are on-going : the successful OMD (Optimisation Multi-Disciplinaire) RNTL/ANR project (see Section 6.4) will be pursued by OMD2, starting in 2009; moreover, collaborations with IFP and Citroën-Peugeot automobile industry will be materialized in 2009 by starting CIFRE PhD.

Though most **medical applications** of the early days of TAO have been hindered as the dialogue with experts could not take place to the required extent, the just-starting DigiBrain project puts TAO back on the domain of medical application: it is concerned with Brain Computer Interface, within the Digiteo structure, involving LRI, INRIA, CEA List and Neurospin.

Autonomic Computing applications have now become an important part of TAO activities, since Cecile Germain-Renaud, now Professor at Université Paris-Sud, joined TAO in 2005, and Balzs Kégl was hired at LAL in Orsay in 2006 (see section 6.1).

Finally, the study of **Social Systems**, more precisely economical multi-agent models and road traffic models, is now full part of TAO activities, following the arrival of respectively Philippe Caillou and Cyril Furtlehner (see Section 6.4). For instance, the ANR proposal TRAVESTI, addressing traffic modelling problems, and coordinated by Cyril Furtlehner, has just been accepted, and will start in 2009.

5. Software

5.1. MoGo

Keywords: *Go*, *Multi-armed bandit*.

Participants: Olivier Teytaud [correspondent], Sylvain Gelly, Jean-Baptiste Hoock, Arpad Rimmel, Julien Pérez.

MoGo (55000 lines of code in C++) is currently one of the best Computer-Go programs worldwide (including advanced options as multithreading and now message-passing parallel version) (see Section 2.3). Only the binary code is released, with hundreds of downloads http://www.lri.fr/~gelly/MoGo_Download.htm. Many computer-go programmers discuss their experiments with MoGo on the computer-go mailing-list. MoGo has also been used in several demonstrations (invited games in Taiwan, Sciences En Fête in France, games in Clermont-Ferrand soon, games in the US Open of Go, tournoi de Paris).

5.2. Covariance Matrix Adaptation Evolution Strategy

Keywords: *Evolutionary Computation*, *real-parameter optimization*, *stochastic optimization*.

Participant: Nikolaus Hansen [correspondent].

The Covariance Matrix Adaptation Evolution Strategy (CMA-ES) is one of the most powerful continuous domain evolutionary algorithms. The CMA-ES is considered state-of-the-art in continuous domain evolutionary computation[7] and has been shown to be highly competitive on different problem classes. The algorithm is widely used in research and industry as witnessed by more than a hundred published applications. We provide source code for the CMA-ES in C, Java, Matlab, Octave, Python, and Scilab including the latest variants of the algorithm [27].

Links: http://www.lri.fr/~hansen/cmaes_inmatlab.html

5.3. GUIDE: A graphical interface for Evolutionary Algorithms

Keywords: *Evolutionary Computation*, *GUI*, *Java*, *Object-oriented*.

Participants: Marc Schoenauer [correspondent], Luis Da Costa.

Abstract: GUIDE is a graphical user interface for easy Evolutionary Algorithm design and coding. It allows the user to describe its genome (the structure that will evolve) graphically, using containers (e.g. tuples, vectors, lists, ...) and elementary types (booleans, integers, real numbers and permutations). All representation-dependent operators (initialization, crossover and mutation) are then automatically defined with default values, built bottom-up from the elementary types, or can be specified by the user. Developing a prototype for a new search space involving complex structures has now become a matter of minutes.

GUIDE was programmed in JAVA by James Manley during the 6 months of his DESS stage in 2004. It is a follow-up of a previous tool developed in collaboration with Pierre Collet in the DREAM FP5 STREP project (http://www.dcs.napier.ac.uk/~benp/dream/dream.htm).
GUIDE has been chosen as the evolutionary basis for the EvoTest project: testing a given program means feeding it with data of a specific structure. In this context, the goal of EvoTest is to automatically evolve test data, relying on an automatic code generator that only requires a description of the structure of the data to evolve – and this is precisely what GUIDE is doing.

The main changes in GUIDE in 2008 have been a complete redesign of the graphical interface, and the use of Velocity Template to generate the code, allowing a complete independence of the application w.r.t. the target library. GUIDE is available on the INRIA GForge as an Open Source software (http://guide.gforge.inria.fr/).

5.4. Simbad Autonomous and Evolutionary Robotics Simulator

Keywords: *Java*, *evolutionary robotics*, *robot simulation*.

Participant: Nicolas Bredche [correspondent].

Abstract: Simbad is an open source Java 3D robot simulator for scientific and educational purposes (Authors: Louis Hugues and Nicolas Bredche). Simbad embeds two stand-alone additional packages: (1) a Neural Network library (PicoNode) and (2) an Artificial Evolution Engine (PicoEvo). The Simbad package is targeted towards Autonomous Robotics and Evolutionary Robotics for research and education. The packages may be combined or used alone. In the scope of Research in Evolutionary Robotics, the Simbad package package helps quick development of new approaches and algorithms thanks to the complete and easy-to-extend libraries. Real-world interface can be easily written to transfer simbad controllers to real robots (the Khepera interface is available). The open source nature of the project combined with easy-to-understand code makes it also a good choice for teaching Autonomous and Evolutionary Robotics. Simbad is used in several AI and robotics courses: IFIPS engineering school (4th and 5th year) ; Master 1 at Université Paris-Sud ; Modex at Ecole Polytechnique.

[7] H.-G. Beyer (2007). Evolution Strategies, *Scholarpedia*, p. 1965

Please refer to : http://simbad.sourceforge.net/.

5.5. Django

Keywords: *Fast theta-subsumption*.

Participant: Michle Sebag [correspondent].

Abstract: Django is an algorithm of theta-subsumption of Datalog clauses, written in C by Jerome Maloberti and freely available under the GNU Public License. This algorithm is an exact one, with a gain of two or three orders of magnitude in computational cost over other theta-subsumption algorithms. Django uses Constraint Satisfaction techniques such as Arc-Consistency, Forward-Checking and M.A.C. (Maintaining Arc-Consistency) and heuristics based on the First Fail Principle.

Django has been widely used and cited in the literature (coll. with the Yokohama University, Japan, U. of Tufts in Arizona, USA, U. of Bari, Italy).

http://tao.lri.fr/tiki-index.php?page=Django.

5.6. OpenDP

Keywords: *Learning*, *Object-oriented*, *Stochastic Dynamic Programming*.

Participants: Olivier Teytaud [correspondent], Sylvain Gelly.

Abstract: OpenDP is an open source code for stochastic dynamic programming[8], based upon the use of (i) time-decomposition as in standard dynamic programming (ii) learning (iii) derivative-free optimization. Its modular design was meant to easily integrate existing source codes: OpenBeagle (with the help of Christian Gagné), EO (with the help of Damien Tessier), CoinDFO, Opt++, and many others, for optimization; the Torch library and the Weka library and some others for learning. It also includes various derandomized algorithms (for robust optimization and sampling) as well as time-pca and robotic-mapping. OpenDP has been experimented on a large set of benchmark problems (included in the environment), allowing for an extensive comparison of function-values approximators and derivative-free optimization algorithms with a tiny number of iterates.

