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

Activity Report 2012

Project-Team DOLPHIN

Parallel Cooperative Multi-criteria Optimization

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

RESEARCH CENTER
Lille - Nord Europe

THEME
Optimization, 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: May 12, 2005 .

1. Members

Research Scientists

Dimo Brockhoff [Research Scientist (CR2) Inria]
Luce Brotcorne [Research Scientist (CR1) Inria, HdR]

Faculty Members

François Clautiaux [Assistant Professor Université Lille 1 - IUT, HdR]
Bilel Derbel [Assistant Professor Université Lille 1 - IEEA]
Clarisse Dhaenens [Professor Université Lille 1 - Polytech'Lille, HdR]
Laetitia Jourdan [Professor Université Lille 1 - IEEA, HdR]
Arnaud Liefooghe [Assistant Professor Université Lille 1 - IEEA]
Nouredine Melab [Professor Université Lille 1 - IEEA, HdR]
El-Ghazali Talbi [Team Leader, Professor Université Lille 1 - Polytech'Lille, HdR]

External Collaborator

Sébastien Verel [Mdc Univ. Nice Sophia-Antipolis]

Engineer

Clive Canape [Associate Engineer]

PhD Students

Sezin Afsar [Inria grant (Cordi), Second year]
Oumayma Bahri [International funding, From Dec 2012]
Martin Bué [CIFRE BeTravel, From Dec 2012]
Imen Chakroun [MESR support, Third year]
Nadia Dahmani [European COADVISE project, Third Year]
Moustapha Diaby [International funding, Fourth Year]
Nicolas Dupin [EDF, Second Year]
Mathieu Djamai [MESR support, Fourth Year]
Matthieu Gérard [CIFRE, Vekia, First Year]
Julie Hamon [CIFRE, Genes Diffusion, Third Year]
Julie Jacques [Alicante, Third Year]
Sophie Jacquin [MESR support, from Dec 2012]
Yacine Kessaci [International support, Third Year]
François Legillon [CIFRE, Second Year]
Rudi Leroy [Maison de la simulation, From Oct 2012]
Khadidja Seridi [International support, Fourth Year]
Apostos Sthathakis [International Support, Second Year]
Bayrem Tounsi [ANR support, From Nov 2012]
Thanh-Do Tran [Inria grant (Cordi), From Dec 2012]
Trong Tuan Vu [Inria grant (Cordi), Second Year]

Post-Doctoral Fellows

Bernabe Dorronsoro [Luxembourg funding, From Sept 2012]
Ekaterina Alekseeva [ERCIM, From Dec 2012]

Administrative Assistant

Julie Jonas [Inria assistant]

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):**

  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,

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

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 different 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

- Francois Clautiaux: Premier accessit for Prix Robert Faure 2012.
- Best paper award at conference ICORES'2012 1st International Conference on Operations Research and Entreprise Systems, Vilamora, Portugal, Feb 2012 [44] . Rita Macedo, Said Hanafi, Francois Clautiaux, Claudio Alves, José Valério de Carvalho, Generalized disaggregation algorithm for the vehicle routing problem with time windows and multiple routes.
- Best paper award at GECCO'2012 (Genetic and Evolutionary Computation Conference, EMO Track), Philadelphia, USA, July 2012 [37] . D. Brockhoff, T. Wagner, H. Trautmann, On the Properties of the R2 Indicator.

BEST PAPERS AWARDS :

[44] **Generalized disaggregation algorithm for the vehicle routing problem with time windows and multiple routes in ICORES 2012, 1st International Conference on Operations Research and Entreprise Systems, Vilamora, Portugal, 4-6 february, 2012**. R. MACEDO, S. HANAFI, F. CLAUTIAUX, C. ALVES, J. M. VALÉRIO DE CARVALHO.

[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).

[37] **On the Properties of the R2 Indicator in GECCO'2012**. D. BROCKHOFF, T. WAGNER, H. TRAUTMANN.

3. Scientific Foundations

3.1. Modeling and landscape analysis

The modeling of problems, the analysis of structures (landscapes) of MOPs and the performance assessment of resolution methods are significant topics in the design of optimization methods. The effectiveness of metaheuristics depends on the properties of the problem and its landscape (roughness, convexity, etc). The notion of landscape has been first described in [89] by the way of the study of species evolution. Then, this notion has been used to analyze combinatorial optimization problems.

3.1.1. Modeling of problems

Generally there are several ways of modeling a given problem. First, one has to find the most suitable model for the type of resolution he or she plans to use. The choice can be made after a theoretical analysis of the model, or after computational experiments. The choice of the model depends on the type of method used. For example, a major issue in the design of exact methods is to find tight relaxations for the problem considered.

Let us note that many combinatorial optimization problems of the literature have been studied in their mono-objective form even if a lot of them are naturally of a multi-objective nature.

Therefore, in the DOLPHIN project, we address the modeling of MOPs in two phases. The first one consists in studying the mono-objective version of the problem, where all objectives but one are considered as constraints. In the second phase, we propose methods to adapt the mono-objective models or to create hand-tailored models for the multi-objective case. The models used may come from the first phase, or from the literature.

3.1.2. Analysis of the structure of a problem

The landscape is defined by a neighborhood operator and can be represented by a graph $G = (V, E)$. The vertices represent the solutions of the problem and an edge (e_1, e_2) exists if the solution e_2 can be obtained by an application of the neighborhood operator on the solution e_1. Then, considering this graph as the ground floor, we elevate each solution to an altitude equals to its cost. We obtain a surface, or landscape, made of peaks, valleys, plateaus, cliffs, etc. The problem lies in the difficulty to have a realistic view of this landscape.

Like others, we believe that the main point of interest in the domain of combinatorial optimization is not the design of the best algorithm for a large number of problems but the search for the most adapted method to an instance or a set of instances of a given problem. Therefore, we are convinced that no ideal metaheuristic, designed as a black-box, may exist.

Indeed, the first studies realized in our research group on the analysis of landscapes of different mono-objective combinatorial optimization problems (traveling salesman problem, quadratic assignment problem) have shown that not only different problems correspond to different structures but also that different instances of the same problem correspond to different structures.

For instance, we have realized a statistical study of the landscapes of the quadratic assignment problem. Some indicators that characterize the landscape of an instance have been proposed and a taxonomy of the instances including three classes has been deduced. Hence it is not enough to adapt the method to the problem under study but it is necessary to specialize it according to the type of the treated instance.

So in its studies of mono-objective problems, the DOLPHIN research group has introduced into the resolution methods some information about the problem to be solved. The landscapes of some combinatorial problems have been studied in order to investigate the intrinsic natures of their instances. The resulting information has been inserted into an optimization strategy and has allowed the design of efficient and robust hybrid methods. The extension of these studies to multi-objective problems is a part of the DOLPHIN project [87], [88].

3.1.3. Performance assessment

The DOLPHIN project is also interested in the performance assessment of multi-objective optimization methods. Nowadays, statistical techniques developed for mono-objective problems can be adapted to the multi-objective case. Nevertheless, specific tools are necessary in many situations: for example, the comparison of two different algorithms is relatively easy in the mono-objective case - we compare the quality of the best solution obtained in a fixed time, or the time needed to obtain a solution of a certain quality. The same idea cannot be immediately transposed to the case where the output of the algorithms is a set of solutions having several quality measures, and not a single solution.

Various indicators have been proposed in the literature for evaluating the performance of multi-objective optimization methods but no indicator seems to outperform the others [90]. The DOLPHIN research group has proposed two indicators: the *contribution* and the *entropy* [82]. The contribution evaluates the supply in term of Pareto-optimal solutions of a front compared to another one. The entropy gives an idea of the diversity of the solutions found. These two metrics are used to compare the different metaheuristics in the research group, for example in the resolution of the bi-objective flow-shop problem, and also to show the contribution of the various mechanisms introduced in these metaheuristics.

3.1.4. Goals

One of the main issues in the DOLPHIN project is the study of the landscape of multi-objective problems and the performance assessment of multi-objective optimization methods to design efficient and robust resolution methods:

- *Landscape study:* The goal here is to extend the study of landscapes of the mono-objective combinatorial optimization problems to multi-objective problems in order to determine the structure of the Pareto frontier and to integrate this knowledge about the problem structure in the design of resolution methods.

