IN PARTNERSHIP WITH:
Université des sciences et technologies de Lille (Lille 1)

Activity Report 2013

Project-Team DOLPHIN

Parallel Cooperative Multi-objective Optimization

IN COLLABORATION WITH: Laboratoire d'informatique fondamentale de Lille (LIFL)

RESEARCH CENTER
Lille - Nord Europe

THEME
Optimization, machine learning and statistical methods

Table of contents

Project-Team DOLPHIN

Keywords: Multi-objective Optimization, Combinatorial Optimization, Parallelism, Metaheuristic, Operational Research

Creation of the Project-Team: 2005 May 12.

1. Members

Research Scientists
Dimo Brockhoff [Inria, Researcher]
Luce Brotcorne [Inria, Researcher, HdR]

Faculty Members
El-Ghazali Talbi [Team leader, Univ. Lille I, Professor, HdR]
Francois Clautiaux [Univ. Lille 1, Associate Professor, until Sep 2013, HdR]
Bilel Derbel [Univ. Lille I, Associate Professor]
Clarisse Dhaenens [Univ. Lille I, Professor, HdR]
Arnaud Liefooghe [Univ. Lille I, Associate Professor]
Marie-Eléonore Marmion [Univ. Lille I, Associate Professor]
Nouredine Melab [Univ. Lille I, Professor, HdR]
Laetitia Jourdan [Univ. Lille I, Professor, HdR]

Engineers
Quentin Brochard [Inria, KALRAY, from Aug 2013 until Oct 2013]
Benjamin Fisset [Inria, from May 2013]
Clive Ferret-Canape [Inria, from Sept 2012]
Vidal Watat Yomba [Inria, until Nov 2013]

PhD Students
Sezin Afsar [Inria CORDI]
Oumayma Bahri [Univ. Tunis, Tunisia]
Martin Bué [CIFRE BeTravel]
Imen Chakroun [Univ. Lille I, until Sep 2013]
Nadia Dahmani [Univ. Tunis, Tunisia]
Moustapha Diaby [Univ. Lille I, until Aug 2013]
Nicolas Dupin [DGA, from Jan 2013]
Matthieu Gérard [CIFRE Vekia]
Julie Hamon [CIFRE Genes Diffusion, until Nov 2013]
Julie Jacques [Alicante until Dec 2013]
Sophie Jacquin [Univ. Lille I, Bourse MESR]
Yacine Kessaci [Univ. Lille I, ATER]
Francois Legillon [CIFRE Tasker, until Sep 2014]
Rudi Leroy [Inria, Maison de la simulation]
Khedidja Seridi [Univ. Lille I, until Aug 2013]
Bayrem Tounsi [Inria, ANR RESPET project]
Thanh-Do Tran [Inria, CORDI-S]
Trong Tuan Vu [Inria, CORDI-S]
Asmae Gannouni [Univ. Lille I from Dec 2013]

Post-Doctoral Fellows
Ekaterina Alekseeva [Inria, EDF]
Bernabé Dorronsoro Diaz [Univ. Lille I]
Samia El Aoud [Inria, ERCIM from Jun 2013]

Visiting Scientists

Larbi Asli [Univ. Algiers, from Sep 2013 until Sep 2013]
Michel Gendreau [Univ. Montreal, from Nov 2013 until Nov 2013]
Samir Hadjar [CERIST Algiers, from Nov 2013 until Dec 2013]
Igor Machado Coelho [Universidad Federal Fluminense, from Nov 2013]
Patrice Marcotte [Univ. Montreal, from Dec 2013 until Dec 2013]
Gilles Savard [Univ. Montreal, from Feb 2013 until Feb 2013]
Ghazi Tekaya [ENSI Universty of Mannouba Tunisia, from Oct 2012 until Jan 2013]
Sadok Bouamama [ENSI Universty of Mannouba Tunisia, from Jan 2013 until Jan 2013]
Sébastien Verel [Univ. Méditerranée, Associate Professor]
Martin Drozdik [Shinshu University, Japan, from Nov 2013]

Administrative Assistant

Julie Jonas [Inria]

2. Overall Objectives

2.1. Presentation

The goal of the DOLPHIN [1] project is the modeling and resolution of large multi-criteria combinatorial problems using parallel and distributed hybrid techniques. We are interested in algorithms using Pareto approaches, which generate the whole Pareto set of a given Multi-Objective Problem (MOP). For this purpose, the research actions can be summarized as follows:

- **Modeling and Analysis of MOPs:** Solving Multi-Objective Problems requires an important analysis phase to find the best suitable method to solve it. This analysis deals with the modeling of the problem and the analysis of its structure.

  To propose efficient models for a Multi-Objective Optimization problem, an important aspect is to integrate all the constraints of the problem. Therefore an interesting preliminary approach is to develop efficient models for the problem in its mono-objective forms in order to be able to develop methods that are taking the characteristics of the studied problem into account.

  While studying the problem in its multi-objective form, the analysis of the structure is another interesting approach. The analysis of the structure of the Pareto front by means of different approaches (statistical indicators, meta-modeling, etc.) allows the design of efficient and robust hybrid optimization techniques. In general, the current theory does not allow the complete analysis of optimization algorithms. Several questions are unanswered: i) why is a given method efficient? ii) why are certain instances difficult to solve? Some work is needed to guide the user in the design of efficient methods.

  The NFL (No Free Lunch) theorem shows that two optimization methods have the same global performance on the whole set of uniform optimization problems. Then, it is crucial to make some hypotheses on the studied problem. This may be done in two steps:

  - analyzing the target problem to identify its landscape properties,
  - including this knowledge in the proposed optimization method.

  Our interest in this project is to answer these questions and remarks for the multi-objective case. Another point considered is the performance evaluation of multi-objective optimization methods. We are also working on approximation algorithms with performance guarantee and the convergence properties of stochastic algorithms.

- **Cooperation of optimization methods (metaheuristics and/or exact methods):**

[1] Discrete multi-objective Optimization for Large scale Problems with Hybrid dIstributed techNiques.

The hybridization of optimization methods allows the cooperation of complementary different methods. For instance, the cooperation between a metaheuristic and an exact method allows us to take advantage of the intensification process of an exact method in finding the best(s) solution(s) in a sub-space, and the diversification process of the metaheuristic in reducing the search space to explore.

In this context, different types of cooperation may be proposed. These approaches are under study in the project and we are applying them to different generic MOPs (flow-shop scheduling problem, vehicle routing problem, covering tour problem, access network design, and the association rule problem in data mining).

- **Parallel optimization methods:** Parallel and distributed computing may be considered as a tool to speedup the search to solve large MOPs and/or to improve the robustness of a given method. Following this objective, we design and implement parallel metaheuristics (evolutionary algorithms, Tabu search approach) and parallel exact methods (branch and bound algorithm, branch and cut algorithm) for solving different large MOPs. Moreover, the joint use of parallelism and cooperation allows the improvement of the quality of the obtained solutions.
- **Framework for parallel and distributed hybrid metaheuristics:** Our team contributes to the development of an open source framework for metaheuristics, named ParadisEO (PARAllel and DIStributed Evolving Objects). Our contribution in this project is the extension of the EO (Evolving Objects) framework [2], which consists in: i) the generalization of the framework to single solution metaheuristics such as local search, tabu search and simulated annealing; ii) the design of metaheuristics for multi-objective optimization; iii) the design of hybrid methods; iv) the development of parallel and distributed models.

  In this project, our goal is the efficient design and implementation of this framework on different types of parallel and distributed hardware platforms:cluster of workstations (COW), networks of workstations (NOW) and GRID computing platforms, using the suited programming environments (MPI, Condor, Globus, PThreads). The coupling with well-known frameworks for exact methods (such as COIN) will also be considered. The exact methods for MOPs developed in this project will be integrated in those software frameworks.

  The experimentation of this framework by different users and applications outside the DOLPHIN project is considered. This is done in order to validate the design and the implementation issues of ParadisEO.
- **Validation:** the designed approaches are validated on generic and real-life MOPs, such as:
  1. Scheduling problems: Flow-shop scheduling problem.
  2. Routing problems: Vehicle routing problem (VRP), covering tour problem (CTP).
  3. mobile telecommunications: Design of mobile telecommunications networks (contract with France Telecom R&D) and design of access networks (contract with Mobinets).
  4. Genomics: Association rule discovery (data mining task) for mining genomic data, protein identification, docking and conformational sampling of molecules.
  5. Engineering design problems: Design of polymers.

  Some benchmarks and their associated optimal Pareto fronts or best known Pareto fronts have been defined and made available on the Web. We are also developing an open source software, named GUIMOO [3], which integrates different performance evaluation metrics and 2D/3D visualization tools of Pareto fronts.

2.2. Highlights of the Year

BEST PAPER AWARD :

[2]This framework was initially developed by Geneura TEAM (Spain), Inria (France), LIACS (Netherlands). http://paradiseo.gforge.inria.fr.

[3]Graphical User Interface for Multi-Objective Optimization (http://guimoo.gforge.inria.fr).

[62] **ParadisEO-MO-GPU: a Framework for Parallel Local Search Metaheuristics in GECCO - Genetic and Evolutionary Computation Conference - 2013**. M. NOUREDINE, T. V. LUONG, B. KARIMA, T. EL-GHAZALI.

3. Research Program

3.1. Hybrid multi-objective optimization methods

The success of metaheuristics is based on their ability to find efficient solutions in a reasonable time [89]. But with very large problems and/or multi-objective problems, efficiency of metaheuristics may be compromised. Hence, in this context it is necessary to integrate metaheuristics in more general schemes in order to develop even more efficient methods. For instance, this can be done by different strategies such as cooperation and parallelization.

The DOLPHIN project deals with *"a posteriori"* multi-objective optimization where the set of Pareto solutions (solutions of best compromise) have to be generated in order to give the decision maker the opportunity to choose the solution that interests him/her.

Population-based methods, such as evolutionary algorithms, are well fitted for multi-objective problems, as they work with a set of solutions [84], [88]. To be convinced one may refer to the list of references on Evolutionary Multi-objective Optimization maintained by Carlos A. Coello [4], which contains more than 5500 references. One of the objectives of the project is to propose advanced search mechanisms for intensification and diversification. These mechanisms have been designed in an adaptive manner, since their effectiveness is related to the landscape of the MOP and to the instance solved.

In order to assess the performances of the proposed mechanisms, we always proceed in two steps: first, we carry out experiments on academic problems, for which some best known results exist; second, we use real industrial problems to cope with large and complex MOPs. The lack of references in terms of optimal or best known Pareto set is a major problem. Therefore, the obtained results in this project and the test data sets will be available at the URL http://dolphin.lille.inria.fr/ at 'benchmark'.

3.1.1. Cooperation of metaheuristics

In order to benefit from the various advantages of the different metaheuristics, an interesting idea is to combine them. Indeed, the hybridization of metaheuristics allows the cooperation of methods having complementary behaviors. The efficiency and the robustness of such methods depend on the balance between the exploration of the whole search space and the exploitation of interesting areas.

Hybrid metaheuristics have received considerable interest these last years in the field of combinatorial optimization. A wide variety of hybrid approaches have been proposed in the literature and give very good results on numerous single objective optimization problems, which are either academic (traveling salesman problem, quadratic assignment problem, scheduling problem, etc) or real-world problems. This efficiency is generally due to the combinations of single-solution based methods (iterative local search, simulated annealing, tabu search, etc) with population-based methods (genetic algorithms, ants search, scatter search, etc). A taxonomy of hybridization mechanisms may be found in [93]. It proposes to decompose these mechanisms into four classes:

- *LRH class - Low-level Relay Hybrid*: This class contains algorithms in which a given metaheuristic is embedded into a single-solution metaheuristic. Few examples from the literature belong to this class.
- *LTH class - Low-level Teamwork Hybrid*: In this class, a metaheuristic is embedded into a population-based metaheuristic in order to exploit strengths of single-solution and population-based metaheuristics.