The merit of the OpenDP platform is twofold. On the one hand, while many of the above algorithms are well-known, their use in a dynamic programming framework is new. On the other hand, such a systematic comparison of these algorithms on general benchmarks did not exist in the literature of stochastic dynamic programming, where many papers only consider one learning method, not necessarily in the same conditions than other published results. These thorough experimentations inspired some theoretical work about the criteria for learning in dynamic environments, noting that cross-validation is neither satisfactory (for example the σ^2 parameter in Gaussian SVM chosen by cross-validation is usually too small in the context of dynamic programming) nor fast enough in that framework.
See main page at http://sourceforge.net/projects/opendp.

5.7. GridObservatory

Keywords: *Archives*, *Autonomic Computing*, *Grid*.

Participants: Michèle Sebag, Cécile Germain-Renaud [correspondent], Tamas Elteto, Xiangliang Zhang, Julien Perez.

[8] Sylvain Gelly and Olivier Teytaud. Opendp: a free reinforcement learning toolbox for discrete time control problems. In *NIPS Workshop on Machine Learning Open Source Software*, 2006.

The Grid Observatory web portal collects and publishes traces of EGEE grid (Enabling Grid for E-sciencE) usage. With extensive monitoring facilities already in place, EGEE grid offers an unprecedented opportunity to observe, and gain understanding of, new computing practices of e-Science. The Grid Observatory portal is a unique facility to observe:

- The requirements of e-Science towards computing. EGEE provides a good approximation of the current and future needs.
- Grid status and middleware activity. These can be explored for a wide range of motivations, from operational goals (e.g. improving performance) to scientific research, both in distributed systems and machine learning areas.

The Grid Observatory portal is part of the more comprehensive *Grid Observatory project* presented in section 6.1.

Portal site: http://www.grid-observatory.org

6. New Results

6.1. Autonomous Computing

Participants: Michèle Sebag, Cécile Germain-Renaud, Balázs Kégl, Tamas Elteto, Xiangliang Zhang, Julien Perez.

6.1.1. Overview

Autonomic Grids have been considered a promising field of ML applications for TAO since 2006, with its implication in the EGEE[9] grid. This implication has resulted in the *Grid Observatory* project, supported by EGEE, DIGITEO and CNRS. The first goal of the Grid Observatory is to provide a publicly accesible repository of grid traces.

The second goal of the Grid Observatory is to provide a better understanding of the Grid and through this, better optimisation.

- Application developers need synthetic characterisations of grid activity and the grid applications for predicting and optimising application performance.
- Grid models are required for dimensioning, capacity planning, or evaluating the impact of evolutions in grid configuration and middleware.
- Self-regulation and self-maintenance are desired functionalities in many areas, ranging from resource allocation to real-time fault diagnosis, including green computing as an increasingly urgent constraint.

An important, often underestimated, factor that increases the complexity of grid modelling and policy design is that the grid are based on a mutualisation paradigm. Considering middleware architecture, a grid federates independently managed resources, thus is not only a collection of heterogeneous and shared resources, but a hierarchical structure. Because the resources are made available and maintained by institutions related to specific scientific communities, sociological, administrative, and institutional constraints must be taken into account. Because the resource must serve the needs of these communities, a new concept has emerged for the grid exploitation model, the Virtual Organizations (VO's), which represent groups of users with similar access rights. A new driving factor is the collective behavior of users, whose activities will tend to be correlated along scientific communities. This has multiple consequences, ranging from what is accessible for observation to the acceptable hypotheses for middleware design. This observation constitues the specificity of the grid target inside the Autonomic Computing field.

[9] Enabling Grids for E-Science in Europe, infrastructure project (2001-2003), (2003-2007), (2008-2010).

The results can be organized along two axes. : modeling the dynamics of the grid, and model-free scheduling policies.

6.1.2. Modeling the dynamics of the grid

The goal is to model the complex interactions between the grid middleware and the e-scientist queries.

In collaboration with Supelec, classical time-series methods have been applied to samples of the activity of the whole EGEE grid [40]. The counting process associated to job arrivals at sites, as well the load at sites, have been explored. The results for the counting point toward a) strong non-stationarity b) self-similarity; preliminary work indicates that a derived process amenable to stationarity (the bursts) can be defined and parameterized. Considering the load, the best model solely so far is fairly complex, belonging to the GARCH category.

The second category of results concerns extending Affinity Propagation (AP) to data steaming [31], [36], [35]. AP extracts the data items, or exemplars, that best represent the dataset using a message passing method. Several steps are made to build StrAP. WAP (Weighted AP) extends AP to to deal with duplicated items with no loss of performance. Hi-WAP (Hierarchical WAP) reduces the quadratic complexity of AP, by applying AP on data subsets and further applying Weighted AP on the exemplars extracted from all subsets. Finally StrAP extends Hierarchical WAP to online clustering by storing the outliers and occasionally updating the exemplars to deal with changes in the data distribution, using Page-Hinkley change-point detection statistical test. Experiments on classical benchmarks show that the Hi-Warp order of magnitude gain in performance compared to AP is not acquired at the expense of a comparable increase in distortion. Experiments with the Intrusion Detection benchmark (KDD99) show that StrAP improves clustering accuracy over the state of the art DenStream algorithm. Ongoing work explores the application of StrAP to streaming the EGEE gLite operational data, with lightweight, probe-free, fault detection and diagnosis as a target.

6.1.3. Model-free scheduling policy

The central tenet of this activity is that the combination of utility functions and reinforcement learning (RL) can provide a general and efficient method for dynamically allocating grid resources in order to optimize the satisfaction of both end-users and participating institutions. The flexibility of an RL-based system allows modeling the state of the grid, the jobs to be scheduled, and the high-level objectives of the various actors on the grid. RL-based scheduling can seamlessly adapt its decisions to changes in the distributions of inter-arrival time, QoS requirements, and resource availability. Moreover, it requires minimal prior knowledge about the target environment, including user requests and infrastructure. [26], [19] focus on a specific multi-objective setting: QoS for responsiveness on one hand, and weighted fair-share on the other hand, under realistic constraints. These include work-conserving scheduling, and also the choice of an on-line policy (SARSA algorithm), where the approximate value function guides the selection of the next action a. Given the relatively high-dimensionality of the continuous state-action space, a non-linear continuous approximation of the value function is required, as proposed in Tesauro's work. Our experimental results, both on a synthetic workload and a real trace from EGEE, show that RL is not only a realistic alternative to empirical scheduler design, but is able to outperform them. Ongoing work deals with a) a more systematic approach of the multi-objective framework and b) a more realistic model of the workload.

6.2. Complex Systems

Participants: Jacques Bibaï, Nicolas Bredèche, Cyril Furtlehner, Anne Auger, Philippe Caillou, Alexandre Devert, Marc Schoenauer, Michèle Sebag.