  This study has been initiated for the bi-objective flow-shop problem. We have studied the convexity of the frontiers obtained in order to show the interest of our Pareto approach compared to an aggregation approach, which only allows one to obtain the Pareto solutions situated on the convex hull of the Pareto front (supported solutions).

  Our preliminary study of the landscape of the bi-objective flow-shop problem shows that the supported solutions are very closed to each other. This remark leads us to improve an exact method initially proposed for bi-objective problems. Furthermore, a new exact method able to deal with any number of objectives has been designed.

- *Performance assessment: The goal here is to extend GUIMOO in order to provide efficient visual and metric tools for evaluating the assessment of multi-objective resolution methods.*

3.2. Hybrid multi-objective optimization methods

The success of metaheuristics is based on their ability to find efficient solutions in a reasonable time [76]. 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 [59], [74]. To be convinced one may refer to the list of references on Evolutionary Multi-objective Optimization maintained by Carlos A. Coello Coello [4], which contains more

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

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'.

3.2.1. 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 [84]. 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.
- *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 if 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.

3.2.2. 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 [68].

3.2.3. 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).

3.3. 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 goal 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.

3.3.1. 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 [73], [83].

3.3.2. 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 generic problems

In this project, some well known optimization problems are re-visited in terms of multi-objective modelization and resolution:

- **Workshop optimization problems:**

  Workshop optimization problems deal with optimizing the production. In this project, two specific problems are under study.

  - **Flow-shop scheduling problem:** The flow-shop problem is one of the most well-known scheduling problems. However, most of the works in the literature use a mono-objective model. 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. A tri-criteria 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.
  - **Cutting problems:** Cutting problems occur when pieces of wire, steel, wood, or paper have to be cut from larger pieces. The objective is to minimize the quantity of lost material. Most of these problems derive from the classical one-dimensional cutting-stock problem, which have been studied by many researchers. The problem studied by the DOLPHIN project is a two-dimensional bi-objective problem, where rotating a rectangular piece has an impact on the visual quality of the cutting pattern. First we have to study the structure of the cutting-stock problem when rotation is allowed, then we will develop a method dedicated to the bi-objective version of the problem.
- **Logistics and transportation problems:**

- **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.
- **Routing problems:** The vehicle routing problem (VRP) is a well-known problem and it has been studied since the end of the 50's. 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 work in the literature.

  The second routing problem is a generalization of the covering tour problem (CTP). In the DOLPHIN project, this problem is solved as a bi-objective problem where a set of constraints are modeled as an objective. The two objectives are: i) minimization of the length of the tour; ii) minimization of the largest distance between a node to be covered and a visited node. As far as we know, this study is among the first works that tackle a classic mono-objective routing problem by relaxing constraints and building a more general MOP.

  The third studied routing problem is the Ring Star Problem (RSP). This problem consists in locating a simple cycle through a subset of nodes of a graph while optimizing two kinds of costs. The first objective is to minimize a ring cost that is related to the length of the cycle. The second one is to minimize an assignment cost from non-visited nodes to visited ones. In spite of its natural bi-criteria formulation, this problem has always been studied in a single-objective form where either both objectives are combined or one objective is treated as a constraint.

  Now our goal is to propose VRP libraries that are able to cope with a large number of constraints. The libraries are conceived in such a way that totally new sets of constraints can be added dynamically, similarly to what is done in constraint programming. This code will be used in future industrial collaborations, and already includes algorithms to use GIS.

For all studied problems, standard benchmarks have been extended to the multi-objective case. The benchmarks and the obtained results (optimal Pareto front, best known Pareto front) are available on the Web pages associated to the project and from the MCDM (International Society on Multiple Criteria Decision Making) Web site. This is an important issue to encourage comparison experiments in the research community.

4.2. Application to mobile telecommunication networks

With the extraordinary success of mobile telecommunication systems, service providers have been affording huge investments for network design and infrastructure. Mobile network design is of outmost importance, and is thus a major issue in mobile telecommunication systems. In fact, with the continuous and rapid growth of communication traffic, large scale planning becomes more and more difficult. Hence, automatic, interactive and self-adaptive optimization algorithms and tools would be very useful and helpful. Advances in this area will certainly lead to important improvements in terms of quality of service, network management and cost deployment.

In the past, the DOLPHIN team has initiated solid industrial collaborations within the domain of mobile networks. In fact, the problem of network design and frequency assignment was studied in collaboration with

France Telecom. In particular, a new formulation/resolution of the problem as a multi-objective constrained combinatorial optimization problem was considered. In collaboration with Mobinets, the DOLPHIN team has also addressed the problem of access network design. The problem consists in minimizing the cost of the access network and maximizing its availability.

More recently, the DOLPHIN team has been interested in new optimization models and algorithms to address new difficult problems raised by new emerging technologies in wireless networks. In fact, wireless communications are evolving from inflexible and monolithic systems to a composite radio environment made of cognitive radio devices and networks of different technologies. Within this context, the challenge is to design new optimization techniques which are not only resource, power, scale, and applications aware, but which are self-adaptive and fully distributed in order to allow the dynamic optimization of radio-devices behaviors depending on the environment constraints e.g., spectrum availability, network traffic, user demand, etc. To achieve this goal, distributed and nature-inspired algorithms, such as ant-colony and bees, will be investigated in order to dynamically and distributively optimize predefined criterion such as throughput, fairness, quality of service to cite a few. It is expected that the techniques developed in this work will lead to the design of new models and algorithms for opportunistic/dynamic spectrum access and cross layer network optimization which are at the core of future generation wireless networks.

4.3. Application to Bioinformatics

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 thema.

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 to analyze 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 datamining 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 number of data increases rapidly. Within the new collaboration, started in 2010, with Genes Diffusion, specializes in genetics and animal reproduction for bovine, swine, equine and rabbit species, we will study combinations of Single Nucleotide Polymorphisms (SNP) that can explain some phenotypic characteristics.

4.3.2. Docking and conformational sampling

In molecular modelling, conformational sampling and docking procedures provide help for understanding the interaction mechanisms between (macro)molecules involved in physiological processes. The processes to be simulated are of a combinatorial complexity (molecule size, number of degrees of freedom) which represents an important challenge for the currently available computing power. Such a challenge can be expressed by three major objectives: (1) the proposition of mathematical models of maximum simplicity that nevertheless provide a relevant description of molecular behavior, (2) the development of powerful distributed optimization algorithms (evolutionary algorithms, local search methods, hybrid algorithms) for sampling the molecular energy surface for stable, populated conformations, and (3) the deployment of those intrinsic distributed algorithms on computational Grids.

Within the framework of ANR DOCK and Decrypton projects, the focus was to propose multi-objective formulations of the conformational and docking problems. The goal was to take into account different criteria characteristics of the complex docking process. Furthermore, in order to deal with the multimodal nature of the problems it is important to define new hybrid mechanisms allowing us to provide algorithms with both diversification and intensification properties. Finally, to deal with the exponential combinatory of these problems when large proteins are concerned parallel and grid computing is highly required. Using grid computing is not straightforward, so a "gridification" process is necessary. Such process allows us to adapt the proposed algorithms to the characteristics of the grid. The gridification process must be exploited by the user in a transparent way. Therefore, coupling ParadisEO-PEO with a generic grid middleware such as Globus is important to provide robust and efficient algorithms to be exploited transparently.

New contacts with the Servier company show that these questions are really challenging ones for the design of new drug molecules.

4.3.3. Optimization for health care

The new collaboration (PhD thesis started in october 2010) with Alicante company, major actor in the hospital decision making, will deal 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 combinatorial optimization will be implemented, requiring extensive work to model the problem, to define criteria optimization and to design specific optimization methods.