[4] http://www.lania.mx/~ccoello/EMOO/EMOObib.html

- *HRH class - High-level Relay Hybrid*: Here, self contained metaheuristics are executed in a sequence. For instance, a population-based metaheuristic is executed to locate interesting regions and then a local search is performed to exploit these regions.
- *HTH class - High-level Teamwork Hybrid*: This scheme involves several self-contained algorithms performing a search in parallel and cooperating. An example will be the island model, based on GAs, where the population is partitioned into small subpopulations and a GA is executed per subpopulation. Some individuals can migrate between subpopulations.

Let us notice that, hybrid methods have been studied in the mono-criterion case, their application in the multi-objective context is not yet widely spread. The objective of the DOLPHIN project is to integrate specificities of multi-objective optimization into the definition of hybrid models.

3.1.2. Cooperation between metaheuristics and exact methods

Until now only few exact methods have been proposed to solve multi-objective problems. They are based either on a Branch-and-bound approach, on the algorithm $A^{\star}$, or on dynamic programming. However, these methods are limited to two objectives and, most of the time, cannot be used on a complete large scale problem. Therefore, sub search spaces have to be defined in order to use exact methods. Hence, in the same manner as hybridization of metaheuristics, the cooperation of metaheuristics and exact methods is also a main issue in this project. Indeed, it allows us to use the exploration capacity of metaheuristics, as well as the intensification ability of exact methods, which are able to find optimal solutions in a restricted search space. Sub search spaces have to be defined along the search. Such strategies can be found in the literature, but they are only applied to mono-objective academic problems.

We have extended the previous taxonomy for hybrid metaheuristics to the cooperation between exact methods and metaheuristics. Using this taxonomy, we are investigating cooperative multi-objective methods. In this context, several types of cooperations may be considered, according to the way the metaheuristic and the exact method cooperate. For instance, a metaheuristic can use an exact method for intensification or an exact method can use a metaheuristic to reduce the search space.

Moreover, a part of the DOLPHIN project deals with studying exact methods in the multi-objective context in order: i) to be able to solve small size problems and to validate proposed heuristic approaches; ii) to have more efficient/dedicated exact methods that can be hybridized with metaheuristics. In this context, the use of parallelism will push back limits of exact methods, which will be able to explore larger size search spaces [86].

3.1.3. Goals

Based on the previous works on multi-objective optimization, it appears that to improve metaheuristics, it becomes essential to integrate knowledge about the problem structure. This knowledge can be gained during the search. This would allow us to adapt operators which may be specific for multi-objective optimization or not. The goal here is to design auto-adaptive methods that are able to react to the problem structure. Moreover, regarding the hybridization and the cooperation aspects, the objectives of the DOLPHIN project are to deepen these studies as follows:

- *Design of metaheuristics for the multi-objective optimization:* To improve metaheuristics, it becomes essential to integrate knowledge about the problem structure, which we may get during the execution. This would allow us to adapt operators that may be specific for multi-objective optimization or not. The goal here is to design auto-adaptive methods that are able to react to the problem structure.
- *Design of cooperative metaheuristics:* Previous studies show the interest of hybridization for a global optimization and the importance of problem structure study for the design of efficient methods. It is now necessary to generalize hybridization of metaheuristics and to propose adaptive hybrid models that may evolve during the search while selecting the appropriate metaheuristic. Multi-objective aspects have to be introduced in order to cope with the specificities of multi-objective optimization.

- *Design of cooperative schemes between exact methods and metaheuristics:* Once the study on possible cooperation schemes is achieved, we will have to test and compare them in the multi-objective context.
- *Design and conception of parallel metaheuristics:* Our previous works on parallel metaheuristics allow us to speed up the resolution of large scale problems. It could be also interesting to study the robustness of the different parallel models (in particular in the multi-objective case) and to propose rules that determine, given a specific problem, which kind of parallelism to use. Of course these goals are not disjoined and it will be interesting to simultaneously use hybrid metaheuristics and exact methods. Moreover, those advanced mechanisms may require the use of parallel and distributed computing in order to easily make cooperating methods evolve simultaneously and to speed up the resolution of large scale problems.
- *Validation:* In order to validate the obtained results we always proceed in two phases: validation on academic problems, for which some best known results exist and use on real problems (industrial) to cope with problem size constraints.

  Moreover, those advanced mechanisms are to be used in order to integrate the distributed multi-objective aspects in the ParadisEO platform (see the paragraph on software platform).

3.2. Parallel multi-objective optimization: models and software frameworks

Parallel and distributed computing may be considered as a tool to speedup the search to solve large MOPs and to improve the robustness of a given method. Moreover, the joint use of parallelism and cooperation allows improvements on the quality of the obtained Pareto sets. Following this objective, we will design and implement parallel models for metaheuristics (evolutionary algorithms, tabu search approach) and exact methods (branch-and-bound algorithm, branch-and-cut algorithm) to solve different large MOPs.

One of the goals of the DOLPHIN project is to integrate the developed parallel models into software frameworks. Several frameworks for parallel distributed metaheuristics have been proposed in the literature. Most of them focus only either on evolutionary algorithms or on local search methods. Only few frameworks are dedicated to the design of both families of methods. On the other hand, existing optimization frameworks either do not provide parallelism at all or just supply at most one parallel model. In this project, a new framework for parallel hybrid metaheuristics is proposed, named *Parallel and Distributed Evolving Objects (ParadisEO)* based on EO. The framework provides in a transparent way the hybridization mechanisms presented in the previous section, and the parallel models described in the next section. Concerning the developed parallel exact methods for MOPs, we will integrate them into well-known frameworks such as COIN.

3.2.1. Parallel models

According to the family of addressed metaheuristics, we may distinguish two categories of parallel models: parallel models that manage a single solution, and parallel models that handle a population of solutions. The major single solution-based parallel models are the following: the *parallel neighborhood exploration model* and the *multi-start model*.

- *The parallel neighborhood exploration model* is basically a "low level" model that splits the neighborhood into partitions that are explored and evaluated in parallel. This model is particularly interesting when the evaluation of each solution is costly and/or when the size of the neighborhood is large. It has been successfully applied to the mobile network design problem (see Application section).
- *The multi-start model* consists in executing in parallel several local searches (that may be heterogeneous), without any information exchange. This model raises particularly the following question: is it equivalent to execute k local searches during a time t than executing a single local search during $k \times t$? To answer this question we tested a multi-start Tabu search on the quadratic assignment problem. The experiments have shown that the answer is often landscape-dependent. For example, the multi-start model may be well-suited for landscapes with multiple basins.

Parallel models that handle a population of solutions are mainly: the *island model*, the *central model* and *the distributed evaluation of a single solution*. Let us notice that the last model may also be used with single-solution metaheuristics.

- In *the island model*, the population is split into several sub-populations distributed among different processors. Each processor is responsible of the evolution of one sub-population. It executes all the steps of the metaheuristic from the selection to the replacement. After a given number of generations (synchronous communication), or when a convergence threshold is reached (asynchronous communication), the migration process is activated. Then, exchanges of solutions between sub-populations are realized, and received solutions are integrated into the local sub-population.
- *The central (Master/Worker) model* allows us to keep the sequentiality of the original algorithm. The master centralizes the population and manages the selection and the replacement steps. It sends sub-populations to the workers that execute the recombination and evaluation steps. The latter returns back newly evaluated solutions to the master. This approach is efficient when the generation and evaluation of new solutions is costly.
- *The distributed evaluation model* consists in a parallel evaluation of each solution. This model has to be used when, for example, the evaluation of a solution requires access to very large databases (data mining applications) that may be distributed over several processors. It may also be useful in a multi-objective context, where several objectives have to be computed simultaneously for a single solution.

As these models have now been identified, our objective is to study them in the multi-objective context in order to use them advisedly. Moreover, these models may be merged to combine different levels of parallelism and to obtain more efficient methods [87], [92].

3.2.2. Goals

Our objectives focus on these issues are the following:

- *Design of parallel models for metaheuristics and exact methods for MOPs*: We will develop parallel cooperative metaheuristics (evolutionary algorithms and local search algorithms such as the Tabu search) for solving different large MOPs. Moreover, we are designing a new exact method, named PPM (Parallel Partition Method), based on branch and bound and branch and cut algorithms. Finally, some parallel cooperation schemes between metaheuristics and exact algorithms have to be used to solve MOPs in an efficient manner.
- *Integration of the parallel models into software frameworks*: The parallel models for metaheuristics will be integrated in the ParadisEO software framework. The proposed multi-objective exact methods must be first integrated into standard frameworks for exact methods such as COIN and BOB++. A *coupling* with ParadisEO is then needed to provide hybridization between metaheuristics and exact methods.
- *Efficient deployment of the parallel models on different parallel and distributed architecture including GRIDs*: The designed algorithms and frameworks will be efficiently deployed on non-dedicated networks of workstations, dedicated cluster of workstations and SMP (Symmetric Multi-processors) machines. For GRID computing platforms, peer to peer (P2P) middlewares (XtremWeb-Condor) will be used to implement our frameworks. For this purpose, the different optimization algorithms may be re-visited for their efficient deployment.

4. Application Domains

4.1. Academic Benchmark Problems

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

4.2. Transportation and logistics

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

4.3. Bioinformatics and Health care

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

4.3.1. Genomic and post-genomic studies

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

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

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

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

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

4.3.2. Optimization for health care

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

5. Software and Platforms

5.1. ParadisEO

Participants: Clive Ferret-Canape, Laetitia Jourdan, Arnaud Liefooghe, Nouredine Melab, Alexandre Quemy, El-Ghazali Talbi [correspondent], Sébastien Verel.

ParadisEO (PARallel and DIStributed Evolving Objects) is a C++ white-box object-oriented framework dedicated to the flexible design of metaheuristics. See web site http://paradiseo.gforge.inria.fr. Based on EO, a template-based ANSI-C++ compliant evolutionary computation library, it is composed of five modules:

- Paradiseo-EO provides tools for the development of population-based metaheuristic (evolutionary and genetic algorithm, genetic programming, particle swarm optimization, etc.)
- Paradiseo-MO provides tools for the development of single solution-based metaheuristics (hill-climbing, tabu search, simulated annealing, iterative local search, variable neighborhood search, incremental evaluation, partial neighborhood, etc.)
- Paradiseo-MOEO provides tools for the design of multi-objective metaheuristics (MO fitness assignment, MO diversity preservation, elitism, performance indicators, easy-to-use state-of-the-art algorithms, etc)

- Paradiseo-PEO provides tools for the design of parallel and distributed metaheuristics (parallel evaluation, parallel evaluation function, island model)
- Paradiseo-SMP provides tools for the design of shared memory parallel metaheuristics (parallel evaluation, island model)

Furthermore, Paradiseo also introduces tools for the design of distributed, hybrid and cooperative models:

- High level hybrid metaheuristics: coevolutionary and relay models.
- Low level hybrid metaheuristics: coevolutionary and relay models.