6.2.1. Developmental Representations for Evolutionary Design

Developmental represenatations provide a new and promising approach to automatic design of complex structures inspired from artificial ontogeny. In this setup, a set of elements, or cells, interacts locally so as to provide global synchronization and communication toward some objectives. The key feature of such systems is to address the efficient design of large scale structures and to provide solution with some guaranties about its scalability and robustness. Proof of principle of the approach, concerning the design of bridges or multi-robot cooperation, have been given. Our main contributions in previous work involve: i) the evolutionary optimization of Echo State Network using new fitness objectives; ii) the design of a specific stopping criterion. This stopping criterion results not only in significant computational gains, but also in an unprecedented robustness of the design solution to perturbations in the environment. The approach was extended to the design of truss structure [14]; the novelty is to use a single cell template all over the structure (achieving different behaviours depending on the local environment), resulting in a low-dimensional search space while featuring excellent flexibility. All those results will build Alexandre Devert's PhD (submitted, to be defended in early 2009).

6.2.2. Swarm Robotics

TAO is an active participant in the EU funded IP Symbrion swarm-robotic project (2008-2012). Tao's role in SYMBRION is to provide the swarm with learning and evolution facilities, based on hardware developed by other partners in the consortium. Early work in this direction has been explored this year based on an ontogenic approach in order to enable multi-robot pattern formation in noisy environments [12]. The specificity of the approach (compared to cellular automata) is to consider a continuous and dynamic topology of the agents in the geographical field. Again, scalability and robustness were achieved through simple, local-only, communication scheme. Lastly, it should be noted that the Complex System SIG benefits from strong interactions with the Reservoir Computing SIG, as both groups are investigating the computational properties of e.g., Echo State Networks from different and complementary perspectives. A joint JST-ANR proposal has also been recently accepted, in collaboration with Suzuki Lab at Kyushu University, dealing with a coupling between symbolic and numerical approaches for swarm robotics.

6.2.3. Social Systems Modelling

In complement to robotic applications, we also used agents as a tool to simulate and understand complex systems, and more specifically social system. Multi-agent based simulation (MABS) is a growing approach for the study of complex domains: it allows an intuitive modelling (agent behavior, interaction rules), simple sceniarii definitions, micro and macro variables observability. In previous work, we used this methodology to study theoretical networks of financial agents. This year, we extended this field of research in three directions. First, by studying a domain with a multi-step decision process and some empirical data: the French academic labor market (maitre de conferences hiring system). Starting with a model of candidates and universities agents, we showed that the high local hiring rate observed in empirical data was more a product of the system structure itself than a consequence of the agent preferences ([39]). Current work includes the use of regional empirical data to obtain a better validation of the model. A second line of research was to study a market with complex behaviors and interactions with strong trust issues: the Rungis wholesale market. Due to the importance of bilateral agreements, a fine definition and tuning of the agents was needed, which is why we used cognitive agents for this simulation ([8], with University of Coimbra and AUDENCIA school of management). Current work includes the use of this simulation to explain empirical facts, such as the strong difference between the official price and the effective price on the market. Finally, a last line of research concerned the study of the agent itself, by exploring new ways to build cognitive agents, such as polychronous networks and Memory Evolutive System (P. Caillou with J. Monteiro and M. Netto (University of Sao Paolo), submitted)

6.2.4. A Statistical Physics Perspective

Basic tools (mean field approaches and associated distributed algorithms) from statistical physics and probability are used to complement the MABS tools developed in tao to address complex systems, both from the modelling and computing viewpoint. The data stream clustering (see section 6.1 for more details) as been identified as a well suited application of such approach, with the setting of a new version of "affinity propagation" which uses an on-line aggregation and hierarchical treatment of the data stream and for which a scaling analyses has been performed [35], [31]. Another line of research also based on this message-passing approach, deals with the problem of learning an approximate Markov Random Field based on generalized Bethe free energy approximations (Cyril Furtlehner, Jean-Marc Lasgouttes(projet Imara), Anne Auger, Inria report in progress).

In addition, some basic properties (update rules, stability properties) of loopy belief propagation have been analyzed (Cyril Furtlehner, Jean-Marc Lasgouttes (EPI Imara)). These theoretical studies are done in the perspective of the ANR project TRAVESTI, to begin in January 2009 upon final financial acceptation decision, and that deals with traffic networks modelling. An interesting question which arises in multi-agent systems is the effect of asymmetry in some decision process (buy or sell in financial systems, accelerate or break in traffic systems...) on the emergence of instabilities (speculative bubbles, traffic jams...). We have formalized this question by introducing a new type of zero-range processes with specific Markov non-reversibility and applied it to the computation of the fundamental diagram of road traffic (Cyril Furtlehner, Jean-Marc Lasgouttes (EPI Imara), Inria report in progress). Problems like the random Ising model or the NK model offers benchmark possibilities. On such a benchmark we have compared in particular a population-based strategy (memetic algorithm) versus a UCT (Upper Confidence Bound, Auer 2001) strategy based on the same local search heuristic. Using extreme value statistics of the local search algorithm combined with simple scaling hypothesis (well verified experimentally) yields a (hopefully) new generic UCT-like approach to combinatorial optimization (Cyril Furtlehner, Olivier Teytaud, Inria report in progress).

6.2.5. Sequential Representation for Temporal Planning

On-going collaboration with Thalès is concerned with validating, understanding, and improving the Divide-and-Evolve (DAE) approach to Temporal Planning, and includes the supervision of Jacques Bibaï's CIFRE PhD. After promising comparative results obtained at the beginning of the PhD [47], DAE entered the IPC'08 (International Planning Competition), and though the overall results were disappointing, because it failed to simply solve about 50% of the instances, DAE obtained equal or better results that the winner of the competition on all instances that it could solve. Based on the analysis of those results, several improvements of DAE have already been implemented. Two papers have been submitted, and another one is in preparation.

6.3. Crossing the Chasm

Participants: Alejandrao Arbelaez, Anne Auger, Robert Busa-Fekete, Luis Da Costa, Alvaro Fialho, Nikolaus Hansen, Balázs Kégl, Marc Schoenauer, Michèle Sebag.

Many forefront techniques in both Machine Learning and Stochastic Search have been very successful in solving difficult real-world problems. However, their application to newly encountered problems, or even to new instances of known problems, remains a challenge, even for experienced researchers of the field - not to mention newcomers, even if they are skilled scientists or engineers from other areas. Theory and/or practical tools are still missing to make them crossing the chasm (from Geoffrey A. Moore's book about the Diffusion of Innovation). The difficulties faced by the users arise mainly from the significant range of algorithm and/or parameter choices involved when using this type of approaches, and the lack of guidance as to how to proceed for selecting them. Moreover, state-of-the-art approaches for real-world problems tend to represent bespoke problem-specific methods which are expensive to develop and maintain. Several works are on-going at TAO are concerned with "Crossing the Chasm", be it in the framework of the joint MSR-INRIA lab in collaboration with Youssef Hamadi (Microsoft Research Cambridge), or within the EvoTest project, where TAO is in charge of automatic generation of the Evolutionary Engine.

Note that a longer-term goal, that could be useful for all of the on-going work described below, is the design of accurate decsriptors that would allow us to describe a given problem (or instance). From thereon, we would be able to learn from extensive experiments what are the good algorithms/parameters for classes of instances, or even indvidual instances, like has been done in the SAT domain by Y. Hamadi and co-authors [10].