5. Software

5.1. ParadisEO

Participants: Clive 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. On Optimizing a Bi-objective Flowshop Scheduling Problem in Uncertain Environment

Participants: Arnaud Liefooghe, Laetitia Jourdan, El-Ghazali Talbi

Existing models from scheduling often over-simplify the problems appearing in real-world industrial situations. The original application is often reduced to a single-objective one, where the presence of uncertainty is neglected. In [23], we focus on multi-objective optimization in uncertain environments. A bi-objective flowshop scheduling problem with uncertain processing times is considered. An indicator-based evolutionary algorithm is proposed to handle these two difficulties (multiple objectives and uncertain environment) at the same time. Four different strategies, based on uncertainty-handling quality indicators, are proposed in the paper. Computational experiments are performed on a large set of instances by considering different scenarios with respect to uncertainty. We show that an uncertainty-handling strategy is a key issue to obtain good-quality solutions, and that the algorithm performance is strongly related to the level of uncertainty over the environmental parameters.

6.2. New Price settings models in the energy field

Participants: L. Brotcorne, S. Afsar

The electricity supply industry is facing in many countries a restructuring process towards deregulation and competition. In that context classical marginal cost based approaches based on estimation of cost production function and demand functions are not well-suited anymore. Indeed, the energy prices have to be defined not only to retrieve the production costs but also in order to take into account the consumer behavior. Consumers make their choice of service, or of energy provider in order to minimize their disutility values. Failing to recognize that may lead to tremendous lack on revenues. In order to capture this hierarchical decision process where a leader (the energy provider) takes explicitly into account the reaction of a follower (the consumers) in his decision process. The energy pricing problems addressed in this are modeled as bilevel programs.

6.3. Bi-level formulation for a Long-Distance Freight Transportation Problem

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

A company wants to convey different types of products from origin i to points of destination j. It can deliver the goods itself or hire a transport company, and subcontract part of the application. The transport company must offer attractive prices while aiming to maximize its profit. The aim of this problem is to determine rates that allow the carrier to maximize its revenues and remain affordable for the customer. The problem is modeled as a bilevel program at the first level, the carrier (leader) wants to maximize its revenues; at the second level, the client. An exact and an evolutionary solution approaches are developped.

6.4. On Local Search for Bi-objective Knapsack Problems

Participant: A. Liefooghe.

In [26], a local search approach is proposed for three variants of the bi-objective binary knapsack problem, with the aim of maximizing the total profit and minimizing the total weight. First, an experimental study on a given structural property of connectedness of the efficient set is conducted. Based on this property, a local search algorithm is proposed and its performance is compared against exact algorithms in terms of running time and quality metrics. The experimental results indicate that this simple local search algorithm is able to find a representative set of optimal solutions in most of the cases, and in much less time than exact algorithms.

6.5. Convergent methods based on aggregation in mathematical models

Participant : François Clautiaux

We designed several algorithms to aggregate variables in integer linear programs. Our methods first solve aggregated models, and converge to the optimal solution of the initial problem by iteratively refining the model.

The first method applies on a large network flow models that use a pseudo-polynomial number of variables. It is based on an initial aggregation of the vertices of the model and its iterative refinement using different optimization techniques. This led to dramatical improvements for a special case of vehicle routing problem. We proposed several theoretical results regarding convergence, suitable discretizations, wort-case analysis and approximation algorithms [44].

The second method applies on column generation approaches for the cutting-stock problem. Our algorithm links groups of dual variables by linear constraints, leading to a problem of smaller dimension, whose solutions are dual-feasible for the initial problem. The corresponding "inner approximation" is iteratively refined by splitting the groups into smaller groups until an optimal dual solution is found. This method allows to produce a valid lower bound at each iteration, which is not the case for classical column-generation schemes [58].

6.6. Investigating the Optimization Goal of Indicator-Based Multiobjective Search

Participant from DOLPHIN: Dimo Brockhoff; External Participants: Heike Trautmann and Tobias Wagner (TU Dortmund University, Germany)

Using a quality indicator in the environmental selection step of evolutionary multiobjective optimization (EMO) algorithms to indicate which solutions shall be kept in the algorithms' population and which should be deleted, introduces a certain search bias. Instead of an "arbitrary" subset of the Pareto front, such (quality) indicator based search algorithms aim at approximating the set of μ solutions that optimizes a given indicator, for which the term *optimal μ-distribution* has been introduced [63]. Also for performance assessment with respect to a given indicator, knowledge about the optimal μ-distributions is helpful as interpreting the *achieved* indicator values with respect to the best *achievable* value becomes possible. For the hypervolume indicator, several results on these optimal μ-distributions are known [63], [62], [75], [69], [70], [61] [64], but the understanding of the optimization goal for other indicators is less developed. Recently, we started to investigate the optimal μ-distributions, both theoretically and numerically, for the so-called $R2$ indicator [79]—another often recommended quality indicator [90]. Instead of the binary version of [79] that takes two solution sets and assigns them a certain quality, we thereby investigated an equivalent unary indicator where one (reference) set is always fixed.

First experiments for problems with two objectives and connected Pareto fronts have been presented in [37] which won the best paper award within the EMO track at GECCO'2013 [5]. Further investigations on problems with disconnected Pareto fronts have been submitted to the Evolutionary Computation journal [72]. We also studied in more detail how the parameters of the $R2$ indicator such as the ideal point or the distribution of

[5] See http://www.sigevo.org/gecco-2012/papers.html.

weight vectors can be used to change the optimization goal [86] and correspondingly proposed the algorithm $R2$-EMOA which is able to steer the search towards preferred regions of the Pareto front by optimizing the $R2$ indicator directly in its environmental selection [85], [72].

6.7. Runtime Analyses of Interactive Evolutionary Algorithms

Participant from DOLPHIN: Dimo Brockhoff; External Participants: Manuel López-Ibáñez (Université Libre de Bruxelles, Belgium), Boris Naujoks (Cologne University of Applied Sciences, Germany), and Gunter Rudolph (TU Dortmund University, Germany)

If a decision maker (DM) expresses preferences, e.g., towards certain points or regions of the search space, during the algorithm run, we call such an algorithm *interactive*. Interactive algorithms are frequently used in the field of multi-criteria decision making, but theoretical results on interactive evolutionary multiobjective algorithms (EMOAs) have not been derived until recently. In [36], we started to analyze interactive versions of an evolutionary algorithm with plus-selection and a population size of one, the so-called iRLS and $i(1+1)$EA. On two pseudo-boolean problems, recently used for theoretically analyzing EMOAs, we could prove upper bounds on the expected runtime of the two mentioned algorithms and on the number of times, the DM is asked about his/her preferences until the most-preferred search point is found. The analyzes showed that the internal value function of the DM has a strong, non-desired influence on the algorithms' runtimes and that the number of questions to the DM are too high for a practical relevant algorithm. It is an open question which algorithm designs are necessary to circumvent these two drawbacks.

6.8. Benchmarking of CMA-ES Variants for Numerical Blackbox Optimization

Participant from DOLPHIN: Dimo Brockhoff; External Participants: Anne Auger and Nikolaus Hansen (Inria Saclay - Ile-de-France)

The covariance matrix adaptation evolution strategy (CMA-ES) is one of the state-of-the-art optimization algorithms for numerical single-objective blackbox optimization [81], [80] [67]. Previously, we proposed to use so-called mirrored mutations to generate new candidate solutions in evolution strategies which turned out to increase the convergence rate for certain variants [71], [65], [66]. Another recent approach to speed up the CMA-ES is to perform an active (i.e. negative) covariance matrix update [60]. In [32], [35], [34], [33], we tested empirically how the combination of mirrored mutations and active CMA-ES perform on the COCO framework [77], [78]. It turned out that both concepts complement each other well without a significant decrease in performance on any of the 24 test functions. Moreover, the main improvement over the standard CMA-ES could be shown to come from the active covariance matrix adaptation while the addition of mirrored mutations only slightly improves the algorithm.

6.9. Self-adaptive method for a three-objective vector-packing problem

Participants: Nadia Dahmani, François Clautiaux, El-Ghazali Talbi

We introduced a new multi-objective packing problem (MOBPP), in which we optimize the number of bins, the maximum weight of a bin, and the loading balancing. We studied the impact and the combination of two complementary decoding strategies for this problem. A feature of our work is to insert the parameters of the decoders in the representation of the solution. It leads to self-adaptive meta-heuristics, where the algorithm iteratively adapts the parameters during the search. We embedded our approaches in a local search and an evolutionary algorithm for the MOBPP. A comprehensive set of experiments were performed on various benchmarks inspired from the literature. Results confirm that our methods lead to more effective muti-objective metaheuristics for this problem.