The ParadisEO framework has been especially designed to best suit to the following objectives:

- Maximum design and code reuse: ParadisEO is based on a clear conceptual separation of the solution methods from the problems they are intended to solve. This separation confers to the user a maximum code and design reuse.
- Flexibility and adaptability: The fine-grained nature of the classes provided by the framework allows a higher flexibility compared to other frameworks.
- Utility: ParadisEO allows the user to cover a broad range of metaheuristics, problems, parallel distributed models, hybridization mechanisms, etc.
- Transparent and easy access to performance and robustness: As the optimization applications are often time-consuming the performance issue is crucial. Parallelism and distribution are two important ways to achieve high performance execution. ParadisEO is one of the rare frameworks that provide the most common parallel and distributed models. These models can be exploited in a transparent way, one has just to instantiate their associated provided classes.
- Portability: The implemented models are portable on distributed-memory machines as well as on shared-memory multiprocessors, as they use standard libraries such as MPI and std::threads. ParadisEO supports the most recent version of standard of the C++ programming, c++11.

This year a new module, Paradiseo-SMP, has been released. All the new features is managed via the Inria Gforge project http://paradiseo.gforge.inria.fr. The version 2.0 has been released in Septembre 2012.

5.1.1. Paradiseo-SMP: a new module for shared memory parallel

This year, we released a new module dedicated to shared memory parallel. This module improves the technical mechanisms of Paradiseo-PEO thanks a new software architecture and the new c+11 features.
Paradiseo-SMP implements parallel evaluation, dynamic heterogeneous island model, and their hybridization. The main features are:

- Dynamic Island Model: topology can be changed during the execution.
- Heterogeneous Islands: different kinds of population-based metaheuristics can communicate (evolutionary and genetic algorithm, particle swarm optimization, etc.).
- Island Model and master/slave model can be hybridized.

All these new features are developed in c++11.

5.1.2. New technical features

Regarding the technical aspects, the compatibility with dependencies taken into account is:

- c++11 features supporting.
- Checked compatibility with different operating systems.
- Reviewed and checked compatibility with new versions of the tools used (CMake, g++, clang, MinGW...).
- Unit and integration test of all additional components, and experiments on classical applications.

5.1.3. Contributions and documentations

Many investigations were made in this context in order to help users to manipulate the framework.

- New quick start guide is available.
- New tutorials:
  - Tutorials SMP.
  - Tutorials GPU.
- Updated implementation for classical problems.

Self-assessment of the team effort (software criteria: http://www.inria.fr/institut/organisation/instances/commission-d-evaluation)

(A-4-up5) Audience: 4 - Used in many universities for teaching and several companies.

(SO-4) Software Originality: 4 - ParadisEO aggregates the last results of the Dolphin team.

(SM-4) Software Maturity: 4 - Extensive documentation, strong software engineering and testing, regression testing, user feedback ...

(EM-2-up3) Evolution and Maintenance: 2 - Basic maintenance with persistent attention to users.

(SDL-4) Software Distribution and Licensing: 4 - CeCILL license, public source, Windows and Mac installer, Linux packages.

(OC) Own Contribution: (Design/Architecture) DA-4, (Coding/Debugging) CD-4, (Maintenance/Support) MS-4, (Team/Project Management) TPM-4

6. New Results

6.1. Bi-level multi-objective optimization for pricing problems in long-haul transportation

Participants: M. Diaby, L. Brotcorne and E-G. Talbi

This work is concerned with the problem of pricing for a long-haul full load goods transportation. More precisely, we are interested in the situation where each vehicle delivers single request at a time. In this environment, we study the problem of pricing and valorization of unutilized capacity between two carriers. The first carrier B, cannot serve all the transportation requests and he thus needs to use outsourcing : second carrier A or his competitors. Carrier A, has to define the prices for carrier B transportation requests. Once carrier A has given its prices for the operations, it is B's decision to turn to A or to another carrier. This sequential and non-cooperative decision-making process can be adequately represented as a bilevel program : carrier B (the follower) wants to minimize transportation cost while A (the leader) seeks to maximize the revenue. Carrier A explicitly incorporates the reaction of carrier B in his optimization process.

Two types of models have been proposed : the bilevel mono-objective model and the bilevel biobjective model. More precisely, two objectives are simultaneously considered for the leader problem : the maximization of revenue and balancing the free load length (limiting the free load distances). We propose exact methods to solve moderate size instance of the problem and the heuristics to solve large-scale instances in reasonable time.

6.2. Approximating multi-objective scheduling problems

Participant: El-ghazali Talbi
External participants: Said Dabia, Tom Van Woensel, Tom De Kok (Eindhoeven Technical University)

In this contribution, we propose a generic approach to deal with multi-objective scheduling problems (MOSPs). The aim is to determine the set of Pareto solutions that represent the interactions between the different objectives. Due to the complexity of MOSPs, an efficient approximation based on dynamic programming is developed. The approximation has a provable worst case performance guarantee. Eventhough the approximate Pareto set consists of fewer solutions, it represents a good coverage of the true set of Pareto solutions. We consider generic cost parameters that depend on the state of the system. Numerical results are presented for the time-dependent multi-objective knapsack problem, showing the value of the approximation in the special case when the state of the system is expressed in terms of time [23].

6.3. Force-Based Cooperative Search Directions in Evolutionary Multi-objective Optimization

Participants: Bilel Derbel, Dimo Brockhoff, Arnaud Liefooghe

In order to approximate the set of Pareto optimal solutions, several evolutionary multi-objective optimization (EMO) algorithms transfer the multi-objective problem into several independent single-objective ones by means of scalarizing functions. The choice of the scalarizing functions' underlying search directions, however, is typically problem-dependent and therefore difficult if no information about the problem characteristics are known before the search process. In [46], we present new ideas of how these search directions can be computed *adaptively* during the search process in a *cooperative* manner. Based on the idea of Newton's law of universal gravitation, solutions attract and repel each other *in the objective space*. Several force-based EMO algorithms are proposed and compared experimentally on general bi-objective ρMNK landscapes with different objective correlations. It turns out that the new approach is easy to implement, fast, and competitive with respect to a $(\mu + \lambda)$-SMS-EMOA variant, in particular if the objectives show strong positive or negative correlations.

6.4. DYNAMO (DYNAmic programming using Metaheuristic for Optimization Problems)

Participants: Sophie Jacquin, Laetitia Jourdan, El-Ghazali Talbi

DYNAMOP (DYNAmic programming using Metaheuristic for Optimization Problems) is a new dynamic programming based on genetic algorithm to solve a hydro-scheduling problem. The representation which is based on a path in the graph of states of dynamic programming is adapted to dynamic structure of the problem and it allows to hybridize easily evolutionary algorithms with dynamic programming. DYNAMOP has been tested on two case studies of hydro-scheduling problem with different price scenarios. Experiments indicate that the proposed approach performs considerably better than classical genetic algorithms and dynamic programming.

6.5. MOCA-I: Multi-Objective Classification Algorithm for Imbalanced Data

Participants: Julie Jacques, Clarisse Dhaenens, Laetitia Jourdan

Dealing with Imbalanced data is a real challenge as predicting the minority class may be very difficult but has a great interest for medical applications for example. Therefore, we propose MOCA-I, a new multi-objective local search algorithm that is conceived to deal with class imbalancy, double meaning of missing data, volumetry and need of highly interpretable results all together [50]. MOCAI is a Pittsburgh multi-objective partial classification rule mining algorithm, using dominance-based multi-objective local search (DMLS). In comparison to state-of-the-art classification algorithms, MOCA-I obtains the best results on the 10 data sets of literature and is statistically better on the real data sets [50].

6.6. Neutrality Analysis is Graph coloring problem

Participants: Aymeric Blot, Clarisse Dhaenens, Laetitia Jourdan, Marie-Eleonore Marmion

Solving neutral problems is challenging as many optimization methods have difficulty to obtain good solutions. Hence, studying the neutrality in order to provide insights on the structure of the problem to be soved may be an answer. This has been done for the graph coloring problem (GCP) for which the neutrality of some hard instances has been quantified. This neutrality property has to be detected as it impacts the search process. Indeed, local optima may belong to plateaus that represent a barrier for local search methods. Then, we also aim at pointing out the interest of exploiting neutrality during the search. Therefore, a generic local search dedicated to neutral problems, NILS, is performed on several hard instances [78].

6.7. Neutrality in Multi-objective Local Search

Participants: Aymeric Blot, Clarisse Dhaenens, Laetitia Jourdan
External Participants: Hernan Aguirre, Kiyoshi Tanaka - Shinshu University, Japan

In multi-objective combinatorial optimization, the dominance-based local search algorithms are faced to sets of non-comparable solutions. In the absence of preferences, these solutions are equally good from the Pareto dominance perspective and can be considered neutral in term of quality, similar to the solutions who shares the same fitness value in mono-objective optimization. We propose two ideas to use the neutrality to improve the current local search algorithms. First, we analyze the distribution of neighbors for both small fully enumerable instances and hard large instances, to understand the distribution of neutral neighbors according to the rank of the solutions. Then, we compare the results of the proposed algorithms with the standard ones according to different indicators.

6.8. Biclustering for GWA data

Participants: Khedidja Seridi, Laetitia Jourdan, El-Ghazali Talbi

We have examined the possibilities of applying biclustering approaches to detect association between SNP markers and phenotype traits. There- fore, we have proposed a multiobjective model for biclustering problems in GWA context. Furthermore, we have proposed an adapted heuristic and meta- heuristic to solve it. The good performances of our algorithms are assessed using synthetic data sets.

6.9. Fitness Landscape Analysis for Multiobjective Optimization

Participant: Arnaud Liefooghe
External participants: Hernan Aguirre, Kiyoshi Tanaka (Shinshu Univ., Japan), Sébastien Verel (Univ. Littoral Côte d'Opale, France)

In [57], we investigate the correlation between the characteristics extracted from the problem instance and the performance of a simple evolutionary multiobjective optimization algorithm. First, a number of features are identified and measured on a large set of enumerable multiobjective NK-landscapes with objective correlation. A correlation analysis is conducted between those attributes, including low-level features extracted from the problem input data as well as high-level features extracted from the Pareto set, the Pareto graph and the fitness landscape. Second, we experimentally analyze the (estimated) running time of the global SEMO algorithm to identify a $(1 + \epsilon)$-approximation of the Pareto set. By putting this performance measure in relation with problem instance features, we are able to explain the difficulties encountered by the algorithm with respect to the main instance characteristics.

In [38], we study the effects of population size on selection and performance scalability of two dominance-based algorithms applied to many-objective optimization. Our aim is to understand the relationship between the size of the Pareto optimal set, a characteristic of the many-objective problem at hand, the population size and the ability of the algorithm to retain Pareto optimal solutions in its population and find new ones. This work clarifies important issues of the dynamics of evolutionary algorithms on many-objective landscapes, particularly related to survival selection. It shows that optimal solutions are dropped from the population in favor of suboptimal solutions that appear non-dominated when survival selection is applied. It also shows that this selection lapse, the dropping of optimal solution, affects the discovery of new optimal solutions and is correlated to population size and the distribution of solutions that survival selection renders. Selection makes less mistakes with larger populations and when the distribution of solutions is better controlled. The results of this study will be helpful to properly set population size and have a clearer idea about the performance expectation of the algorithm.

6.10. On Set-based Local Search for Multiobjective Combinatorial Optimization

Participant from DOLPHIN: Arnaud Liefooghe
External participants: Matthieu Basseur, Adrien Goëffon (Univ. Angers, France), Sébastien Verel (Univ. Littoral Côte d'Opale, France)

In [42], we formalize a multiobjective local search paradigm by combining set-based multiobjective optimization and neighborhood-based search principles. Approximating the Pareto set of a multiobjective optimization problem has been recently defined as a set problem, in which the search space is made of all feasible solution-sets. We here introduce a general set-based local search algorithm, explicitly based on a set-domain search space, evaluation function, and neighborhood relation. Different classes of set-domain neighborhood structures are proposed, each one leading to a different set-based local search variant. The corresponding methodology generalizes and unifies a large number of existing approaches for multiobjective optimization. Preliminary experiments on multiobjective NK-landscapes with objective correlation validates the ability of the set-based local search principles. Moreover, our investigations shed the light to further research on the efficient exploration of large-size set-domain neighborhood structures.