6.3.1. Adaptive Operator Selection

In order to adapt on-line the mechanism that chooses among the different variation operators in Evolutionary Algorithms, we have proposed two original features

[10] F.Hutter, Y.Hamadi, H.H.Hoos, and K.Leyton-Brown. Performance Prediction and Automated Tuning of Randomized and Parametric Algorithms, CP'2006.

- Using a Multi-Armed Bandit algorithm for operator selection [13]: each operator is viewed as an arm of a MAB problem. Because the context is dynamic, a statistical test (Page-Hinkley) is used to detect abrupt changes and restart the bandit;
- Using Extreme values rather than averages as a reward for operators: It has been advocated in many domains that extremely rare but extremely beneficial events can be much more consequential than average good events. This has been validated on the OneMax problem, where the optimal strategy for a given fitness level is known [15], as well as on k-path problems (paper to be presented in LION'09 conference in Trento, January 09).
- On-going work is investigating the recombination of the above ideas with the Compass approach of our colleagues from Angers University[11].

6.3.2. Adaptation for Continuous Optimization

Building on the well-known Covariance Matrix Adaptation Evolution Strategy (CMA-ES) algorithm, that adapts the covariance matrix of the Gaussian mutation of an Evolution Strategy based on the path followed by the evolution, several improvements and generalizations have been proposed:

- an adaptive encoding that can apply to any distribution-based search strategy has been proposed [20]. The mechanism renders the underlying search strategy rotational invariant and facilitates an adaptation to non-separable problems. On non-separable, badly scaled problems adaptive encoding can improve the performance of many search algorithms by orders of magnitude.
- a version of CMA with linearly scaling computational complexity and linear space requirement has been proposed at [27] (compared to quadratic for the original algorithm). In high dimensional search spaces (larger than hundred) the new variant can be advantageous not only on cheap to evaluate search problems but even on very expensive non-separable problems.

6.3.3. Meta-parameter tuning for Machine Learning Algorithms

Non-parametric learning algorithms usually require the tuning of hyper-parameters that determine the complexity of the learning machine. Tuning these parameters is usually done manually based on (cross) validation schemes. The goal of this theme is to develop principled methods to carry out this optimization task automatically using global optimization algorithms. The theme is part of the MetaModel project (https://users.web.lal.in2p3.fr/kegl/metamodel).

6.3.4. Learning Heuristics Choice in Constraint Programming

Several heuristics have been proposed to choose which branch to explore next within Constraint Programming algorithms. The idea we are exploring is to learn which one is the best given the characteristics of the current node of the tree (e.g. domain sizes, number of still unsatisfied constraints, etc) [9].

6.4. Continuous Optimization

Participants: Anne Auger, Nikolaus Hansen, Mohamed Jebalia, Marc Schoenauer, Olivier Teytaud, Raymond Ros, Fabien Teytaud.

Research in continuous optimization at TAO is centered on stochastic search algorithms that are often population based and typically derivative-free. We are interested in fundamental aspects, algorithm design and comparison of different search methods (stochastic and deterministic). One key feature of stochastic optimization algorithms is how the parameters of the search distributions are adapted during the search. Studies on adaptive algorithms are also part of crossing the chasm module. They are based on the well-known Covariance Matrix Adaptation Evolution Strategy (CMA-ES) algorithm that adapts the covariance matrix of the Gaussian mutation of an Evolution Strategy.

[11] J.Maturana, F.Saubion: A Compass to Guide Genetic Algorithms. PPSN 2008: 256–265.

6.4.1. Performance assessment

In the last decades, numerous algorithms taking inspiration from nature have been proposed to handle continuous optimization problems. On the other hand, gradient-based, quasi-Newton algorithms, pattern search algorithms and more recently Derivative-Free-Optimization algorithms have been proposed and improved by applied mathematicians, relying on theoretical studies that guarantee their convergence under some (more or less) restrictive hypotheses. We have conducted comparisons of several bio-inspired algorithms (CMA-ES, Particle Swarm Optimization (PSO), Differential Evolution (DE)) with the deterministic derivative-free algorithms: BFGS and NEWUOA [50]. Moreover, though comparisons of the performance of different optimizers are made in research studies, few optimizers are usually tested within a single work. Different works usually do not use the same experimental settings, hampering their comparability, and often comparisons are biased to certain types of test functions: for a long time, most Evolutionary Algorithms (EAs) have been tested mostly on separable problems. For those reasons we are preparing a workshop on Black Box Optimization Benchmarking http://coco.gforge.inria.fr/doku.php?id=bbob-2009 for the next Genetic and Evolutionary Computation Conference (GECCO 2009) where we will provide to the participants (1) the implementation of a well-motivated benchmark function testbed, (2) the experimental set-up, (3) generation of data output for (4) post-processing and presentation of the results in graphs and tables.

6.4.2. Optimization in presence of uncertainties

Evolutionary algorithms (EAs) are known to be robust in presence of uncertainties, i.e when the objective function is noisy (for example, the function can be the result of an experiment in a lab where the outcome might fluctuate with the temperature). Robustness of EAs in terms of convergence and convergence rates have been theoretically investigated in [22], [1]. Moreover, deficiency of formulating noisy optimization problems in terms of minimization of expectation for multiplicative noise models have been pointed out [22]. Part of this work was done in the context of the ANR/RNTL OMD project. In the context of Steffen Finck's visit (collaboration with Voralberg, Austria) we are testing the Simultaneous Perturbation Stochastic Approximation (SPSA) algorithm designed for optimization of noisy objective functions. Finally, a new algorithm for measuring and handling uncertainty in rank-based search algorithms has been proposed [21], [4] and applied to CMA-ES. A revision of the uncertainty measurement and further methods for uncertainty treatment are work in progress.

6.4.3. Multi-Objective optimization

Multi-objective (MO) optimization (or vector optimization) consist in optimizing simultaneously two or more conflicting objective functions. Recent MO algorithms are based on selecting a set of solutions maximizing the volume defined by this set and a given reference point. The spread of optimal set of points on the Pareto front and the influence of the reference point has been investigated [4]. Based on previous work on Covariance Matrix Adaptation for MO[12], a recombination scheme for the strategy parameters in the MO-CMA-ES has been recently developed [30].

6.4.4. Complexity bounds

Some theoretical bounds have been derived for black-box optimization [29], showing ultimate limits for evolutionary algorithms and for algorithms reaching some optimality properties; billiard algorithms were used for implementing algorithms as close as possible to the theoretical limits.

Also, non-validity of the No-Free-Lunch Theorem in continuous optimization and the design of continuous optimization algorithms has been investigated [2].

6.4.5. On the efficiency of derandomization

The efficiency of quasi-random points has been analyzed in [28] and applied to CMA-ES. These results in particular show that this "derandomization" is very stable, and better for wide families of criteria. In [49] a

[12] C. Igel, N. Hansen, and S. Roth. Covariance matrix adaptation for multi-objective optimization. *Evolutionary Computation*, 15(1):1–28, 2007.

two-point step-size adaptation rule has been proposed for evolution strategies. The new rule is a derandomized implementation of self-adaptation and can be advantageous in noisy environments.