6.10. Multiple Neighborhood Exploration Through Adaptive Search

Participants: Bilel Derbel, Houda Derbel, El-Ghazali Talbi, Hiba Yahyaoui

Variable neighborhood descent (VND) and its several variants are based on the systemic change of neighborhoods within the search. It is well known that the performance of a VND-like algorithm highly depends on the order/way the neighborhoods are alternated. In this work, we focus on designing new meta-strategies for deciding what neighborhood structure to apply through the search. Two new approaches are proposed to tackle this issue. In the first approach [41], we model the search by considering the neighborhood tree induced by alternating the use of different structures within a local search descent. We investigate the issue of designing a search strategy operating at the neighborhood tree level by exploring different paths of the tree in a heuristic way. We show that allowing the search to 'backtrack' to a previously visited solution and resuming the iterative variable neighborhood descent by 'pruning' the already explored neighborhood branches leads to the design of effective and efficient search heuristics. In the second approach, we investigate deterministic and randomized adaptive strategies for selecting the next neighborhood to apply at runtime. The adaptive strategies are based on computing a reward for each neighborhood with respect to the observed average ratio of solution quality and time cost.

6.11. CoBRA: A cooperative coevolutionary algorithm for bi-level optimization

Participants: François Legillon, Arnaud Liefooghe, El-Ghazali Talbi

In [43] we present CoBRA, a new evolutionary algorithm, based on a coevolutionary scheme, to solve bi-level optimization problems. It handles population-based algorithms on each level, each one cooperating with the other to provide solutions for the overall problem. Moreover, in order to evaluate the relevance of CoBRA against more classical approaches,a new performance assessment methodology, based on rationality, is introduced. An experimental analysis is conducted on a bi-level distribution planning problem, where multiple manufacturing plants deliver items to depots, and where a distribution company controls several depots and distributes items from depots to retailers. The experimental results reveal significant enhancements, particularly over the lower level, with respect to a more classical approach based on a hierarchical scheme.

6.12. Neutrality in the Graph Coloring Problem

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

The graph coloring problem is often investigated in the literature. Many insights about the existence of many neighboring solutions with the same fitness value are raised but as far as we know, no deep analysis of this neutrality has ever been conducted in the literature. We have quantified the neutrality of some hard instances of the graph coloring problem. This neutrality property has to be detected as it impacts the search process. Indeed, local optima may belong to plateaus that represents a barrier for local search methods. We also aim at pointing out the interest of exploiting neutrality during the search. Therefore, a generic local search dedicated to neutral problems (NILS) and previously tested on flowshop problems, is performed and tested on several hard instances. Results show that taking into account neutrality allows to obtain better results than when not considering it.

6.13. Local Search in the Context of Classification Rule Mining

Participants: Julie Jacques, Laetitia Jourdan, Clarisse Dhaenens

Many multi-objective algorithms have been proposed to solve the classification rule mining problem; the vast majority of them are based on genetic algorithms. We propose an algorithm, MOCA - Multi-Objective Classification Algorithm -, to solve this problem. The originality of MOCA is to be a dominance-based multi-objective local search (DMLS) using a Pittsburgh representation of rules. We evaluated several DMLS implementations and neighborhood operators on literature datasets and one real dataset. Then we compared the best obtained algorithm against several efficient approaches of the literature. The experiments show that the proposed approach is very competitive in comparison to other algorithms tested. Moreover, our approach is able to deal with very large real datasets and manages to have a good accuracy.

6.14. MOCA-I: discovering rules and guiding decision maker in the context of partial classification in large and imbalanced datasets

Participants: Julie Jacques, Laetitia Jourdan, Clarisse Dhaenens

In this work we focus on the modeling and the implementation as a multi-objective optimization problem of a Pittsburgh classification rule mining algorithm adapted to large and imbalanced datasets, as encountered in hospital data. Indeed hospital data comes with problems such as class imbalance, volumetry or inconsistency, and optimization approaches have to take into account such specificities. We present MOCA-I, an adaptation of MOCA dedicated to this kind of problems. We propose its implementation as a dominance-based local search in opposition to existing multi-objective approaches based on genetic algorithms. We associate to this algorithm an original post-processing method based on the ROC curve to help the decision maker to choose the most interesting set of rules. Our approach is currently compared to state-of-the-art classification rule mining algorithms (both classic approaches such as C4.5 and optimization approaches), giving as good or better preliminary results, using less parameters. Moreover, our approach has been compared to C4.5 and C4.5-CS on a real dataset (hospital data) with a larger set of attributes, giving the best results. The complete evaluation is still going on.

6.15. A method to combine combinatorial optimization and statistics to mine high-throughput genotyping data

Participants : Julie Hamon, Clarisse Dhaenens, Julien Jacques (MODAL)

In the context of genomic analysis (collaboration with Genes Diffusion), dealing with high-throughput genotyping data, the objective of our study is to select a subset of SNPs (single nucleotide polymorphisms) explaining a trait of interest. We propose a method combining combinatorial optimization and statistics to extract a subset of interesting SNPs. The combinatorial part aims at exploring in an efficient way the large search space induced by the large number of possible subsets and statistics are used to evaluate the selection. We propose a first method based on an ILS (iterated local search) and using a regression. Three criteria used to evaluate the quality of the regression are compared. One of them (the k-fold validation) shows better performance. We also compare this approach to classical statistical approaches on simulated datasets. Results are promising as the proposed approach outperforms most of these statistical approaches [51].

6.16. Design and implementation of performance or energy-aware parallel optimization algorithms

Problems in practice are nowadays becoming more and more complex and time-intensive and their resolution requires to harness more and more computational resources. In parallel, the recent advances in hardware architecture enable to provide such required tremendous computational power through massively multi-core and GPU infrastructures. Such huge amount of cores is often provided through heterogeneous single or multi-clusters. The exploitation of such infrastructures clearly poses two fundamental and conflictual issues which are two major challenging perspectives of the Dolphin project that have been investigated during the 2012 year: (1) *Performance-aware issue*: how to design, implement and validate efficient and effective algorithms for such target machines to solve large size combinatorial optimization problems? ; (2) *Energy-aware issue*: using a large amount of computational resources for the deployment of large scale algorithms is energy-consuming. Therefore, the second issue is how to deal with the performance issue with a minimized cost in terms of energy consumption?

To deal with these issues, we have proposed new approaches summarized in the following sections.

6.16.1. Design and implementation of performance-aware optimization algorithms

In order to allow one to solve large size combinatorial optimization problems, we have revisited the design and implementation of meta-heuristics and exat (B&B) algorithms for two major hardware platforms: heterogeneous multi and many-core clusters and computational grids including multiple clusters.