6.11. Feature selection in high dimensional regression problems for genomics

Participants: Julie Hamon, Clarisse Dhaenens (External collaborator : Julien Jacques)

In the context of genomic selection in animal breeding, an important objective consists in looking for explicative markers for a phe-notype under study. In order to deal with a high number of markers, we propose to use combinatorial optimization to perform variable selection. Results show that our approach outperforms some classical and widely used methods on simulated and "closed to real" datasets [76]. Familial relationships have also been used in this specific context and allow to improve results.

6.12. Indicator-Based Multiobjective Optimization

Participant: Dimo Brockhoff
External Participants: Johannes Bader (formerly at ETH Zurich, Switzerland), Youssef Hamadi (Microsoft Research, Cambridge, UK), Souhila Kaci (Université Montpellier 2, France), Lothar Thiele (ETH Zurich, Switzerland), Heike Trautmann (University of Munster, Germany) Tobias Wagner (TU Dortmund, Germany), and Eckart Zitzler (PH Bern, Switzerland)

Indicator-based (evolutionary) multiobjective optimization algorithms have been first introduced in 2004 and typically use a quality indicator, assigning a solution set a real value, as a direct, internal performance criterion. Given that the indicator and the number μ of desired points is fixed, the optimization goal, also denoted by the term *optimal μ-distribution*, is then defined as the solution set(s) of size μ which maximizes the indicator value.

In 2013, we continued to investigate, theoretically and numerically, the optimal μ-distributions for the R2 indicator, an often recommended indicator based on scalarization functions [73]. We also proposed a new multiobjective optimizer with an R2-indicator-based selection [70]. With respect to the even more common *hypervolume indicator*, we combined the idea of the weighted hypervolume indicator with the idea of interactive algorithms and proposed a new algorithm that adapts the weighted hypervolume's weight function according to the user's preferences during the search. Last, we summarized our knowledge on the weighted hypervolume indicator and proposed a general framework of how to employ it within the hypervolume-based W-HypE algorithm [18].

6.13. A Hybrid Metaheuristic for Multiobjective Unconstrained Binary Quadratic Programming

Participant : Arnaud Liefooghe
External participants : Jin-Kao Hao (Univ. Angers, France), Sébastien Verel (Univ. Littoral Côte d'Opale, France)

The conventional Unconstrained Binary Quadratic Programming (UBQP) problem is known to be a unified modeling and solution framework for many combinatorial optimization problems. In [29], we extend the single-objective UBQP to the multiobjective case (mUBQP) where multiple objectives are to be optimized simultaneously. We propose a hybrid metaheuristic which combines an elitist evolutionary multiobjective optimization algorithm and a state-of-the-art single-objective tabu search procedure by using an achievement scalarizing function. Finally, we define a formal model to generate mUBQP instances and validate the performance of the proposed approach in obtaining competitive results on large-size mUBQP instances with two and three objectives.

6.14. Multi-core GPU-based parallel optimization

We have mainly investigated the design and implementation on multi-core GPU-based platforms of meta-heuristics and tree-based exact optimization methods focusing on Branch and bound (B&B) algorithms (Ph.D thesis of I. Chakroun).

- **GPU-based Metaheuristics**
  Participants: N. Melab, T-V. Luong, K. Boufaras and N. Melab
  We came out with a pioneering work on single-solution methods. The hierarchy of parallel models has been rethought on GPU dealing with CPU-GPU data transfer optimization, thread control and automatic mapping of candidate solutions to threads. The implementation of the proposed approaches is provided through ParadisEO-GPU in [62] (nominated for Best Paper Award). High speedups ups have been achieved for some problems.
- **Multi-core GPU-based B&B algorithms**
  For exact optimization, we have revisited the design and implementation of highly irregular B&B algorithms on GPU dealing with hierarchical device memory optimization, on GPU combined with multi-core [45] dealing with CPU-GPU data transfer optimization and work partitioning, and on GPU-enhanced computational grids. Accelerations up to $\times 217$ are achieved on Tesla Nvidia C2050 on large Flow-Shop problems.

6.15. Energy-aware scheduling for clouds

Participants: Y. Kessaci, N. Melab, E-G. Talbi

High-performance computing (HPC) is moving from in-house to cloud-based HPC. One of the major issues of this later is the scheduling of HPC applications taking into account the energy criterion in addition to performance. In [54], we have addressed that issue (Ph.D thesis of Y. Kessaci). We have proposed several metaheuristics for cloud managers and experimented on OpenNebula using different (VMs) arrival scenarii and different hardware infrastructures. The results show that our approaches outperform the scheduler provided in OpenNebula by a significant margin in terms of energy consumption and number of scheduled VMs.

6.16. Heterogenous Multi-CPU Multi-GPU Parallel Branch-and-Bound Tree Search

Participants: Trong-Tuan Vu, Bilel Derbel, Nouredine Melab

In this work [71], we push forward the design of parallel and distributed optimization algorithms running on heterogenous systems consisting of multiple CPUs coupled with multiple GPUs. We consider parallel Branch-and-Bound (B&B), viewed as a generic algorithm searching in a dynamic tree representing a set of candidate solutions built dynamically at runtime. Given that several distributed CPUs and GPUs coming from possibly different clusters connected through a network can be used to parallelize the tree search, we give new insights into how to fully benefit from such a heterogeneous environment. More precisely, we describe a two-level generic and fully distributed parallel approach taking into account PU characteristics. In the first level, we use data streaming in order to allow parallelism between hosts and devices. The evaluation of tree nodes is done inside a GPU while the CPU-host is performing the pruning, selection and decomposition operations in parallel. In the second level, our approach incorporates an adaptive dynamic load balancing scheme based on distributed work stealing, in order to flow workloads efficiently from overloaded PUs to idle ones at runtime. We deployed our approach over a distributed system of up to 20 GPUs and 128 CPUs coming from three clusters. Different scales and configurations of PUs were experimented with the B&B algorithm and the well-known FlowShop combinatorial optimization problem as a case study. Firstly, on one single GPU, we improve on the running time of previous B&B GPUs implementation by at least a factor of two. More importantly, independently of CPUs or GPUs scale or power, our approach provides a substantial speed-up which is *nearly optimal* compared to the ideal performance one could expect in theory.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Grants with Industry

- EDF (2011-2013): Bilevel mathematical programming and pricing problems.
- EDF (2011-2014): Scheduluing outages of nuclear plants.
- Tasker (2011-2014) : Scheduling of applications in hybrid cloud computing systems.
- Alicante (2010-2013): PhD of Julie Jacques. Knowledge extraction by optimization methods for improving the process of inclusion in clinical trials.
- Genes Diffusion (2010-2013): PhD of Julie Hamon. Analysis of data from high throughput genotyping: cooperation between statistics and combinatorial optimization.
- Strat&Logic (2012-2015): PhD of Sylvain Dufourny. Optimization of economic decisions in a competitive business management simulator.
- Vekia (2012-2015). The goal of the project is to develop an efficient and generic software for employee scheduling in retail.

8. Partnerships and Cooperations

8.1. Regional Initiatives

- PPF (Bioinformatics): This national program within the University of Lille 1 deals with solving bioinformatics and computational biology problems using combinatorial optimization techniques, 2010-2013.
- PPF HPC (High performance computing), 2010-2013.
- CIA (Campus Intelligence Ambiante) project from CPER (Contrat Plan Etat Région): Transversal research action: “High performance computing”, 2010-2013.

8.2. National Initiatives

8.2.1. ANR

- ANR project Transports Terrestres Durable “RESPET - Gestion de réseaux de service porte-à-porte efficace pour le transport de marchandises”, in collaboration with LAAS (Toulouse), DHL, JASSP, LIA (Univ. Avignon) (2011-2014).
- ANR project Modèles Numériques “NumBBO - Analysis, Improvement and Evaluation of Numerical Blackbox Optimizers” (2012-2016) in collaboration with Inria Saclay, TAO team, Ecole des Mines de St. Etienne, CROCUS team, and TU Dortmund University, Germany (2012-2016).

8.3. European Initiatives

8.3.1. Collaborations in European Programs, except FP7

Program: COST

Project acronym: IC0804

Project title: Energy efficiency in large scale distributed systems

Duration: Jan 2009 - May 2013

Coordinator: J. M. Pierson

Other partners: More than 20 European countries.

Abstract: The COST Action IC0804 proposes realistic energy-efficient alternate solutions to share IT distributed resources. As large scale distributed systems gather and share more and more computing nodes and Storage resources, their energy consumption is exponentially increasing. While much effort is nowadays put into hardware specific solutions to lower energy consumptions, the need for a complementary approach is necessary at the distributed system level, i.e. middleware, network and applications. The Action characterizes the energy consumption and energy efficiencies of distributed applications.

8.3.2. Collaborations with Major European Organizations

University of Luxembourg: CSC, ILIAS (Luxembourg)

Design of parallel and hybrid metaheuristics to solve complex optimization problems

University of Malaga: ETSI Informatica (Spain)

Parallel metaheuristics for dynamic optimization

8.4. International Initiatives

8.4.1. Inria Associate Teams

8.4.1.1. STEM

Title: deciSion Tools for Energy Management (STEM)

Inria principal investigator: L. Brotcorne

International Partners (Institution - Laboratory - Researcher):

> Polytechnic School of Montréal (Canada) - Département de mathématique et génie industriel
>
> Université de Montréal (Canada) - Département d’informatique et recherche opérationnelle

Duration: 2012 - 2014

See also: http://dolphin.lille.inria.fr/Dolphin/EA-DOLPHIN

The economic rise of developing countries, together with the need to meet ever more stringent pollution reduction targets, will increase the stress on the global energy system. Within this framework, the goal of the current project is to develop decision tools for energy management in a context of market deregulation. We will focus on two issues, namely demand management and production planning.

The first problem is concerned with the efficient management of consumption. More precisely, the short or long term behaviour of customers can be influenced through signals sent by a utility (or several utilities) to the end-users. These signals can take the form of an "optimal" pricing scheme, or yet of devices (timers, automatic switches, etc.) designed to induce an "optimal" behaviour from the users.

The second issue is concerned with efficient management of sustainable energy production. Indeed the development of renewable energy introduces new parameters in the supply/demand global equilibrium process. The issue is to achieve the right trade-off between costs (production, security) and revenues when determining the daily hydro-electricity generation and storage within an environment where demand is stochastic.

The first problem is modeled as a bilevel program, the second one as a integer mutli-objective stochastic program. Efficient and effective solution methods are developed and implemented to solve these problems.