6.5. Optimal Decision Making

Keywords: *Monte-Carlo Tree Search*, *Sequential data*, *Upper Confidence Tree*, *active learning*, *stochastic dynamic optimization*.

Participants: Olivier Teytaud, Philippe Rolet, Lou Fedon, Romaric Gaudel, Cyril Furtlehner, Jean-Baptiste Hoock, Fabien Teytaud, Arpad Rimmel, Julien Prez.

This special interest group is devoted to all aspects of artifical intelligence related to sequential data; in particular, sequential decision with uncertainty and sequential learning. Several highly visible successes in computer-Go have provided both technical publications and popularization (section 6.5.1). Other applications far from Go have been realized and should be published soon (section 6.5.2).

6.5.1. Sequential decision under uncertainty applied to Computer-Go

The game of Go is a more than 2000 years old Asian game which is very important in China, Korea, Taiwan, and Japan. It is in particular interesting as it is much more difficult for computers than chess (in which humans can't win against computers any more, unless a handicap is given to the machine). As a consequence, the efficiency of new algorithms for this game is highly interesting [42], [43], [41]. We successfully parallelized Monte-Carlo Tree Search [18], with both message-passing parallelization and shared-memory parallelization. The essential idea of this parallelization is to share the upper part of the tree, with messages compacting statistics, instead of sending positions and results on the network; the result is a very good speed-up in 19x19 Go, without shared-memory; the parallelization is less efficient in 9x9 Go but provides nonetheless a significant improvement. These results are applicable far from the game of Go, and were developped as a collaboration with Thomas Herault (PARAL team, Lri) and Sara/Univ. Maastricht (Nederlands) [38].

This has a strong impact in 19x19 Go with the first ever win against a professional player (8th Dan Pro) with 9 handicap stones. A grid-based building of opening book has been launched, with an original strategy based on Monte-Carlo Tree Search algorithms. A survey paper was published [17]. In [32], several forms of active learning are combined, including

- expert rules, coming from the ages;
- offline learning, based on last century's high-level games;
- online learning, i.e. classical online values as in UCT, but without exploration term;
- transient learning, i.e. online learnt value function (including extrapolation).

The two first rules are essential for the first visit in a node; the third one is essential asymptotically in the number of trials; the fourth one is essential as a transition between the offline part and the online part. This multi-level learning is the first source code combining in Go all these levels.

Figure 3. Left: The Huygens computer. Middle: games in Taiwan. Right: Interactive table.

The communications of the ACM, vol. 51, Nb. 10, (10/08), page 13, published the first ever won against a professional player in 19x19, as well as several newspapers. MoGo was also interfaced with an interactive table (joint work with Microsoft [37]). The video presentation of the table can be watched at http://www.youtube.com/watch?v=OQvVk1RLziY&feature=PlayList&p=90C0DB7A3DB9B52C&index=21.

6.5.2. Other applications of UCT and bandits

A joint work P. Rolet/M. Sebag/O. Teytaud has been devoted to the design of an optimal algorithm for active learning. Based on a prior (similar to Bayesian priors), this algorithm has asymptotically (in the computational power) an optimal complexity w.r.t. the number of requests to the oracle labelling examples. An implementation has been realized, showing the practicability of the approach. A joint work with A. Auger was applied to the feasability of optimal optimization [2] thanks to UCT algorithms.

Interestingly, both the application to active learning and the application to optimal non-linear optimization combine:

- "Billiard" algorithms that are used in both cases for generating conditional distributions;
- Partially observable Markov Decision processes (POMDP) - the essential idea is the rewriting of non-linear optimization or active learning as POMDPs;
- UCT, which is highly competitive in this one-actor framework.

6.6. Reservoir Computing

Participants: Hélène Paugam-Moisy, Nicolas Bredèche, Alexandre Devert, Fei Jiang, Cédric Hartland, Miguel Nicolau, Marc Schoenauer, Michèle Sebag.

Reservoir Computing is concerned with large Neural Networks where only some macro-parameters of the topology and the weights are specified, and the actual network and weights are generated randomly, within the constraints specified by the macro-characteristics. The work on Reservoir Computing, or more precisely for 2008 at TAO, Echo State Networks (ESNs), is mainly concerned with Fei Jiang's PhD work and Miguel Nicolau's post-doc work within the GENNETEC European project. However, this on-going work on Neural Network topologies is presently being boosted by the arrival in September 2008 of Hélène Paugam-Moisy, in "délégation" at INRIA from Université Lyon 2 – hence the separation of this SIG from the Complex System SIG where this work originally belonged to.

6.6.1. Echo State Networks

Fei Jiang's PhD is dealing with the optimization of the topology of large Neural Networks, co-supervised by Hugues Berry (EPI Alchemy) and Marc Schoenauer. His work in 2008 have turned toward ESNs, and have resulted in a paper in PPSN conference [23] where he investigates the Evolutionary Reinforcement Learning of ESNs using the CMA-ES algorithm to optimize the out-going weights: in Reinforcement Learning context, the optimization problem is not quadratic any more. Note that this work was first published as a poster in GECCO [24]. On-going work is concerned with identifying the reasons why some ESNs perform significantly better than others, even though they have been generated with the same macro-caracteristics (density of connections, range of internal weights). The goal is to identify other descriptors of the topology that would explain those differences.

Several other on going researches in TAO are also indirectly concerned with ESNs, that they use, together with CMA-ES for learning the weights, as a basic tool for their work. Cédric Hartland uses ESNs as robot controllers, studying their memory capacities (paper submitted). Alexandre Devert uses ESNs as basic controllers for his Continuous Cellular Automata approaches [14] (PhD to be defended in early January 2009).

6.6.2. Genetic Regulatory Network models

Within the GENNETEC project, TAO is studying Genetic Regulatory Networks (GRNs) as possible models for network generation. A first work demonstrated that networks designed using Banzhaf's model for GRNs[13] are far more evolvable than randomly-generated networks when it comes to evolve them toward some specific topology properties, be they scale-free properties [25] (a journal paper is also submitted) or small-world properties [44]. Further work will check whether such generative process can be used to optimize the computational properties of ESNs, as described above, and whether a bridge can be built toward Genetic Programming, as initially advocated by W. Banzhaf.