- **Multi-core GPU-based hybrid meta-heuristics** - *Participants: T-V. Luong, N. Melab and E-G. Talbi.*
  In [28], we have revisited the design and implementation of respectively single-solution and population-based meta-heuristics for single-core CPU coupled with a GPU device. We have investigated and proposed a new guidline for combining multi-core and GPU computing for hybrid meta-heuristics. Efficient approaches have been proposed for CPU-GPU data transfer optimization and task repartition between the GPU device and the CPU cores. Extensive experiments have been performed on an 8-core CPU coupled with a GPU card using Ant colonnies combined with a local serach applied to the Quadratic Assignment Problem (QAP). The reported results show that the use of multi-core computing, in addition to GPU computing, provides a performance improvement of up to 75%.
- **GPU-accelerated Branch-and-Bound algorithms** - *Participants: I. Chakroun and N. Melab.*
  Branch-and-Bound (B&B) algorithms are based on an implicit enumeration of a dynamically built tree-based search space. Pruning tree nodes (sub-problems) is traditionally used as a powerful mechanism to reduce the size of the explored search space. Such mechanism requires to perform the bounding operation which consists in applying a lower bound function to the generated sub-problems. Preliminary experiments performed on the Flow-Shop scheduling problem (FSP) have shown that the bounding operation consumes over 98% of the execution time of the B&B algorithm. Therefore, we have investigated the use of GPU computing as a major complementary way to speed up the search. We have revisited the design and implementation of the parallel bounding model for FSP on GPU accelerators dealing with two major issues: (1) thread divergence caused by the highly irregular nature of the explored tree and the SIMD execution model of GPU ; (2) data access optimization required for mapping efficiently different data structures on the hierarchy of memories provided in the GPU device. In [14], we have proposed a GPU-based parallel bounding model together with a data refactoring approach to deal with thread divergence. In [45] (an extended version submitted to the CCPE journal is being revised), we have proposed an efficient data optimization strategy based on a deep analysis of the complexity of the different data structures of the FSP lower bound algorithm in terms of memory size and access latency. The different proposed approaches for the two issues have been extensively experimented using and Nvidia Tesla C2050 GPU card. Compared to a CPU-based execution, accelerations up to more than $\times 100$ are achieved for large problem instances.
- **Peer-to-peer Branch-and-Bound algorithms** - *Participants: T-T. Vu, B. Derbel and N. Melab.*
  To deal with dynamic load balancing in large scale distributed systems, we have proposed in [50] to organize computing resources following a logical peer-to-peer overlay and to distribute the load according to the so-defined overlay. We have used a tree as a logical structure connecting distributed nodes and we balance the load according to the size of induced subtrees. We have conducted extensive experiments involving up to 1000 computing cores and provided a throughout analysis of different properties of our generic approach for two different applications, namely, the standard Unbalanced Tree Search and the more challenging parallel Branch-and-Bound algorithm. Substantial improvements are reported in comparison with the classical random work stealing and two finely tuned application specific strategies taken from the literature.

6.16.2. Design and implementation of energy-aware optimization algorithms

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

Cloud computing is an emerging computer science paradigm of distributed computing in which applications, data and infrastructures are proposed as a service that can be consumed in a ubiquitous, flexible and transparent way. Cloud computing brings with it such benefits via cloud managers which hide to the user some complex and challenging issues such as scheduling. However, the solutions to these issues provided in cloud managers are sometimes limited. For instance, the scheduling approach proposed in many cloud managers like OpenNebula is limited regarding the criteria taken into account. Energy consumption, which is highly critical for many applications such as High Performance Computing (HPC), is rarely considered. In [42] (selected for a special issue of FGCS journal) , we have addressed energy-aware scheduling of energy and time-consuming applications for cloud infrastructures. We have proposed a multi-start parallel local search heuristic for cloud managers (EMLS-ONC) with the focus put on OpenNebula. EMLS-ONC has been experimented using different (VMs) arrival scenarii and different hardware infrastructures. The results show that EMLS-ONC outperforms the scheduler provided in OpenNebula by a significant margin in terms of energy consumption and number of scheduled VMs.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts 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.
- BTravel (2011-2015). This project deals with the optimization of group travel plannings.
- NewCo (2011-2012) : Optimisation of client programs in the tourism industry.

8. Partnerships and Cooperations

8.1. Regional Initiatives

+ PPF Bioinformatics: This program within the University of Lille 1 deals with solving bioinformatics and computational biology problems using combinatorial optimization techniques, 2010-2013.
+ PPF High Performance Computing, This program deals with parallel optimization, 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. FP7 Projects

8.3.2. 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.

8.3.3. 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):

Université de Montréal (Canada) - Département d’informatique et recherche opérationnelle - Francois Gilbert

Polytechnic School of Montreal (Canada) - Département de mathématique et génie industriel - Michel Gendreau

Duration: 2012 - 2014

See also: http://dolphin.lille.inria.fr/Dolphin/STEM

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 and Ecole Polytechnique of Montreal, Canada
- University of Dortmund, Germany
- ETH Zurich, Switzerland
- SINTEF, Norway

8.4.3. Participation In International Programs

- Inria STIC-Tunisie,2011-2013.
- Inria STIC-Algérie, 2011-2013.
- CNRS PICS Luxembourg, 2011-1014.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

The project had visitors during the year 2010:

- Prof. Michel Gendreau, University of Montreal
- Prof. Pascal Bouvry, University of Luxembourg
- Dr. Gleb Belov, Univ. Essen, Germany
- Dr. Manuel Lopez-Ibanez, IRIDIA, Université Libre de Bruxelles, Belgium,
- Dr. Boris Naujoks, Cologne University of Applied Sciences, Gummersbach, Germany
- Prof. Gunter Rudolph, TU Dortmund University, Germany

8.5.2. Visits to International Teams

- D. Brockhoff, June 2012, TU Dortmund University, Germany
- D. Brockhoff, March 2012, ETH Zurich, Switzerland
- E-G. Talbi, Dec 2012, Univ. Luxembourg, Luxembourg
- A. Liefooghe, jan 2012, University of Malaga, Spain

9. Dissemination

9.1. Scientific Animation

9.1.1. Organizations of sessions, workshops and conferences

- Conference chair and organization of META'2012 Int. Conf. on Metaheuristics, Sousse, Tunisia, Oct 2012.
- Program chair of NIDISC'2012 workshop on Nature Inspired Distributed Computing in cunjunction with IEEE/ACM IPDPS'2012, Shanghai, China, May 2012.
- Organization of the Theory of Randomized Search Heuristics Workshop (ThRaSH'2012), Lille, France, May 2012
- Organization of the French summer school on evolutionary computation (EA'2012), Quiberon, France, June 2012
- Co-organization of the evolutionary multiobjective optimization session at EURO 2012 (Vilnius, Lithuania)
- Scientific commitee for conference CPAIOR 2012 (Nantes)
- Organization commitee for RIO conference 2012 (Valenciennes)
- Co-guest-editor for a special issue on Evolutionary Multiobjective Optimziation in the Journal of Multi-criteria Decision Analysis (Wiley)
- Co-organizer of the PPSN'2012 workshop on Theoretical Aspects of Evolutionary Multiobjective Optimization, Taormina, Italy, September 1, 2012, together with Gunter Rudolph (TU Dortmund University, Germany)
- Organization of the "Intelligent optimization in Bioinformatics" session at LION'2012 (LION-BIO), Paris, France, January 2012.

9.1.2. 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.
- Coordinator of the High Performance Computing research action at LIFL labs.
- co-leader of the group PM2O of the ROADEF
- secreatary of the association Evolution Artificielle
- Scientific co-leader of the EuroWorking Group on Pricing and Revenue Management.
- Board Member of the ROADEF society.

9.1.3. Reviewing

9.1.3.1. Research projects

- Reviewer of research projects, National Science Center, Poland.
- Expert reviewer for the ANR “Emergence” programme.
- Expert reviewer for the CNRS PEPS “Biologie-Mathématiques-Informatique” programme.
- Expert reviewer BQR university of Paris 13
- Expert reviewer for the ANR “Emergence” programme.

9.1.3.2. Journal papers

- IEEE Transactions on Computers (IEEE TC).
- Journal of Parallel and Distributed Computing (JPDC).
- Parallel Computing.
- Computational Optimization and Applications (COAP, Springer)
- Engineering Optimization (GENO, Taylor & Francis)
- European Journal of Operational Research (EJOR, Elsevier)
- Journal of Heuristics (HEUR, Springer)
- Knowledge-Based Systems (KNOSYS, Elsevier)
- Evolving Systems
- International Journal on Artificial Intelligence Tools (IJAIT)
- Knowledge and Information Systems (KAIS)
- Memetic Computing
- Soft Computing
- Supercomputing
- Artificial Intelligence Journal
- Evolutionary Computation
- IEEE Transactions on Evolutionary Computation
- Journal of Multicriteria Decision Analysis
- Systems, Man and Cybernetics - Part B
- Theoretical Computer Science
- Computers and operations Research
- Transportation Science
- Transportation Research
- Operation Research

9.1.4. Program committees

- IEEE CSE’2012, Track: Distributed and Parallel Computing.
- High Performance Computing & Simulation (HPCS’2012).
- IEEE IPDPS workshops: PCO’2012 and NIDISC’2012.
- Grid’5000 school 2012.
- 6th Learning and Intelligent OptimizatioN Conference, LION 2012 (Paris, France, 2012)
- 12th European Conference on Evolutionary Computation in Combinatorial Optimisation, EvoCOP 2012 (Malaga, Spain, 2012)
- Special Session on Evolutionary Multiobjective Optimization, IEEE Congress on Evolutionary Computation, CEC-EMO 2012 (Brisbane, Australia, 2012)