8.4.2. Inria International Partners

- University of Sydney, Australia
- University of Montreal, Canada
- Ecole Polytechnique of Montreal, Canada

8.4.2.1. Declared Inria International Partners

- University of Luxembourg, Luxembourg

8.4.2.2. Informal International Partners

- University of Shinshu, Nagano, Japan: Evolutionary multi-objective optimization, landscape analysis, and search performance (JSPS project 2013-2016)
- Cooperation with Hernan Aguirre et Tanaka : Internship in Japan of A. Blot co-supervised by H. Aguirre, C. Dhaenens, L. Jourdan and Tanaka

8.4.3. Participation In other International Programs

- Inria STIC-Tunisie 2011-2013.
- CNRS PICS Luxembourg 2012-2014.
- Japanese Government Grant Program 2013.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

- Dr. Hernan Aguirre, Shinshu University, Japan
- Prof. Kiyoshi Tanaka, Shinshu University, Japan
- Prof. Michel Gendreau, University of Montreal
- Prof. Pascal Bouvry, University of Luxembourg

8.5.1.1. Internships

- Martin Drozdik [PhD student, Shinshu University, Japan, from Nov 2013]

8.5.2. Visits to International Teams

- E-G. Talbi, June 2013, Univ. Colchester, Sussex, UK
- E-G. Talbi, April 2013, Univ. Murcia, Spain

9. Dissemination

9.1. Scientific Animation

Organization:

- NIDISC'2013, Nature Inspired Distributed Computing, in IEEE IPDPS, Boston, USA, May 2013.
- GreenDaysLille, Lille, Nov 2013.
- Special issue on New advances in metaheuristics, Journal of Mathematical Modelling and Applications, co-edited by L. Jourdan and E-G. Talbi
- Special issue on Emergent nature inspired algorithms for multi-objective optimization, Computers and Operations Research (COR), co-edited by J. Figueira and E-G. Talbi
- Special issue on Scalable optimization in grid, cloud and intelligent network computing, Concurrency and Computation : Practice and Experience, co-edited by J. Kolodziej, S. U. Khan and E-G. Talbi
- Special issue on Metaheuristics on GPUs, Journal of Parallel and Distributed Computing (JPDC), co-edited by E-G. Talbi and G. Hasle
- International conference EA 2013 Artificial Evolution (Oct 2013 Bordeaux, France)
- Intelligent optimization in Bioinformatics session in LION 7 (Catania, Italy, January 2013) organized by Clarisse Dhaenens and Laetitia Jourdan
- Problem structure vs. algorithm performance in multiobjective combinatorial optimization session at LION 2013, co-organized by Hernan Aguirre, Arnaud Liefooghe, Kiyoshi Tanaka and Sébastien Verel (Catania, Italy, January 2013)
- Special issue on Evolutionary Multiobjective Optimization, European Journal of Operational Research, co-edited by Dimo Brockhoff, Bilel Derbel, Arnaud Liefooghe and Sébastien Verel
- Evolutionary Multiobjective Optimization session at the MCDM 2013 conference, co-organized by Dimo Brockhoff, Bilel Derbel, Arnaud Liefooghe and Sébastien Verel (Malaga, Spain, June 2013)
- Artificial Evolution Summer School (AESS 2013, Quiberon, France, June 2013), co-organized by Dimo Brockhoff, Bilel Derbel, Arnaud Liefooghe and Sébastien Verel (Malaga, Spain, June 2013)
- Special issue on Evolutionary Multiobjective Optimization, Journal of Multi-Criteria Decision Analysis, co-edited by Dimo Brockhoff and Kalyanmoy Deb, published as Volume 20, Issue 5-6, in November 2013
- Lorentz Center workshop "SIMCO - Set-Oriented and Indicator-Based Multi-Criteria Optimization" in Leiden, Netherlands in September 2013, co-organized by Dimo Brockhoff together with Michael Emmerich, André Deutz, and Boris Naujoks, about 40 participants, see http://www.lorentzcenter.nl/lc/web/2013/583/info.php3?wsid=583 and http://simco.gforge.inria.fr/
- GECCO 2013 workshop entitled "Blackbox Optimization Benchmarking" in Amsterdam, Netherlands in July 2013, co-organized by Dimo Brockhoff together with Anne Auger, Bernd Bischl, Nikolaus Hansen, Olaf Mersmann, Petr Pošík, and Heike Trautmann, see http://coco.gforge.inria.fr/doku.php?id=bbob-2013
- Special session on uncertainty handling at the 22nd International Conference on Multiple Criteria Decision Making (MCDM'2013) in Malaga, Spain in June 2013, co-organized by Dimo Brockhoff and El-Ghazali Talbi together with Jürgen Branke
- invited track chair for the EMO track at the GECCO'2013 conference in Amsterdam, Netherlands, Dimo Brockhoff together with Frank Neumann, see http://www.sigevo.org/gecco-2013/organizers-tracks.html#emo

Research management:

- Manager (Chargé de mission) of supercomputing for Université Lille 1.
- Scientific leader for Lille of the Grid'5000 nation-wide and EGI european-wide grid infrastructures.
- Scientific leader of the challenge “Large scale combinatorial optimization" of the HEMERA nation-wide grid and cloud computing research action (AEN) of Inria.
- Member of the steering committee of the Aladdin-Grid5000 nation-wide technological developement action of Inria.
- Co-leader of the PPF “Supercomputing" at Université Lille 1.
- Chair of the “Parallel Evolutionary Systems” track of GECCO'2013, Amsterdam, Netherlands, July 2013.

Reviewing:

- Computers and Operations Research
- European Journal of Operational Research
- Journal of Multi-Criteria Decision Analysis
- IEEE Transactions on Evolutionary Computation
- Applied soft computing (ASOC)
- Soft Computing (SOCO)
- KAI (Knowledge and Information Systems)
- Journal of Mechanical Engineering Science
- Computer Languages, Systems and Structures
- 4OR - A Quarterly Journal of Operations Research
- Journal of Supercomputing
- International Transactions in Operational Research
- Computers and Industrial Engineering
- MEME (Memetic Computing Journal)
- Evolutionary Computation
- Theoretical Computer Science
- Artificial Intelligence Journal
- IEEE Transactions on Systems, Man and Cybernetics - Part B
- Journal of Multi-Criteria Decision Analysis

Program committees:

- MICAI 2013, track Evolutionary and Nature-inspired Metaheuristics (November 2013, Mexico City, Mexico)
- ECAL 2013, European Conference on Artificial Life, (September 2013, Taormina, Italy)
- IEEE Congress on Evolutionary Computation (IEEE CEC 2013) (Cancun, Mexico, June 2013)
- International conference MIC - Metaheuristics International Conference 2013 (Singapor)
- Genetic and Evolutionary Computation Conference (GECCO 2013), (Amsterdam The Netherlands, 2013)
- 7th International Conference on Evolutionary Multi-criterion Optimization (EMO 2013, Sheffield, UK, 2013)
- 7th Learning and Intelligent OptimizatioN Conference (LION 7, Catania, Italy, January 2013)
- EA 2013 Artificial Evolution, 21-23 October 2013, Bordeaux, France

- 6th Workshop on Artificial Life and Evolutionary Algorithms (ALEA 2013), as a part of EPIA 2013 (AÃ§ores, Portugal, 2013)
- Genetic and Evolutionary Computation Conference (GECCO 2013), Evolutionary Combinatorial Optimization and Metaheuristics (ECOM) track (Amsterdam The Netherlands, 2013)
- IEEE Symposium Series on Computational Intelligence (IEEE SSCI 2013, Singapour, 2013)
- 13th European Conference on Evolutionary Computation in Combinatorial Optimisation (EvoCOP 2013, Vienna, Austria, 2013)
- 7th International Conference on Evolutionary Multi-criterion Optimization (EMO 2013, Sheffield, UK, 2013)
- 7th Learning and Intelligent OptimizatioN Conference (LION 7, Catania, Italy, January 2013)
- ICANNGA'2013 Int. Conf. on Adaptive and Natural Computing Algorithms, Lausanne, Switzerland, Apr 2013.
- HAIS'2013 8th Int. Conf. on Hybrid Artificial Intelligence Systems, Salamanca, Spain, Sept 2013.
- ECAL'2013 8th European Conf. on Artificial Life, Taormina, Italy, Sept 2013.
- IC3'2013 Int. Conf. On Contemporary Computing, Noida, India, Aug 2013.
- GPC'2013 Int. Conf. On Grid and Pervasive Computing, Daegu, Korea, May 2013.

Commission:

- President of the recruiting committee for associate professorship in computer science (COS McF 27 - Univ. Lille 1 - 2013) - 3 positions.
- External member of the recruiting committee for associate professorship in computer science (COS McF 27 - Univ. Littoral Cote d'Opale - 2013), (COS McF 26 - Univ Bordeaux - 2013).
- External member of the recruiting committee for professorship in computer science (COS PR27- Univ. Tours - 2013).
- External reviewer for the PhD student grants at Microsoft Research Cambridge
- External reviewer for the Luxembourg National Research Fund (FNR)
- President of the Technological Development Commission (CDT) of Inria Lille.
- President of the Research Positions Commission (CER - Commission des Emplois de Recherche) of Inria Lille.
- External project reviewer, Qatar National Research Fund (QNRF) (2013).

Dessimination:

- Dimo Brockhoff: invited GECCO'2013 tutorial on Evolutionary Multiobjective Optimization
- El-ghazali Talbi: invited CEC'2013 tutorial on Parallel and Distributed Evolutionary Algorithms

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Engineering school : Clarisse Dhaenens, Graphs and Combinatorics, 80 HeqTD,Polytech Lille, University Lille 1, France

Engineering school : Clarisse Dhaenens, Operations Research, 70 HeqTD,Polytech Lille, University Lille 1, France

Engineering school : Clarisse Dhaenens, Algorithmics and programming, 45 HeqTD,Polytech Lille, University Lille 1, France

Master: D. Brockhoff, Advanced Control, 18h, M2, Ecole Centrale Paris, Chatenay-Malabry, France

Licence : L. Jourdan, Initiation à la programmation, 54 heures équivalent TD, niveau L1, université de Lille 1, France

Master : L. Jourdan, Fouille de données, 60 heures en équivalent TD, niveau (M1-Miage) université de Lille 1, France

Master : L. Jourdan, Informatique décisionnelle, 36 heures en équivalent TD, niveau (M1-Informatique) université de Lille 1, France

Master : L. Jourdan, Mise à niveau en Informatique décisionnelle, 24 heures en équivalent TD, niveau (M1-Miage) université de Lille 1, France

Licence: A. Liefooghe, Algorithmic and Data structure, 36h, L2, Université de Lille 1, France

Licence: A. Liefooghe, Algorithmic - Operations Research, 36h, L3, Université de Lille 1, France

Master: A. Liefooghe, Databases, 30h, M1, Université de Lille 1, France

Master: A. Liefooghe, Object-oriented Design and Programming, 52h, M1, Université de Lille 1, France

Master: A. Liefooghe, Combinatorial Optimization, 10h, M2, Université de Lille 1, France

Master of Advanced Scientific Computing: Nouredine Melab, Supercomputing, 33, M2, université Lille 1, France

Master Computer Science: Nouredine Melab, Parallel and Distributed Programming, 20, M1, université Lille 1, France

Master MIAGE: Nouredine Melab, Operations Research, 45, M1, université Lille 1, France

Polytech Lille : Marie-Eléonore Marmion, Database, 67h ETD, 1st year, Université Lille 1, France

Polytech Lille : Marie-Eléonore Marmion, Algorithm and Programming, 45h ETD, 1st year, Université Lille 1, France

Polytech Lille : Marie-Eléonore Marmion, Graph, 10h ETD, 1st year, Université Lille 1, France

Polytech Lille : Marie-Eléonore Marmion, Data Mining, 10h ETD, 3rd year, Université Lille 1, France

Master : Bilel Derbel, Combinatorial Optimization, 35h, M2, University Lille 1, France

Master : Bilel Derbel, Grid Computing, 16h, M2, University Lille 1, France

Master : Bilel Derbel, Parallel and Distributed Programming, 12h, M1, University Lille 1, France

Master : Bilel Derbel, Advanced Object Programming, 92h, M1, University Lille 1, France

Master : Bilel Derbel, Design of Distributed Applications, 60h, M1, University Lille 1, France

Master : Bilel Derbel, Algorithms and Applications, 28h, M1, University Lille 1, France

Engineering school : El-Ghazali Talbi, Advanced optimization, 36h, Polytech'Lille, University Lille 1, France

Engineering school : El-Ghazali Talbi, Data mining, 36h, Polytech'Lille, University Lille 1, France