7. Contracts and Grants with Industry

7.1. Contracts and Grants with Industry

Contracts managed by INRIA

- **ONCE-CS** – 2005-2008 (147 kEur). *Open Network Connecting Excellence in Complex Systems*, European *Coordinated Action* from FP6. Coordinator Jeff Johnson, Open University, UK;
  Participants: Bertrand Chardon, Marc Schoenauer.
- **OMD-RNTL** – 2005-2009 (72 kEur). *Optimisation Multi-Disciplinaire*, Coordinator Rodolphe Leriche, Ecole des Mines de St Etienne;
  Participants: Anne Auger, Nikolaus Hansen, Olivier Teytaud and Marc Schoenauer.
- **Renault** – 2005-2008 (45 kEur). *Optimisation multi-disciplinaire du bloc-moteur*, side-contract to Claire LeBaron's CIFRE Ph.D.;
  Participants: Claire LeBaron, Marc Schoenauer.
- **EvoTest** – 2006-2009 (231 kEur). *Evolutionary Testing*, European *Specific Targeted Research Project* from FP6. Coordinator Tanja E.J. Vos, Instituto Tecnolgico de Informtica, Spain;
  Participants: Luis Da Costa, Marc Schoenauer.
- **GENNECTEC** – 2006-2009 (379 kEur). *GENetic NETworks: Emergence and Complexity*, European *Specific Targeted Research Project* from FP6. Coordinator Franois Képs, Génople and CNRS, France;
  Participants: Cyril Furtlehner, Miguel Nicolau, Marc Schoenauer.
- **SCOUT** – 2007-2008 from STIC Asia program, coordinated by MICA, Hanoi (Vietnam). TAO is the INRIA correspondant for this project (15kEur). Other partners are from Vietnam (IFI, CARGIS), China (LIAMA), Cambodia (ITC) and France (IRD, LRI-Paris Sud / TAO, MaIA-LORIA, IGN).
- **Thalès** – 2007-2010 (14kEur). *Evolutionary Temporal Planning*, side-contract to Jacques Bibaï's CIFRE Ph.D.;
  Participants: Jacques Bibaï, Marc Schoenauer
- IFP – 6 months 2008 (3kEur), *Couplage CMA-ES - mthodes base de gradient*. Participants: Anne Auger, Marc Schoenauer.
- **Adaptive Combinatorial Search** – 2008-2011 (110 kEur), project of the INRIA-Microsoft joint lab, co-headed with Youssef Hamadi (Microsoft Research Cambridge).
  Participants: Alejandrao Arbelaez, Anne Auger, Alvaro Fialho, Nikolaus Hansen, Marc Schoenauer, Michèle Sebag.
- **SYMBRION** – 2008-2013 (420 kEur). *Symbiotic Evolutionary Robot Organisms*, European Integrated Project (IP) coordinated by University Stuttgart.
  Participants: Nicolas Bredèche, Ouri Maler, Marc Schoenauer, Michle Sebag.

[13] W. Banzhaf, Artificial Regulatory Networks and Genetic Programming, in R. Riolo, Ed., *Genetic Programming Theory and Practice 2003*, pp 43–62, Kluwer

Contracts managed by CNRS or Paris-Sud University

- **PASCAL2**, Network of Excellence, 2008-2013 (34 kE in 2008). Coordinator John Shawe-Taylor, University of Southampton. M. Sebag is manager of the Challenge Programme.
- **KD-Ubiq**, Coordinated Action, 2005-2008 (19 kE). Coordinator Michael May, Fraunhofer Institute. M. Sebag is responsible of the Benchmarking WP.
- **EGEE-III** FP7 IP - 2008-2010 (30 kEur)
- **Grid Observatory** DIGITEO grant 2008-2009 (80 kEur) Participants: Cécile Germain, Michèle Sebag, Balázs Kégl, Tamas Elteto.
- **Observatoire de la Grille** CNRS grant - Projets Exploratoires Pluridisciplinaires(PEPS) 2008-2009 (7 kEur) Participants: Cécile Germain, Michèle Sebag, Balázs Kégl.
- **EGEE-II** FP6 IP - 2006-2008 (10 kEur) Participants: Cécile Germain, Michèle Sebag, Xiangliang Zhang, Julien Perez.
- **NeuroLog** RNTL 2007-2009 (10 kEur) Participants: Cécile Germain.
- **DEMAIN** PPF (Interdisciplinary program) of the Ministry of Research 2006-2009 (10KE) Participants: Cécile Germain (coordinator), Michèle Sebag, Xiangliang Zhang, Julien Perez.

8. Other Grants and Activities

8.1. International actions

8.1.1. Organization of conferences and scientific events

- Cécile Germain-Renaud, *Grid Observatory session at EGEE'08* , Chair, 2008
- Nikolaus Hansen, GECCO Genetic and Evolutionary Computation Conference, *Evolution Strategies and Evolutionary Programming* Track Chair, 2008

8.1.2. Management positions in scientific organizations

- EGEE, Enabling Grids for E-SciencE : Cécile Germain-Renaud is a member of the NA4 steering committee, head of the WG *Short Deadline Jobs* and head of the *Grid Observatory* cluster (2007-2010)
- International Society on Genetic and Evolutionary Algorithms (ACM-SIGEVO since 2006): Marc Schoenauer, Board Member since 2000.

8.2. European actions

8.2.1. Organization of conferences and scientific events

- Anne Auger, *Dagstuhl Seminar "Theory of Evolutionary Computation"*, co-organizer, 2008;
- Michèle Sebag, *Large Scale Learning Challenge Workshop, Helsinki*, co-Chair, 2008;
- Michèle Sebag, *2nd Pascal Challenge Workshop, Venice*, Chair, 2006.

8.2.2. Management positions in scientific organizations

- Parallel Problem Solving from Nature: Marc Schoenauer, Member of Steering Committee, (since 1998)
- Pattern Analysis, Statistical Learning and Computational Modelling NoE: Michèle Sebag, Member of Steering Committee (PASCAL 2004-2008; PASCAL2, 2008-)
- Ubiquitous Knowledge Discovery: Michèle Sebag, Steering Committee (KD-Ubiq, 2004-2008)

8.2.3. Collaborations with joint publications

- Globalisation and Innovation Laboratory - GIL, University of Coimbra, Portugal. Multi-agent systems for Social Modelling [8] (Section 6.2).

8.3. National actions

8.3.1. Organization of conferences and scientific events

- Michèle Sebag, *4th Franco-Japanese Workshop, Paris*, co-Chair, 2008.
- Michèle Sebag, *Apprenteo, Machine Learning Group in Digiteo*, Chair, 2006.
- Michel`e Sebag, *Apprentissage: la carte, le territoire et l'horizon*, Chair, 2008

8.3.2. Management positions in scientific organizations

- INRIA Saclay
  - Marc Schoenauer, président de la Commission Scientifique (2008-).
  - Olivier Teytaud, représentant CUMI (2008-).
- Université Paris-Sud
  - Nicolas Bredèche, membre du Conseil du Laboratoire de Recherche en Informatique (2004-); membre de la Commission de Spécialistes du Département d'Informatique (2003-2008).
  - Philippe Caillou, membre du Conseil Scientifique (2006-)
  - Cécile Germain-Renaud, membre (élue) du Conseil de l'UFR de Sciences(2007-)
  - Michèle Sebag, membre du Conseil du Laboratoire de Recherche en Informatique (2004-); membre de la Commission de Spécialistes du Département d'Informatique (2003-2008).
  - Olivier Teytaud, représentant des B pour le comité d'évaluation du LRI.
- Exercice national de prospective sur les grilles de production
  - Cécile Germain-Renaud, présidente du groupe thématique *Sciences de l'ingénieur et informatique*.

8.3.3. Management positions in scientific societies

- Association Française pour l'Intelligence Artificielle: Michèle Sebag, president, (2004-)
- Association Evolution Artificielle: Marc Schoenauer, founding president and member of steering committee (1994-).