- Genetic and Evolutionary Computation Conference (Philadelphia, USA, 2012) (GECCO'2012)
- 2nd International Conference on Operations Research and Enterprise Systems, ICORES 2012 (Barcelona, Spain, 2012)
- 13e congrès de la Société francaise de Recherche Opérationnelle et d'Aide à la décision, ROADEF'2012 (angers, France, 2012)
- Genetic and Evolutionary Computation Conference (GECCO'2012)
- Learning and Intelligent OptimizatioN (LION'2012)
- Parallel Problem Solving from Nature (PPSN'2012)
- Simulated Evolution And Learning (SEAL'2012)
- BIOMA'2012 Fifth Int. Conf. on Bioinspired Optimization Methods and their Applications, Bohinj, Slovenia, May 2012.
- GSC'2012 Workshop (Green Supply Chain 2012, Arras, May 2012.
- EvoPar'2012, 1st EvoApplication track on Parallel Architectures and Distributed Infrastructures, Malaga, April 2012.
- VANETs - from Theory to Practice (VTP 2012) workshop held in conjunction with the WoWMoM conference, San Francisco, USA, June 2012.
- Advisory board of EVOLVE'2012, Mexico, Aug 2012.
- SEAL'12 Ninth Int. Conf. on Simulated Evolution and Learning, Hanoi, Vietnam, Dec 2012.
- GPC'2012 Int. Conf. On Grid and Pervasive Computing, Hong Kong, May 2012.
- IC3'2012 Int. Conf. On Contemporary Computing, New Delhi, India, Aug 2012.
- SCCG'2012 Int. Workshop on Soft Computing Techniques in Cluster and Grid Computing Systems in conjunction with Int. Conf. On P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC), Victoria, Canada, Nov 2012.
- TPNC'2012 Int. Conf. on the Theory and Practice of Natural Computing, Tarragona, Spain, Sept 2012.
- INNOV'2012 Int. Conf. on Communications, Computations, Networks and Technologies, Venice, Italy, Oct 2012.
- HPCS'2012 Int. Conf. on High Performance Computing and Simulation, Madrid, Spain, July 2012.
- GECCO'2012 (Genetic and Evolutionary Computation Conference),Philapdelphia, USA.
- PPSN XII (Parallel Problem Solving Conference), Taormina, Italy, Sept 2012.
- EvoCop'2012 (Int. Conf of Evolcutionary Computation for Combinatorial Optimization), Malaga, Spain, Apr 2012
- EvoBio'2012 (European Workshop on Evolutionary Computation and Bioinformatics), Malaga, Spain, Apr 2013.
- NPC'2012 (IFIP NPC International Conference on Network and Parallel Computing), Gwangju, Korea, Sept 2012
- BICCIB'2012 (International Conference on Biologically Inspired Computing and Computers in Biology), San Diego, USA, May 2012

9.1.5. Phd committees

L. Brotcorne was a jury member of the following PhD thesis:

- Pierre Lebodic, " Variantes non standards de Problèmes d'optimisation combinatoires", Université de Paris Sud, Sept 2012, Jury member (referee): L. Brotcorne.

C. Dhaenens was a jury member of the following PhD thesis:

- Ahmed Atahran, “Etude et résolution d’un problème de Transport à la demande”, Université de Tours, Dec 2012. Jury: C. Dhaenens (referee), C. Lenté, O. Péton, F. Semet, V. T’kindt, R. Wolfer Cavalo.
- Nadarajen Veerapen, “controle autonome d’opérateurs pour la recherche locale”, Université d’Angers, Nov 2012. Jury: L. Bordeaux, C. Dhaenens(referee), Y. Hamadi, B. Mazure, F. Saubion.

L. Jourdan was a jury member of the following PhD thesis:

- Daniel de Angelis Cordeiro, “The impact of cooperation on new high performance computing platforms”, Université de Grenoble, encadrant : Denis Trystam - Feb 2012 Jury member (referee): L. Jourdan
- Rong-Qiang Zeng *Métaheuristiques Multi-objectif basées sur des voisinages pour l’approximation d’ensembles de Pareto* Université d’Angers, encadrants : Jin-Kao Hao, Matthieu Basseur - July 2012 - Jury member (referee): L. Jourdan
- Cecile Vila, “Optimisation multicritère prenant en compte les préférences de panels d’usagers: Application à l’éclairage de bureaux”, ENTPE Lyon, Dec 2012, L. Jourdan (referee).
- Fréderic Lardeux, “Algorithmes autonomes et modélisations de problèmes”, Université d’Angers, encadrant : Frederic Saubion - Nov 2012- Jury member (referee): L. Jourdan

N. Melab participate to the following Phd/HDR juries:

- Mohamed Esseghir Lalami, “Contribution à la résolution de problèmes d’optimisation combinatoire: méthodes heuristiques et parallèles”, Université de Toulouse, Oct 2012, Jury: N. Melab (referee)
- Mouad Yagoubi, “Optimisation évolutionnaire multi-objectif parallèle : application à la combustion Diesel”, Université de Paris Sud XI, July 2012, Jury member: N.Melab.
- Imen Ketata, “Méthode de découverte de sources de données en environnement de grille de données tenant compte de la sémantique”, Université Paul Sabatier, Jan 2012, Jury member: N.Melab.

E-G. Talbi participate to the following Phd/HDR juries:

- C. Rego (HDR), “Heuristic search and learning for combinatorial optimization”, University of Versailles Saint-Quentin en Yvelines, Jan 2012, Jury : A. Bui, F. Glover, A. Lokketangen, C. Roucairol, E-G. Talbi (reviewer), M. Widmer.
- D. Delahaye (HDR), “Modélisation et optimisation du trafic aérien”, Ecole Nationale d’Aviation Civile de Toulouse, Mar 2012, Jury : J-K. Hao, M. Mongeau, M. Sevaux, M. Schoenauer, E-G. Talbi (reviewer).
- Jesica De Armas Adrian, “Cutting problems: Parallel exact and approximate approaches for mono-objective and multi-objecive formulation”, University of La Laguna, Tenerife, Spain, Apr 2012, Reviewer.
- I. Michael Scriven, “Derivation and application of approximate electromagnetic noise models using decentralized parallel particle swarm optimization”, Griffith University, Brisbane, Australia, July 2012, Jury : A. Lewis, E-G. Talbi, J-W. Lu.
- Tony Wauters, “Reinforcement learning enhanced heuristic search for combinatorial optimization”, University of Gant, Belgium, Nov 2012, Jury: D. Cattrysse, P. De Causmaecker, A. Nowé, E-G. Talbi, K. Tuyls, G. Vanden Berghe, K. Verbeeck
- Afetah Moghaddam, “Production scheduling - Unavailability of the resources”, Université Technologique de Troyes, Troyes, France, Nov 2012, Jury: R. Aggoune, H. E. Aguirre, L. Amodeo, N. Sauer, E-G. Talbi, J. Teghem, F. Yalaoui
- Yuhan Guo, “Metaheuristics for solving large size long-term car pooling problem and an extension”, Université d’Artois, Béthune, France, Nov 2012. Jury: V-D. Cung, G. Goncalves, J-K. Hao, T. Hsu, M-J. Huguet, E-G. Talbi. President.
- Carlos Segura Gonzalez, “Parallel optimization schemes: A hybrid scheme based on hyperheuristics and evolutionary computation”, Dec 2012, University of La Laguna, Tenerife, Spain. Reviewer.
- S. Puechmorel (HDR), “Modèles dynamiques en gestion du trafic aérien”, Dec 2012, Ecole Nationale d’Aviation Civile de Toulouse, Reviewer.