Engineering school : El-Ghazali Talbi, Operations research, 60h, Polytech'Lille, University Lille 1, France

Engineering school : El-Ghazali Talbi, Graphs, 25h, Polytech'Lille, University Lille 1, France

9.2.2. Supervision

PhD : Julie Hamon, Optimisation combinatoire pour la sélection de variables en régression en grande dimension : Application en génétique animale, Université Lille 1, 26/11/2013, Clarisse Dhaenens, Julien Jacques (MODAL)

PhD : Khedidja SERIDI, Approches multi-objectives pour le biclustering : applications aux microarrays (puce à ADN), Université de Lille 1, soutenance 5/7/2013, Co-direction : El-Ghazali Talbi et Laetitia Jourdan

PhD : Julie Jacques, Classification sur données médicales à l'aide de méthodes d'optimisation et de datamining, appliquée au pré-screening dans les essais cliniques, Université de Lille 1, soutenance 2/12/2013, Co-direction : Clarisse Dhaenens et Laetitia Jourdan

PhD : Yacine KESSACI, Multi-criteria Scheduling on Cloud, Université Lille 1, 11/28/2013, Nouredine Melab and El-Ghazali Talbi

PhD : Imen CHAKROUN, Parallel Heterogeneous Branch and Bound Algorithms for Multi-core and Multi-GPU Environments, Université Lille 1, 06/28/2013, Nouredine Melab

PhD : Mathieu DJAMAI, Peer to Peer Branch and Bound Algorithms for Computational Grids, Université Lille 1, 03/11/2013, Nouredine Melab and Bilel Derbel

PhD in progress : Sophie Jacquin, Combining exact method and metaheuristics for production problems, début : 1/10/2012, Co-direction : El-Ghazali Talbi et Laetitia Jourdan

PhD in progress : Sylvain Dufourny, Optimisation de décisions économiques concurrentielles dans un simulateur de gestion d'entreprise, Novembre 2012, Clarisse Dhaenens

PhD in progress : Thanh-Do TRAN, Benchmarking Continuous Multiobjective Optimization Algorithms, 12/2011, Dimo Brockhoff and El-Ghazali Talbi

PhD in progress : Rudi LEROY, Massively parallel tree-based exact algorithms for hybrid clusters, 11/05/2012, Nouredine Melab

PhD in progress : Francois LEGILLON, Static and Dynamic Resource Brokering on multi-clouds, 09/01/2010, Nouredine Melab and El-Ghazali Talbi

PhD in progress : Trong Tuan VU, Large scale heterogeneous tree-based exact algorithms for grids, 11/05/2012, 09/01/2010, Bilel Derbel and Nouredine Melab

PhD : Mustapha DIABY, Approche de gestion de revenus pour un problème de tarification pour le transport longue distancd, UniversitÃ© de Lille 1, soutenance Nov 2013, El-Ghazali Talbi et Luce Brotcorne

PhD in progress : Nadia Dahmani, Multi-objective packing problems, 12/2009, El-Ghazali Talbi and François Clautiaux

PhD in progress : A. Stathakis, Satellite payload reconfiguration optimization, 12/2010, El-Ghazali Talbi and Pascal Bouvry

PhD in progress : A. Q. Nguyen, Green scheduling on cloud computing systems, 11/2012, El-Ghazali Talbi and Pascal Bouvry

PhD in progress : Oumayma Bahri, Fuzzy multi-objective optimization, 11/2013, El-Ghazali Talbi and Nayla Ben-Omar

PhD in progress : Asma Gannouni, Stochastic multi-objective optimization using metaheuristics , 11/2013, El-Ghazali Talbi and Rachid Ellaia

9.2.3. Juries

- Clarisse Dhaenens : Caractérisation d'instances difficiles pour des problèmes d'optimisation NP-difficiles de Valentin Weber, Université de Grenoble, Encadrants : Nadia Brauner, Yann Kieffer - July 2013 (Rapporteur et Présidente).
- Clarisse Dhaenens : Extraction de motifs contraints dans des donnés bruitées de K. Mouhoubi, Université de Paris XIII, Encadrants : Lucas Létocart, C. Rouveirol - September 2013 (Rapporteur).
- Clarisse Dhaenens : Metaheuristics, Heuristics and Exact Algorithms to Solve Constrained Hybrid Flow Shop : Application to a Three-stage Supply Chain de Walid Besbes, Université de Mons (Belgique), Encadrants : Taicir Loukil, Jacques Teghem - September 2013.
- Clarisse Dhaenens : Column generation for Bi-Objective integer Linear programs : Application to Bi-Objective Vehicle Routing Problems de Boasu Sarpong, Université de Toulouse, Encadrants : Christian Artigues, Nicolas Jozefowiez - December 2013 (Rapporteur).
- L. Jourdan: Métaheuristiques pour l'optimisation combinatoire sur processeurs graphiques (GPU) de Audrey DELEVACQ de l'Université de Reims, encadrants : Pierre Delisle et Michael Krajecki - February 4th 2013 (Rapporteur)

- L. Jourdan Hybrid Evolutionary Metaheuristics for Multiobjective Decision Supportde Ahmed M. KAFAFY de l'université de Lyon, encadrants : Stéphane Bonnevay et Ahmed Bounekkar - October 24th 2013 (Rapporteur)
- L. Jourdan: Optimisation multi-objectif de missions de satellites d'observation de la Terre de Panwadee Tangpattanakul, LAAS and INSA Toulouse, encadrant : Pierre Lopez et Nicolas Jozefowiez - September, 26th 2013 - (Présidente de Jury)
- E-G.Talbi: La métaheuristique CAT pour le design de réseaux logistiques déterministes et stochastiques de Marc-André Carle, Université Laval, Québec, Canada. encadrant: Nicolas Zuffery, Jan 2013 (Rapporteur)
- E-G. Talbi, Perfectionnement de métaheuristiques pour l'optimisation continue de Ilhem Boussaid, Université USTHB (Algérie) et Université Paris Créteil (France), encadrants: M. Ahmed-Nacer, P. Siarry, Juin 2013 (Rapporteur)
- E-G. Talbi: Modélisation dynamique de la densité de population via les réseaux cellulaires et optimisation multobjectif de l'auto-partage de Laurent Moalic Université Franche-Comté (France), encadrents: A. Caminada, S. Lamrous, F. Spies, Dec 2013 (Rapporteur).

9.3. Popularization

- Fête de la science
- Big Data Event (Mar 2013): Conference for industrial - Intervention on "Modeling and multi-objective optimization for knowledge discovery"

10. Bibliography

Major publications by the team in recent years

[1] J.-C. Boisson, L. Jourdan, E.-G. Talbi. *Metaheuristics based de novo protein sequencing: A new approach*, in "Applied Soft Computing", 2011, vol. 11, n° 2, pp. 2271-2278, http://hal.inria.fr/inria-00522628

[2] C. Dhaenens, J. Lemesre, E.-G. Talbi. *K-PPM: A new exact method to solve multi-objective combinatorial optimization problems*, in "European Journal of Operational Research", 2010, vol. 200, n° 1, pp. 45-53, http://hal.inria.fr/inria-00522771

[3] J. R. Figueira, A. Liefooghe, E.-G. Talbi, A. P. Wierzbicki. *A parallel multiple reference point approach for multi-objective optimization*, in "European Journal of Operational Research", 2010, vol. 205, n° 2, pp. 390 - 400, http://hal.inria.fr/hal-00522619

[4] N. Jozefowiez, F. Semet, E.-G. Talbi. *Target Aiming Pareto Search and its application to the vehicle routing problem with route balancing*, in "Journal of Heuristics", 2007, vol. 13, pp. 455-469

[5] A. Khanafer, F. Clautiaux, E.-G. Talbi. *New lower bounds for bin packing problems with conflicts*, in "European Journal of Operational Research", 2010, vol. 2, n° 206, http://hal.inria.fr/inria-00522668

[6] A. Liefooghe, L. Jourdan, E.-G. Talbi. *A software framework based on a conceptual unified model for evolutionary multiobjective optimization: ParadisEO-MOEO*, in "European Journal of Operational Research", 2010, to appear, http://hal.inria.fr/hal-00522612

[7] A. LIEFOOGHE, L. PAQUETE, J. FIGUEIRA. *On local search for bi-objective knapsack problems*, in "Evolutionary Computation", 2013, vol. 21, n° 1, pp. 179-196 [*DOI :* 10.1162/EVCO_A_00074], http://hal.inria.fr/hal-00676625

[8] T. V. LUONG, N. MELAB, E.-G. TALBI. *GPU Computing for Parallel Local Search Metaheuristics*, in "IEEE Transactions on Computers", 2013, vol. 62, n° 1, pp. 173-185, http://hal.inria.fr/inria-00638805

[9] M.-E. MARMION, L. JOURDAN, C. DHAENENS. *Fitness Landscape Analysis and Metaheuristics Efficiency*, in "Journal of Mathematical Modelling and Algorithms in Operations Research", 2013, vol. 12, n° 1, pp. 3-26 [*DOI :* 10.1007/s10852-012-9177-5], http://hal.inria.fr/hal-00807352

[10] E.-G. TALBI. , *Metaheuristics: From Design to Implementation*, Wiley, 2009

Publications of the year

Doctoral Dissertations and Habilitation Theses

[11] I. CHAKROUN. , *Algorithmes Branch and Bound parallèles hétérogènes pour environnements multi-coeurs et multi-GPU*, Université des Sciences et Technologie de Lille - Lille I, June 2013, http://hal.inria.fr/tel-00841965

[12] M. DJAMAI. , *Algorithmes Branch&Bound Pair-à-Pair pour Grilles de Calcul*, Université des Sciences et Technologie de Lille - Lille I, March 2013, http://hal.inria.fr/tel-00841704

[13] J. HAMON. , *Optimisation combinatoire pour la sélection de variables en régression en grande dimension : Application en génétique animale*, Université des Sciences et Technologie de Lille - Lille I, November 2013, http://hal.inria.fr/tel-00920205

[14] J. JACQUES. , *Classification sur données médicales à l'aide de méthodes d'optimisation et de datamining, appliquée au pré-screening dans les essais cliniques*, Université des Sciences et Technologie de Lille - Lille I, December 2013, http://hal.inria.fr/tel-00919876

[15] Y. KESSACI. , *Ordonnancement multi-critère sur Clouds*, Université des Sciences et Technologie de Lille - Lille I, November 2013, http://hal.inria.fr/tel-00915043

Articles in International Peer-Reviewed Journals

[16] M. ABBASI, L. PAQUETE, A. LIEFOOGHE, M. PINHEIRO, P. MATIAS. *Improvements on bicriteria pairwise sequence alignment: algorithms and applications*, in "Bioinformatics", 2013, vol. 29, n° 8, pp. 996-1003 [*DOI :* 10.1093/BIOINFORMATICS/BTT098], http://hal.inria.fr/hal-00797793

[17] D. BERNABE, E. ALBA. *Special issue: Bio-inspired algorithms with structured populations*, in "Soft Computing", July 2013, vol. 7, pp. 1107-1108, http://hal.inria.fr/hal-00931294

[18] D. BROCKHOFF, J. BADER, L. THIELE, E. ZITZLER. *Directed Multiobjective Optimization Based on the Weighted Hypervolume Indicator*, in "Journal of Multi-Criteria Decision Analysis", November 2013, vol. 20, n° 5-6, pp. 291-317 [*DOI :* 10.1002/MCDA.1502], http://hal.inria.fr/hal-00920178

[19] L. BROTCORNE, S. HANAFI, R. MANSI. *One-level reformulation of the bi-level Knapsack problem using dynamic programming*, in "Discrete Optimization", 2013, vol. 10, n^{o} 1, pp. 1-10 [*DOI :* 10.1016/J.DISOPT.2012.09.001], http://hal.inria.fr/hal-00759250