8.3.4. Collaborations with joint publications

- U. Paris-Sud, LAL (Balázs Kégl, Autonomic Computing; C. Loomis, Grid Computing) [26], [19] (Section 6.1).

8.4. Honors

8.4.1. Prizes and Awards

- Mogo, developed by S. Gelly, J.-B. Hoock, A. Rimmel, O. Teytaud and Y. Wang, was awarded
  - the 1st prize at the Go Olympiads in 2007;
  - the 1st prize in the Taiwan World Championship (2008, National University of Tainan, Taiwan - prize of 50 000 Taiwan Dollars);

   - the 1st prize in the GPW Cup 2008 (Hakone, Japan, 2008).

  It has been the first ever Go program to win

   - a human professional player in even game (9x9 Go, 5th Dan pro, Amsterdam 2007);
   - a human professional player in non-blitz even game (9x9 Go, 5th Dan pro, Paris 2008);
   - a human professional player in 19x19 Go, handicap 9 (US Open, Portland, 2008 - the opponent is a top level player who won the US Open two days after his defeat against MoGo).

- Sylvain Gelly, PhD Award, Chancellerie des Universités (2008)
- Sylvain Gelly, Gilles Kahn PhD Award, 2nd prize, Académie des Sciences, (2008)
- Marc Schoenauer, 2008 *EvoStar Award for Outstanding Contribution of Evolutionary Computation in Europe*, during EvoStar 2008 in Napoli.

8.4.2. Keynote Addresses – International

- Michèle Sebag, *IEEE Forum on Data Mining, Hong-Kong* 2008: Which Parameters/Algorithm/System should I use?
- Michèle Sebag, *Spring Mining and Learning workshop, Traben-Farbach* 2008: Kernel-based Propositionalization
- Marc Schoenauer, *International Conference on Computational Intelligence and Security (CIS'08)*, December 2008, Crossing the Chasm for Evolutionary Algorithms: Issues, and Lessons from the Continuous Case.
- Marc Schoenauer, *Genetic Programming in Theory and Practice*, May 2008: Crossing the Chasm - Lessons from the continuous case.

8.4.3. Keynote Addresses – France

- Michèle Sebag, *4th Franco-Japanese Wkshop, Paris* 2008: Data Streaming with Affinity Propagation
- Marc Schoenauer, *Modelling, Computation and Optimization in Information Systems and Management Sciences* (MCO'08), Metz, September 2008. Bio-inspired algorithms for continuous optization: the Coming of Age.
- Marc Schoenauer, *Journées FREMIT*, Toulouse, décembre 2008: Stratégies d'évolution + adaptation de la matrice de covariance = des stratégies gagnantes pour l'optimisation continue sans contraintes.
- Olivier Teytaud, *Journée Digiteo*, Paris 2008.

9. Dissemination

9.1. Animation of the scientific community

9.1.1. Editorial boards

- ECJ, *Evolutionary Computation*, MIT Press: M. Schoenauer (editor in chief, 2002-)
- GPEM, *Genetic Programming and Evolvable Machines*, Springer: M. Schoenauer and M. Sebag (associate editors, 2000-)
- MLJ, *Machine Learning Journal*, Springer: M. Sebag (editorial board, 2002-2008)
- ASOC, *Applied Soft Computing*, Elsevier: M. Schoenauer (associate editor, 2000-)
- *Natural Computing Series*, Springer Verlag: M. Schoenauer (editorial board)

- *Mathématiques Appliquées*, Springer Verlag: M. Schoenauer (editorial board)

9.1.2. Chair in Organizing Committees

- LSL, *Large Scale Learning Wshop*, Helsinki: M. Sebag, co-Chair (2008).
- ECML/PKDD, *European Conference on Machine Learning / Practice of Knowledge Discovery in Databases*, Europe: M. Sebag, area Chair (2008)
- KDD, *Knowledge Discovery from Databases*: M. Sebag, area Chair 2008
- ICML, *International Conference on Machine Learning*: M. Sebag, area Chair (2008, 2009),

9.1.3. Program Committee Member (international events)

- ACM-GECCO, *Genetic and Evolutionary Computation COnference*, USA: A. Auger (2006-), N. Bredèche (2006-), N. Hansen (2003-), M. Schoenauer (1999-)
- EGEE UF, *EGEE User Forum*: C. Germain (2007-)
- EvoStar, *Series of Conferences and Workshops in Evolutionary Computation*: M. Schoenauer (1998-), N. Bredèche (2006-), N. Hansen (2008-)
- FOGA, *Foundations of Genetic Algorithms*: A. Auger (2004-), M. Schoenauer (1996-)
- IEEE-CEC, *Congress on Evolutionary Computation*: A. Auger (2006-), N. Hansen (2005-), M. Schoenauer (1999-), M. Sebag (2000), O. Teytaud (2005-)
- ILP, *Inductive Logic Programming*: M. Sebag (2003-)
- NIPS, *Neural Information Processing Systems*: M. Sebag (2008)
- NPC, *IFIP Network and Parallel Computing*: C. Germain (2007-)
- PPSN, *Parallel Problem Solving from Nature*: A. Auger (2008), N. Hansen (2004-), M. Schoenauer (1994-), M. Sebag (1996-), O. Teytaud (2008)

9.1.4. Program Committee Member (national events)

- EA, *Evolution Artificielle*: A. Auger (2005-), N. Bredèche (2005-), N. Hansen (2007-), M. Schoenauer (1994-), M. Sebag (1994-), O. Teytaud (2005-)
- CAp, *Conférence d'Apprentissage*: M. Sebag (1999-), O. Teytaud (2005-)
- RFIA, *Reconnaissance des Formes et Intelligence Artificielle*: M. Sebag, comité éditorial (2004-)
- *Les 40 ans de l'INRIA*: M. Schoenauer (2008).

9.1.5. Evaluation committees and invited expertise

- European Commission (FP7 projects), EU: M. Schoenauer; Michèle Sebag
- ANR TecSan: Cécile Germain-Renaud
- ANR SYSCOMM: Marc Schoenauer, Président du Comité d'Évaluation

9.1.6. Other evaluation activities

- Reviewer for PhD dissertations: Marc Schoenauer (4, including one from Adelaide Univ., Australia); Michèle Sebag (2);
- Reviewer for Habilitation: Marc Schoenauer (1), Michèle Sebag (1);
- Member of the PhD jurys: Anne Auger (1), Cécile Germain-Renaud (1), Michèle Sebag (2), Olivier Teytaud (1)

9.1.7. Popularisation of research results

- The collection of Chairs, designed within a collaboration between TAO and with the architect consortium ECZT, are still exhibited (since April 2007) in the permanent Design Collection of Beaubourg, the French National Modern Art Museum (http://www.inria.fr/saclay/ressources-1/computer-culture/artlgorithm/view?set_language=en).
- Jeudi de la Recherche, U. Paris-Sud (2008): Michèle Sebag, Olivier Teytaud.
- Fête de la Science, U. Paris-Sud (2008): Cédric Hartland.
- Fête de la Science, Antony (2008): Olivier Teytaud
- MoGo (computer-go tool) was exhibited
  - IAGO (Paris tournament of Go, 2008);
  - US Open 2008 (Portland, 2008);
  - Taiwan invited games (many articles in newspapers, National University of Tainan, Taiwan).
- MoGo also discussed in "Sciences & Vie", "Micro Hebdo", "Slash Dot", ...