9.1.6. Commission

- President of the Technological Development Commission (CDT) of Inria Lille.
- Member of the admission committee of associate professors (COS- MCF) in computer science at Université du Littoral - Côte d'Opale.
- Expert member for the AEQES Belgium agency for the evaluation of teaching - evaluation of Bachelor and Master in computer science and engineering teaching at UMONS, UCL and ULB universities.
- Presidence of the CER commission of the Lille Inria center (Commission des Emplois de Recherche).
- Member of the admission committee of associate professors (COS- MCF) in operations research at Université de Tours.
- Member of the admission committee of associate professors (COS- MCF) in operations research at Université de Grenoble.
- Member of the admission committee of associate professors (COS- MCF) in Applied Mathematics at Université Lille 3.
- Invited Member on the Inria CR Evaluation Commission.
- Invited Member of the Inria COST GTRI.
- Président du jury du prix de la TSL (Transportation and Logistics Sections) Informs 2012.
- Membre de la commission de selection des Bourses Eole attribuées par le réseau Franco Néerlandais
- Déléguée Scientifique des Relations Internationale du Centre de Lille

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence : C. Dhaenens, Algorithmics, 30h, L3, Engineering school Polytech'Lille.

Licence : C. Dhaenens, Graphs and combinatorics, 90h, L3, Engineering school Polytech'Lille.

Licence : L. Jourdan, Data mining, 25h, L1, Université de Lille 1, France,

Licence: L. Jourdan, Initiation à la programmation, 54h, L1, Université de Lille 1, France

Licence : L. Jourdan, Programming, 54h, L1, Université de Lille 1, France

Licence : F. Clautiaux, Object oriented programming, 80h, DUT informatique, Université de Lille 1, France

Licence : F. Clautiaux, Mathematical tools for modelling, 64h, DUT informatique, Université de Lille 1, France

Licence : F. Clautiaux, Object oriented design, 48h, DUT informatique, Université de Lille 1, France

Licence : F. Clautiaux, Operating systems, 48h, DUT informatique, 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, Decision Support Systems mining, 24h, M1, 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: N. Melab, Co-head of the supercomputing (Calcul Scientifique) master 2 at Université Lille 1.

Master: N. Melab: Operations Research, 82h, M2, Université Lille 1

Master: N. Melab, Supercomputing, 55h, M1 et M2, Université Lille 1

Master: C. Dhaenens, Operations Research, 70h, M1, , Engineering school Polytech'Lille.

Master: E-G. Talbi, Operations research, 40h, M1, Polytech'Lille, France

Master: E-G. Talbi, Data mining, 35h, M2, Polytech'Lille, France

Master: E-G. Talbi, Advanced Optimization, M2, Polytech'Lille, France

Master: L. Jourdan, Informatique Décisionnelle, 70h, M1 et M1 FA , Université de Lille 1, France,

Master: L. Jourdan, Mise à niveau en informatique décisionnelle et en recherche opérationnelle 25h, M1, Université de Lille 1, France

Administration: head of apprenticeship in Computer Sciences at UFR IEEA

Master: B. Derbel, co-supervisor of the Master 2 MOCAD (Complex Models, Algorithms, Data)

Master: B. Derbel, Combinatorial Optimization, 35h, M2, Université de Lille 1, France

Master: B. Derbel, Grid Computing, 16h, M2, Université de Lille 1, France

Master: B. Derbel, Parallel and Distributed Programming, 12h, M1, Université de Lille 1, France

Master: B. Derbel, Advanced Object Programming, 52h, M1, Université de Lille 1, France

Master: B. Derbel, Design of Distributed Applications, 60h, M1, Université de Lille 1, France

9.2.2. Supervision

PhD soutenues :

PhD : Ahcène Bendjoudi, Hierarchical parallel branch and bound on large scale Grids, June 2012, E-G. Talbi and N. Melab.

PhD in progress :

- S. Afsar, Bilevel approaches for energy pricing problems, Oct 2011, L. Brotcorne
- O. Bahri, Multi-objective optimization and possibility theory, Dec 2012, E-G. Talbi, N. Ben Amor
- M. Bué, Défintion d'offres de services en tenant compte du comportement de réservation hôtelière des clients , Oct 2012, L. Brotcorne and F. Clautiaux
- I. Chakroun, Méthodes B&B parallèles sur GPU, N.Melab.
- N. Dahmani, Multi-objective packing problems, Sept 2013, F. Clautiaux and E-G. Talbi
- M. Diaby, Yield Management and Supply chain Management, Sept 2010, L. Brotcorne and E-G. Talbi
- M. Djamai, Méthodes exactes arborescentes pair-à-pair sur grilles de calcul, Sept 2009, B. Derbel et N.Melab.
- S. Dufourny, Optimization of economic decisions in a competitive business management simulator, Oct 2011, C. Dhaenens
- N. Dupin, Robust scheduling of nuclear outages, Apr 2011, M. Porcheron, E-G. Talbi, F. Vanderbeck
- J. Hamon, Analysis of data from high throughput genotyping: cooperation between statistics and combinatorial optimization, C. Dhaenens
- J. Jacques, Knowledge extraction by optimization methods for improving the process of inclusion in clinical trials, Oct 2010, C. Dhaenens and L. Jourdan
- S. Jacquin, Hybrid approaches for optimization problems under uncertainty, Oct 2012, E-G. Talbi, L. Jourdan
- Y. Kessaci, Métaheuristiques multiobjectifs pour l'ordonnancement d'applications sur Clouds, Oct 2009, N. Melab and E-G. Talbi.
- F. Legillon, Métaheuristiques pour l'arbitrage d'applications sur fédérations de Clouds, Oct 2011, N. Melab and E-G. Talbi.

- R. Leroy, Parallel Tree-based Exact Algorithms using Heterogeneous Many and Multi-core Computing for Solving Challenging Problems in Combinatorial Optimization, Oct 2012, N.Melab.
- K. Seridi, Métaheuristiques multiobjectives pour le biclustering, Oct 2009, L. Jourdan and E-G. Talbi
- A. Sthathakis, Satellite payload reconfiguration optimization, Oct 2011, P. Bouvry, G. Danoy, E-G. Talbi
- B. Tounsi, Bi-level modeling and solving of transportation problems, Oct 2012, L. Brotcorne
- T-D. Tran, Benchmarking Continuous Multiobjective Optimization Algorithms, Dec 2012, D. Brockhoff and E-G. Talbi.
- T-T. Vu, Méthodes exactes pair-à-pair en environnement virtualisé volatile et à large échelle, Oct 2011, B. Derbel et N.Melab.

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, p. 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, p. 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, p. 390 - 400, http://hal.inria.fr/hal-00522619.

[4] L. JOURDAN, C. DHAENENS, E.-G. TALBI. *Evolutionary Feature Selection for Bioinformatics*, in "Computational Intelligence in Bioinformatics", IEEE CS/Wiley, 2007, p. 117–139.

[5] 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, p. 455-469.

[6] 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.

[7] 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.

[8] M. MEZMAZ, N. MELAB, E.-G. TALBI. *An efficient load balancing strategy for grid-based branch and bound algorithm*, in "Parallel Computing", 2007, vol. 33, n° 4-5, p. 302–313.

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

[10] A.-A. TANTAR, N. MELAB, E.-G. TALBI, B. PARENT, D. HORVATH. *A parallel hybrid genetic algorithm for protein structure prediction on the computational grid*, in "Future Gener. Comput. Syst.", 2007, vol. 23, n° 3, p. 398–409.

Publications of the year

Articles in International Peer-Reviewed Journals

[11] A. ALLANI, E.-G. TALBI, K. MELLOULI. *Hybridization of genetic and quantum algorithm for gene selection and classification of microarray data*, in "International. Journal of Foundation of Computer Science", 2012, vol. 23, n^o^ 2, p. 431-444, http://hal.inria.fr/hal-00750699.

[12] M. BASSEUR, A. LIEFOOGHE, L. KHOI, B. EDMUND. *The efficiency of indicator-based local search for multi-objective combinatorial optimisation problems*, in "Journal of Heuristics", 2012, vol. 18, n^o^ 2, p. 263-296, http://hal.inria.fr/hal-00609252.

[13] A. BENDJOUDI, N. MELAB, E.-G. TALBI. *Hierarchical branch and bound algorithm for computational Grids*, in "Future Generation Computer Journal", 2012, vol. 28, n^o^ 8, p. 1168-1176, http://hal.inria.fr/hal-00750691.