[20] I. CHAKROUN, N. MELAB, M.-S. MEZMAZ, D. TUYTTENS. *Combining multi-core and GPU computing for solving combinatorial optimization problems*, in "Journal of Parallel and Distributed Computing", December 2013, vol. 73, n^{o} 12, pp. 1563-1577 [*DOI :* 10.1016/J.JPDC.2013.07.023], http://hal.inria.fr/hal-00935890

[21] I. CHAKROUN, M. NOUREDINE. *Towards an heterogeneous and adaptive parallel Branch-and-Bound algorithm*, in "Journal of Computer and System Sciences", 2014, http://hal.inria.fr/hal-00935899

[22] F. CLAUTIAUX, M. DELL AMICO, M. IORI, A. KHANAFER. *Lower and Upper Bounds for the Bin Packing Problem with Fragile Objects*, in "Discrete Applied Mathematics", 2014, vol. 163, n^{o} 1, pp. 73-86, http://hal.inria.fr/hal-00689038

[23] S. DABIA, E.-G. TALBI, T. VAN WOENSEL, T. DE KOK. *Approximating multi-objective scheduling problems*, in "Computers and Operations Research", 2013, vol. 40, n^{o} 5, pp. 1165-1175, http://hal.inria.fr/hal-00830040

[24] L. ESPERET, A. PARREAU. *Acyclic edge-coloring using entropy compression*, in "European Journal of Combinatorics", 2013, vol. 34, n^{o} 6, pp. 1019-1027 [*DOI :* 10.1016/J.EJC.2013.02.007], http://hal.inria.fr/hal-00843770

[25] J. HUMEAU, A. LIEFOOGHE, E.-G. TALBI, S. VEREL. *ParadisEO-MO: From Fitness Landscape Analysis to Efficient Local Search Algorithms*, in "Journal of Heuristics", 2013, vol. 19, n^{o} 6, pp. 881-915 [*DOI :* 10.1007/S10732-013-9228-8], http://hal.inria.fr/hal-00832029

[26] S. ITURRIAGA, S. NESMACHNOW, D. BERNABE, P. BOUVRY. *Energy efficient scheduling in heterogeneous systems with a parallel multiobjective local search*, in "Computing And Informatics", April 2013, vol. 32, pp. 1001-1022, http://hal.inria.fr/hal-00872333

[27] Y. KESSACI, M. NOUREDINE, T. EL-GHAZALI. *A Multi-start Local Search Heuristic for an Energy Efficient VMs Assignment on top of the OpenNebula Cloud Manager*, in "Future Generation Computer Systems", August 2013, http://hal.inria.fr/hal-00924858

[28] A. LIEFOOGHE, L. PAQUETE, J. FIGUEIRA. *On local search for bi-objective knapsack problems*, in "Evolutionary Computation", 2013, vol. 21, n^{o} 1, pp. 179-196 [*DOI :* 10.1162/EVCO_A_00074], http://hal.inria.fr/hal-00676625

[29] A. LIEFOOGHE, S. VEREL, J.-K. HAO. *A hybrid metaheuristic for multiobjective unconstrained binary quadratic programming*, in "Applied Soft Computing", 2014, vol. 16, pp. 10-19 [*DOI :* 10.1016/J.ASOC.2013.11.008], http://hal.inria.fr/hal-00801793

[30] T. V. LUONG, N. MELAB, E.-G. TALBI. *GPU Computing for Parallel Local Search Metaheuristics*, in "IEEE Transactions on Computers", 2013, vol. 62, n^{o} 1, pp. 173-185, http://hal.inria.fr/inria-00638805

[31] M.-E. MARMION, L. JOURDAN, C. DHAENENS. *Fitness Landscape Analysis and Metaheuristics Efficiency*, in "Journal of Mathematical Modelling and Algorithms in Operations Research", 2013, vol. 12, n^{o} 1, pp. 3-26 [*DOI :* 10.1007/S10852-012-9177-5], http://hal.inria.fr/hal-00807352

[32] S. NESMACHNOW, D. BERNABE, J. E. PECERO-SANCHEZ, P. BOUVRY. *Energy-aware scheduling on multicore heterogeneous grid computing systems*, in "The Journal of Grid Computing", May 2013 [*DOI :* 10.1007/S10723-013-9258-3], http://hal.inria.fr/hal-00872985

[33] M. REDOUANE, E.-G. TALBI, L. JOURDAN, B. SARASOLA, E. ALBA. *Multi-environmental cooperative parallel metaheuristics for solving dynamic optimization problems*, in "The Journal of Supercomputing", 2013, vol. 63, n^o 3, pp. 836-853, http://hal.inria.fr/hal-00806249

[34] S. VEREL, A. LIEFOOGHE, L. JOURDAN, C. DHAENENS. *On the structure of multiobjective combinatorial search space: MNK-landscapes with correlated objectives*, in "European Journal of Operational Research", January 2013, vol. 227, n^o 2, pp. 331-342 [*DOI :* 10.1016/J.EJOR.2012.12.019], http://hal.inria.fr/hal-00760097

Invited Conferences

[35] E.-G. TALBI. *Keynote speaker: Metaheuristics for multi-objective optimization - from design to implementation*, in "EGH'2013 Workshop on Optimization and Applied Mathematics", Colchester, United Kingdom, June 2013, http://hal.inria.fr/hal-00836282

[36] E.-G. TALBI. *Keynote speaker: Multiobjective metaheuristics*, in "ORBEL'2013 27th Annual Conference of the Belgian Operational Research Society", Kortrijk, Belgium, February 2013, http://hal.inria.fr/hal-00836273

[37] E.-G. TALBI. *Tutorial: Parallel and distributed evolutionary algorithms*, in "CEC'2013 Congress on Evolutionary Computation", Cancun, Mexico, June 2013, http://hal.inria.fr/hal-00836245

International Conferences with Proceedings

[38] H. AGUIRRE, A. LIEFOOGHE, S. VEREL, K. TANAKA. *A study on population size and selection lapse in many-objective optimization*, in "IEEE Congress on Evolutionary Computation (CEC 2013)", Cancún, Mexico, 2013, pp. 1507-1514, http://hal.inria.fr/hal-00825310

[39] H. AGUIRRE, A. LIEFOOGHE, S. VEREL, K. TANAKA. *Effects of population size on selection and scalability in evolutionary many-objective optimization*, in "Learning and Intelligent OptimizatioN Conference (LION 7)", Catania, Italy, Lecture Notes in Computer Science, 2013, vol. 7997, pp. 450-454 [*DOI :* 10.1007/978-3-642-44973-4_48], http://hal.inria.fr/hal-00805164

[40] A. AUGER, D. BROCKHOFF, N. HANSEN. *Benchmarking the Local Metamodel CMA-ES on the Noiseless BBOB'2013 Test Bed*, in "GECCO (Companion), workshop on Black-Box Optimization Benchmarking (BBOB'2013)", Amsterdam, Netherlands, July 2013, http://hal.inria.fr/hal-00825840

[41] O. BAHRI, N. BEN AMOR, E.-G. TALBI. *A possibilistic framework for solving multi-objective problems under uncertainty*, in "IEEE NIDISC Workshop on Nature Inspired Computing", Boston, United States, May 2013, http://hal.inria.fr/hal-00837569

[42] M. BASSEUR, A. GOËFFON, A. LIEFOOGHE, S. VEREL. *On set-based local search for multiobjective combinatorial optimization*, in "Genetic and Evolutionary Computation Conference (GECCO 2013)", Amsterdam, Netherlands, 2013, pp. 471-478, http://hal.inria.fr/hal-00805166

[43] D. Bernabe, F. Pinel, P. Bouvry, S. U. Khan. *It's Not a Bug, It's a Feature. Wait-free Asynchronous Cellular Genetic Algorithm*, in "10th International Conference on Parallel Processing and Applied Mathematics", Warsaw, Poland, September 2013, http://hal.inria.fr/hal-00872991

[44] D. Brockhoff, Y. Hamadi, S. Kaci. *Using Comparative Preference Statements in Hypervolume-Based Interactive Multiobjective Optimization*, in "Learning and Intelligent Optimization (LION)", Gainesville, FL, United States, Springer, February 2014, http://hal.inria.fr/hal-00935231

[45] I. Chakroun, M. Nouredine. *Operator-level GPU-accelerated Branch and Bound algorithms*, in "International Conference on Computational Science, ICCS", Barcelone, Spain, June 2013, http://hal.inria.fr/hal-00807893

[46] B. Derbel, D. Brockhoff, A. Liefooghe. *Force-based Cooperative Search Directions in Evolutionary Multi-objective Optimization*, in "7th International Conference on Evolutionary Multi-Criterion Optimization", Sheffield, United Kingdom, March 2013, vol. 7811 [*DOI :* 10.1007/978-3-642-37140-0_30], http://hal.inria.fr/hal-00765179

[47] D. Ghrab, B. Derbel, I. Jemili, A. Dhraief, A. Belghith, E.-G. Talbi. *Coloring based Hierarchical Routing Approach*, in "The 4th International Conference on Ambient Systems, Networks and Technologies", Halifax, Canada, Elsevier, June 2013, http://hal.inria.fr/hal-00782013

[48] S. Iturriaga, S. Nesmachnow, D. Bernabe, E.-G. Talbi, P. Bouvry. *A parallel hybrid evolutionary algorithm for the optimization of broker virtual machines subletting in cloud systems*, in "The 2-nd International Workshop on Soft Computing Techniques in Cluster and Grid Computing Systems (SCCG), part of the 8th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing", Compiegne, France, October 2013, http://hal.inria.fr/hal-00872986

[49] S. Iturriaga, P. Ruiz, S. Nesmachnow, D. Bernabe, P. Bouvry. *A Parallel Multi-objective Local Search for AEDB Protocol Tuning*, in "Nature Inspired Distributed Computing (NIDISC) sessions of the International Parallel and Distributed Processing Symposium (IPDPS) 2013 Workshop", boston, United States, May 2013, http://hal.inria.fr/hal-00872994

[50] J. Jacques, J. Taillard, D. Delerue, L. Jourdan, C. Dhaenens. *MOCA-I: Discovering Rules and Guiding Decision Maker in the Context of Partial Classification in Large and Imbalanced Datasets*, in "Learning and Intelligent OptimizatioN Conference (LION 7)", Catania, Italy, Lecture Notes in Computer Science, 2013, pp. 37-51, http://hal.inria.fr/hal-00806757

[51] J. Jacques, J. Taillard, D. Delerue, L. Jourdan, C. Dhaenens. *The benefits of using multi-objectivization for mining Pittsburgh partial classification rules in imbalanced and discrete data*, in "Genetic and Evolutionary Computation Conference (GECCO 2013)", Amsterdam, Netherlands, 2013, pp. 543-550, http://hal.inria.fr/hal-00806777

[52] I. Jemili, D. Ghrab, A. Belghith, B. Derbel, A. Dhraief. *Collision Aware Coloring Algorithm for wireless sensor networks*, in "The 9th International Wireless Communications & Mobile Computing Conference (IWCMC)", CAGLIARI, SARDINIA, Italy, IEEE, July 2013, http://hal.inria.fr/hal-00808332

[53] Y. Kessaci, N. Melab, E.-G. Talbi. *A Pareto-based genetic algorithm for optimized assignment of virtual machines requests in a multi-cloud environment*, in "IEEE Conference on Evolutionary computation (CEC)", Cancun, Mexico, June 2013, http://hal.inria.fr/hal-00837567