9.1.8. Summer schools, tutorials, invited seminars

- Anne Auger and Nikolaus Hansen, GECCO Conference, Tutorial, Atlanta US, 2008.
- Anne Auger and Nikolaus Hansen, PPSN Conference, Tutorial, Dortmund Germany, 2008.
- Anne Auger, JET Summer School, Tutorial, Porquerolles, 2008.
- Marc Schoenauer, JET Summer School, Tutorial, Porquerolles, 2008.
- Michèle Sebag, KD-Ubiq Summer School, Tutorial (6 hours), Porto, 2008.
- Michèle Sebag, Dagstuhl Seminar on Evolutionary Testing, Lecture, 2008.
- Michèle Sebag, IA Fondamentale, Lecture on Machine Learning, 2008.

9.2. Enseignement

9.2.1. Defended doctorates

- Nicolas Baskiotis, 22/9/08, Université Paris-Sud, supervisor Michèle Sebag;
- Mohamed Jebalia, 19/12/08, Université Pierre et Marie Curie, co-supervisors Anne Auger and Marc Schoenauer.

9.2.2. Graduate Courses

- Master 2 Recherche (U. Paris-Sud), Data Mining and Machine Learning (24 h): Michèle Sebag, Balazs Kégl, Antoine Cornuéjols.
- Master 2 Recherche (U.Paris-Sud), Artificial Evolution and Evolutionary Robotics (24 hours): Anne Auger, Nicolas Bredèche and Marc Schoenauer.
- Master 2 Recherche (U.Paris-Sud), Artificial and Natural Perception : Nicolas Bredèche (3h).

9.2.3. Undergraduate course

- Anne Auger: Ecole Centrale Paris, cours “Contrôle avancé” (part: Genetic Algorithms), (12h).

9.2.4. Other research-related teaching activities

At *Ecole Polytechnique*:

- Projects in Evolutionary Robotics in the *Modex d’Electronique*: Cédric Hartland, Marc Schoenauer.
- Majeure “SEISM” (Engineering Science): one lesson (+ hands-on experiments) on Evolutionary Topological Optimum Design, Marc Schoenauer;
- *Stages d’option* (internships), Marc Schoenauer, Michèle Sebag.

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Articles in International Peer-Reviewed Journal

[2] A. AUGER, O. TEYTAUD. *Continuous Lunches are free plus the design of optimal optimization algorithms.*, in "Algorithmica", accepted, 2009.

[3] A. CORNUÉJOLS, M. SEBAG. *A note on phase transition and computational pitfalls of learning from sequences*, in "Journal of Intelligent Information Systems", vol. 31, n^{O} 2, 2008, p. 177-189.

[4] N. HANSEN, A. NIEDERBERGER, L. GUZZELLA, P. KOUMOUTSAKOS. *A Method for Handling Uncertainty in Evolutionary Optimization with an Application to Feedback Control of Combustion*, in "IEEE Transactions on Evolutionary Computation", 2009, http://hal.inria.fr/inria-00276216/en/.

[5] T. SUTTORP, N. HANSEN, C. IGEL. *Efficient Covariance Matrix Update for Variable Metric Evolution Strategies*, in "Machine Learning", 2009.

[6] A. TERMIER, M.-C. ROUSSET, M. SEBAG, K. OHARA, T. WASHIO, H. MOTODA. *DryadeParent, An Efficient and Robust Closed Attribute Tree Mining Algorithm*, in "IEEE Trans. on Knowledge and Data Engineering", vol. 20, n^{O} 3, March 2008, p. 300-320.

Articles in National Peer-Reviewed Journal

[7] L. CHATRIOT, C. FITER, G. CHASLOT, S. GELLY, J.-B. HOOCK, J. PEREZ, A. RIMMEL, O. TEYTAUD. *Combiner connaissances expertes, hors-ligne, transientes et en ligne pour l'exploration Monte-Carlo*, in "Revue d'Intelligence Artificielle", 2008, http://hal.inria.fr/inria-00343509/en/.

Invited Conferences

[8] P. CAILLOU, T. BAPTISTA, C. CURCHOD. *Multi-agent Based simulation for Decision-Making: an application to Rungis food market*, in "GDN 2008, Coimbra Portugal", J. P. C. JOAO CLIMACO (editor), 2008, p. 193-194, http://hal.inria.fr/inria-00288111/en/.

International Peer-Reviewed Conference/Proceedings

[9] A. ARBELAEZ, Y. HAMADI. *Exploiting Weak Dependencies in Tree-based Search*, in "Proceedings of the 24th Annual ACM Symposium on Applied Computing", to appear, ACM Press, ACM, 2009.

[10] A. AUGER, J. BADER, D. BROCKHOFF, E. ZITZLER. *Theory of the Hypervolume Indicator: Optimal μ-Distributions and the Choice of the Reference Point*, in "Foundations of Genetic Algorithms", accepted, ACM, 2009.

[11] N. BREDECHE, Y. CHEVALEYRE. *The Robot Swarm Re-localization Problem*, in "Proceedings of the 5th IEEE International Conference on Robotics and Biomimetics (ROBIO 2008)", 2009.

[12] N. BREDECHE. *A Multi-Cellular Developmental System in Continuous Space using Cell Migration*, in "Simulation of Adaptive Behavior, Osaka Japon", M. ASADA, ET AL. (editors), Lecture Notes in Computer Science, vol. 5040, 2008, p. 260-269, http://hal.inria.fr/inria-00288037/en/.

[13] L. DA COSTA, A. FIALHO, M. SCHOENAUER, M. SEBAG. *Adaptive Operator Selection with Dynamic Multi-Armed Bandits*, in "Genetic and Evolutionary Computation Conference (GECCO)", C. RYAN, ET AL. (editors), ACM Press, ACM, 2008, p. 913–920, http://hal.inria.fr/inria-00278542/en/.

[14] A. DEVERT, N. BREDECHE, M. SCHOENAUER. *Artificial Ontogeny for Truss Structure Design*, in "Workshop on Spatial Computing (SCW) at the second IEEE International Conference on Self-Adaptive and Self-Organizing Systems", 2008.

[15] A. FIALHO, L. DA COSTA, M. SCHOENAUER, M. SEBAG. *Extreme Value Based Adaptive Operator Selection*, in "Parallel Problem Solving from Nature (PPSN'08)", G. RUDOLPH, ET AL. (editors), LNCS, Springer, 2008, p. 175–184, http://hal.inria.fr/inria-00287355/en/.

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[26] J. PEREZ, C. GERMAIN-RENAUD, B. KÉGL, C. LOOMIS. *Utility-based Reinforcement Learning for Reactive Grids*, in "The 5th IEEE International Conference on Autonomic Computing, Chicago États-Unis", 2008, http://hal.inria.fr/inria-00287354/en/.

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