[54] Y. KESSACI, N. MELAB, E.-G. TALBI. *A Pareto-based Genetic Algorithm for Optimized Assignment of VM Requests on a Cloud Brokering Environment*, in "CEC - IEEE Congress on Evolutionary Computation - 2013", Cancun, Mexico, 2013, http://hal.inria.fr/hal-00835010

[55] F. LEGILLON, N. MELAB, D. RENARD, E.-G. TALBI. *Cost minimization of service deployment in a multi-cloud environment*, in "IEEE Conference on Evolutionary computation (CEC)", Cancun, Mexico, June 2013, http://hal.inria.fr/hal-00837565

[56] F. LEGILLON, N. MELAB, E.-G. TALBI. *Cost minimization of service deployment in a public cloud environment*, in "IEEE NIDISC Workshop on Nature Inspired Computing", Boston, United States, May 2013, http://hal.inria.fr/hal-00837570

[57] A. LIEFOOGHE, S. VEREL, H. AGUIRRE, K. TANAKA. *What makes an instance difficult for black-box 0-1 evolutionary multiobjective optimizers?*, in "International Conference on Artificial Evolution (EA 2013)", Bordeaux, France, Lecture Notes in Computer Science, Springer, 2013, http://hal.inria.fr/hal-00855252

[58] M.-E. MARMION, A. BLOT, L. JOURDAN, C. DHAENENS. *Neutrality in the Graph Coloring Problem*, in "Learning and Intelligent OptimizatioN Conference", Catania, Italy, P. PARDALOS, G. NICOSIA (editors), LNCS (Springer), 2013, pp. 125–130, http://hal.inria.fr/hal-00919750

[59] N. MELAB, T. V. LUONG, K. BOUFARAS, E.-G. TALBI. *ParadisEO-MO-GPU: a Framework for Parallel GPU-based Local Search Metaheuristics*, in "ACM GECCO'2013", Amsterdam, Netherlands, July 2013, http://hal.inria.fr/hal-00841956

[60] M.-S. MEZMAZ, R. LEROY, N. MELAB, D. TUYTTENS. *A Multi-Core Parallel Branch-and-Bound Algorithm Using Factorial Number System*, in "IPDPS 2014 : 28th IEEE International Parallel & Distributed Processing Symposium", Phoenix (Arizona), United States, IEEE (editor), Manish Parashar (Rutgers University, USA), May 2014, http://hal.inria.fr/hal-00934841

[61] S. NESMACHNOW, S. ITURRIAGA, D. BERNABE, E.-G. TALBI, P. BOUVRY. *List scheduling heuristics for virtual machine mapping in cloud systems*, in "VI Latin American Symposium on High Performance Computing (HPCLatam)", Mendoza, Argentina, July 2013, http://hal.inria.fr/hal-00872987

[62] *Best Paper*
M. NOUREDINE, T. V. LUONG, B. KARIMA, T. EL-GHAZALI. *ParadisEO-MO-GPU: a Framework for Parallel Local Search Metaheuristics*, in "GECCO - Genetic and Evolutionary Computation Conference - 2013", Amsterdam, Netherlands, 2013, http://hal.inria.fr/hal-00835012.

[63] F. PINEL, D. BERNABE, P. BOUVRY, S. U. KHAN. *Savant: Automatic Parallelization of a Scheduling Heuristic with Machine Learning*, in "Fifth World Congress on Nature and Biologically Inspired Computing (NaBIC)", Fargo, United States, August 2013, http://hal.inria.fr/hal-00872988

[64] J. SCHLEICH, G. DANOY, D. BERNABE, P. BOUVRY. *An Overlay Approach for Optimising Small-World Properties in VANETs*, in "EVOCOMNET/EVOApplications, part of EVO*", Vienna, Austria, April 2013, http://hal.inria.fr/hal-00872995

[65] M. SEREDYNSKI, D. BERNABE, D. KHADRAOUI. *Comparison of Green Light Optimal Speed Advisory Approaches*, in "16th International IEEE Annual Conference on Intelligent Transportation Systems", the hague, Netherlands, October 2013, http://hal.inria.fr/hal-00872992

[66] K. SERIDI, L. JOURDAN, E.-G. TALBI. *Multi-objective path relinking for biclustering: application to microarray data*, in "EMO'2013 Evolutionary Multi-objective Optimization", Sheffield, United Kingdom, March 2013, pp. 200-214, http://hal.inria.fr/hal-00837571

[67] K. SERIDI, L. JOURDAN, E.-G. TALBI. *Multiobjective Path Relinking for Biclustering: Application to Microarray Data*, in "Evolutionary Multi-Criterion Optimization - 7th International Conference, EMO 2013", Sheffield, United Kingdom, R. C. PURSHOUSE, P. J. FLEMING, C. M. FONSECA, S. GRECO, J. SHAW (editors), Springer, 2013, vol. 7811, pp. 200-214, http://hal.inria.fr/hal-00825857

[68] A.-A. TANTAR, A. Q. NGUYEN, P. BOUVRY, B. DORRONSORO, E.-G. TALBI. *Computational intelligence for cloud management: current trends and opportunities*, in "Proceedings of the IEEE Congress on Evolutionary Computation (CEC), part of World Conference in Computational Intelligence (WCCI)", Cancun, Mexico, June 2013, http://hal.inria.fr/hal-00837568

[69] T.-D. TRAN, D. BROCKHOFF, B. DERBEL. *Multiobjectivization with NSGA-II on the Noiseless BBOB Testbed*, in "GECCO (Companion), workshop on Black-Box Optimization Benchmarking (BBOB'2013)", Amsterdam, Netherlands, July 2013, http://hal.inria.fr/hal-00825831

[70] H. TRAUTMANN, T. WAGNER, D. BROCKHOFF. *R2-EMOA: Focused Multiobjective Search Using R2-Indicator-Based Selection*, in "Learning and Intelligent OptimizatioN Conference (LION 7)", Catania, Italy, January 2013, short paper, http://hal.inria.fr/hal-00807901

[71] T.-T. VU, B. DERBEL, N. MELAB. *Adaptive Dynamic Load Balancing in Heterogenous Multiple GPUs-CPUs Distributed Setting: Case Study of B&B Tree Search*, in "7th International Learning and Intelligent OptimizatioN Conference (LION)", Catania, Italy, Lecture Notes in Computer Science, January 2013, http://hal.inria.fr/hal-00765199

[72] T.-T. VU, F. HUET. *A Lightweight Continuous Jobs Mechanism for MapReduce Frameworks*, in "13th IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing, CCGrid 2013", Netherlands, June 2013, pp. 269-276, http://hal.inria.fr/hal-00916103

[73] T. WAGNER, H. TRAUTMANN, D. BROCKHOFF. *Preference Articulation by Means of the R2 Indicator*, in "Evolutionary Multi-criterion Optimization (EMO 2013)", Sheffield, United Kingdom, March 2013, vol. 7811, pp. 81-95 [*DOI :* 10.1007/978-3-642-37140-0_10], http://hal.inria.fr/hal-00807867

[74] H. YAHYAOUI, S. KRICHEN, B. DERBEL, E.-G. TALBI. *A Variable Neighborhood Descent for solving the Single Machine Total Weighted Tardiness Problem*, in "The 5th international conference on modeling, simulation and applied optimization (ICMSAO)", Hammamet, Tunisia, IEEE, April 2013, http://hal.inria.fr/hal-00808361

Conferences without Proceedings

[75] D. ARENAS, R. CHEVRIER, C. DHAENENS, S. HANAFI, J. RODRIGUEZ. *Application of a Co-evolutionary Genetic Algorithm to solve the Periodic Railway Timetabling Problem*, in "International Conference on

Industrial Engineering and Systems Management", Rabat, Morocco, October 2013, http://hal.inria.fr/hal-00879745

[76] J. HAMON, C. DHAENENS, G. EVEN, J. JACQUES. *Feature selection in high dimensional regression problems for genomic*, in "Tenth International Meeting on Computational Intelligence Methods for Bioinformatics and Biostatistics", Nice, France, June 2013, http://hal.inria.fr/hal-00839705

[77] J. HAMON, C. DHAENENS, G. EVEN, J. JACQUES. *Modèles mixtes en génétique animale : sélection de variables par optimisation combinatoire*, in "45ème Journées De Statistiques", Toulouse, France, May 2013, http://hal.inria.fr/hal-00839707

[78] M.-E. MARMION, A. BLOT, L. JOURDAN, C. DHAENENS. *Neutralité du problème de coloration de graphe*, in "ROADEF 2013 : 14e congrès de la Société Française de Recherche Opérationnelle et d'Aide à la Décision", Troyes, France, 2013, http://hal.inria.fr/hal-00840361

Scientific Books (or Scientific Book chapters)

[79] M. BASSEUR, A. LIEFOOGHE. *Metaheuristics for bi-objective flowshop scheduling*, in "Metaheuristics for production scheduling", Wiley & Sons, 2013, http://hal.inria.fr/hal-00825307

[80] E.-G. TALBI. , *Metaheuristics for bi-level optimization*, Springer, May 2013, 288 p. , http://hal.inria.fr/hal-00843857

[81] E.-G. TALBI. *A taxonomy of metaheuristics for bilevel optimization*, in "Metaheuristics for bilevel optimization", E.-G. TALBI (editor), Springer, May 2013, http://hal.inria.fr/hal-00838136

Research Reports

[82] J. HUMEAU, A. LIEFOOGHE, E.-G. TALBI, S. VEREL. , *ParadisEO-MO: From Fitness Landscape Analysis to Efficient Local Search Algorithms*, Inria, 2013, n^{o} RR-7871, http://hal.inria.fr/hal-00665421

[83] M.-E. MARMION, A. BLOT, L. JOURDAN, C. DHAENENS. , *Neutrality in the Graph Coloring Problem*, Inria, January 2013, n^{o} RR-8215, 15 p. , http://hal.inria.fr/hal-00781001

References in notes

[84] C. A. COELLO COELLO, D. A. VAN VELDHUIZEN, G. B. LAMONT (editors). , *Evolutionary algorithms for solving multi-objective problems*, Kluwer Academic Press, 2002

[85] H. E. AGUIRRE, K. TANAKA. *Working principles, behavior, and performance of MOEAs on MNK-landscapes*, in "European Journal of Operational Research", 2007, vol. 181, n^{o} 3, pp. 1670–1690

[86] M. BASSEUR. , *Design of cooperative algorithms for multi-objective optimization: Application to the Flow-shop scheduling problem*, University of Sciences and Technology of Lille, France, June 2005

[87] C. COTTA, E.-G. TALBI, E. ALBA. *Parallel hybrid approaches*, in "Parallel Metaheuristics", USA, J. Wiley and Sons, 2005, pp. 347–370

[88] K. DEB. , *Multi-objective optimization using evolutionary algorithms*, John Wiley and sons, 2001

[89] D. E. GOLDBERG. , *Genetic Algorithms in Search, Optimization, and Machine Learning*, Addison-WesleyReading, Massachusett, USA, 1989

[90] S. A. KAUFFMAN. , *The Origins of Order*, Oxford University Press, 1993

[91] G. KOCHENBERGER, F. GLOVER, B. ALIDAEE, C. REGO. *A unified modeling and solution framework for combinatorial optimization problems*, in "OR Spectrum", 2004, vol. 26, n^{o} 2, pp. 237–250

[92] A. J. NEBRO, F. LUNA, E.-G. TALBI, E. ALBA. *Parallel multi-objective optimization*, in "Parallel Metaheuristics", USA, J. Wiley and Sons, 2005, pp. 371–394

[93] E.-G. TALBI. *A Taxonomy of Hybrid Metaheuristics*, in "Journal of Heuristics", 2002, vol. 8, n^{o} 5, pp. 541–564