[14] I. CHAKROUN, M. MEZMAZ, N. MELAB, A. BENDJOUDI. *Reducing thread divergence in a GPU-accelerated branch-and-bound algorithm*, in "Concurrency and Computation: Practice and Experience", 2012, http://hal.inria.fr/hal-00731859.

[15] R. CHEVRIER, A. LIEFOOGHE, L. JOURDAN, C. DHAENENS. *Solving a Dial-a-Ride Problem with a Hybrid Multi-objective Evolutionary Approach: Application to Demand Responsive Transport*, in "Applied Soft Computing", April 2012, vol. 12, n^o^ 4, p. 1247-1258, http://hal.inria.fr/inria-00591138.

[16] 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", 2012, to appear, http://hal.inria.fr/hal-00689038.

[17] D. CORNE, C. DHAENENS, L. JOURDAN. *Synergies between operations research and data mining: The emerging use of multi-objective approaches*, in "European Journal of Operational Research", 2012, vol. 221, p. 469-479 [*DOI :* 10.1016/J.EJOR.2012.03.039], http://hal.inria.fr/hal-00731073.

[18] J. C. HERNANDEZ-CASTRO, J. M. E. TAPIADOR, P. PERIS-LOPEZ, J. CLARK, E.-G. TALBI. *Metaheuristic traceability attack against SLMAP, an RFID lightweight authentification protocol*, in "International. Journal of Foundation of Computer Science", 2012, vol. 23, n^o^ 2, p. 543-565, http://hal.inria.fr/hal-00750696.

[19] Y. KESSACI, M. NOUREDINE, E.-G. TALBI. *A Pareto-based Metaheuristic for Scheduling HPC Applications on a Geographically Distributed Cloud Federation*, in "Journal of Cluster Computing", May 2012, http://hal.inria.fr/hal-00749048.

[20] A. KHANAFER, F. CLAUTIAUX, S. HANAFI, E.-G. TALBI. *The min-conflict packing problem*, in "Computers and Operations Research", 2012, vol. 39, n^o^ 9, p. 2122-2132, http://hal.inria.fr/hal-00750711.

[21] A. KHANAFER, F. CLAUTIAUX, E.-G. TALBI. *Tree decomposition based heuristics for the two-dimensional bin packing problem with conflicts*, in "Computers and Operations Research", 2012, vol. 39, n^o^ 1, p. 54-63, http://hal.inria.fr/hal-00750717.

[22] M. R. KHOUADJIA, B. SARASOLA, E. ALBA, L. JOURDAN, E.-G. TALBI. *A comparative study between dynamic adapted PSO and VNS for the vehicle routing problem with dynamic requests*, in "Applied Soft Computing", 2012, vol. 12, n° 4, p. 1426-1439, http://hal.inria.fr/hal-00750715.

[23] A. LIEFOOGHE, M. BASSEUR, J. HUMEAU, L. JOURDAN, E.-G. TALBI. *On Optimizing a Bi-objective Flowshop Scheduling Problem in Uncertain Environment*, in "Computers and Mathematics with Applications", 2012, vol. 64, n° 2, p. 3747-3762 [*DOI :* 10.1016/J.CAMWA.2012.02.051], http://hal.inria.fr/hal-00676627.

[24] A. LIEFOOGHE, J. HUMEAU, S. MASMOUDI, L. JOURDAN, E.-G. TALBI. *On dominance-based multi-objective local search: design, implementation and experimental analysis on scheduling and traveling salesman problems*, in "Journal of Heuristics", 2012, vol. 18, n° 2, p. 317-352, http://hal.inria.fr/hal-00750688.

[25] A. LIEFOOGHE, J. HUMEAU, S. MESMOUDI, L. JOURDAN, E.-G. TALBI. *On dominance-based multiobjective local search: design, implementation and experimental analysis on scheduling and traveling salesman problems*, in "Journal of Heuristics", 2012, vol. 18, n° 2, p. 317-352 [*DOI :* 10.1007/S10732-011-9181-3], http://hal.inria.fr/hal-00628215.

[26] A. LIEFOOGHE, L. PAQUETE, J. FIGUEIRA. *On Local Search for Bi-objective Knapsack Problems*, in "Evolutionary Computation", 2012, to appear [*DOI :* 10.1162/EVCO_A_00074], http://hal.inria.fr/hal-00676625.

[27] L. LOUKIL, M. MEHDI, N. MELAB, E.-G. TALBI, P. BOUVRY. *Parallel hybrid genetic algorithms for solving Q3AP on computational Grids*, in "International. Journal of Foundation of Computer Science", 2012, vol. 23, n° 2, p. 483-500, http://hal.inria.fr/hal-00750703.

[28] T. V. LUONG, N. MELAB, E.-G. TALBI. *GPU Computing for Parallel Local Search Metaheuristics*, in "IEEE Transactions on Computers", 2012, http://hal.inria.fr/inria-00638805.

[29] M. REDOUANE, B. SARASOLA, E. ALBA, L. JOURDAN, E.-G. TALBI. *A comparative study between dynamic adapted PSO and VNS for the vehicle routing problem with dynamic requests*, in "Appl. Soft Comput.", 2012, vol. 12, n° 4, p. 1426-1439 [*DOI :* 10.1016/J.ASOC.2011.10.023], http://hal.inria.fr/hal-00729043.

[30] E.-G. TALBI, M. BASSEUR, A. J. NEBRO, E. ALBA. *Multi-objective optimization using metaheuristics: non-standard algorithms*, in "International Transactions in Operational Research", 2012, vol. 19, n° 1, p. 283-306, http://hal.inria.fr/hal-00750705.

[31] L. VANNESCHI, Y. PIROLA, G. MAURI, P. COLLARD, S. VEREL. *A Study of Neutrality of Boolean Function Landscapes in Genetic Programming*, in "Journal of Theoretical Computer Science (TCS)", March 2012, vol. 425, p. 34 – 57 [*DOI :* 10.1016/J.TCS.2011.03.011], http://hal.inria.fr/hal-00563462.

International Conferences with Proceedings

[32] D. BROCKHOFF, A. AUGER, N. HANSEN. *Comparing Mirrored Mutations and Active Covariance Matrix Adaptation in the IPOP-CMA-ES on the Noiseless BBOB Testbed*, in "GECCO Companion '12", Philadelphia, PA, États-Unis, July 2012, p. 297-303 [*DOI :* 10.1145/2330784.2330827], http://hal.inria.fr/hal-00746120.

[33] D. BROCKHOFF, A. AUGER, N. HANSEN. *On the Effect of Mirroring in the IPOP Active CMA-ES on the Noiseless BBOB Testbed*, in "GECCO Companion '12", Philadelphia, PA, États-Unis, July 2012, p. 277-284 [*DOI :* 10.1145/2330784.2330824], http://hal.inria.fr/hal-00746123.

[34] D. BROCKHOFF, A. AUGER, N. HANSEN. *On the Impact of a Small Initial Population Size in the IPOP Active CMA-ES with Mirrored Mutations on the Noiseless BBOB Testbed*, in "GECCO Companion '12", Philadelphia, PA, États-Unis, July 2012, p. 285-290 [*DOI :* 10.1145/2330784.2330825], http://hal.inria.fr/hal-00746122.

[35] D. BROCKHOFF, A. AUGER, N. HANSEN. *On the Impact of Active Covariance Matrix Adaptation in the CMA-ES With Mirrored Mutations and Small Initial Population Size on the Noiseless BBOB Testbed*, in "GECCO Companion '12", Philadelphia, PA, États-Unis, July 2012, p. 291-296 [*DOI :* 10.1145/2330784.2330826], http://hal.inria.fr/hal-00746121.

[36] D. BROCKHOFF, M. LÓPEZ-IBÁÑEZ, B. NAUJOKS, G. RUDOLPH. *Runtime Analysis of Simple Interactive Evolutionary Biobjective Optimization Algorithms*, in "Parallel Problem Solving from Nature (PPSN'2012)", Taormina, Italie, September 2012, p. 123-132 [*DOI :* 10.1007/978-3-642-32937-1_13], http://hal.inria.fr/hal-00746132.

[37] *Best Paper*
D. BROCKHOFF, T. WAGNER, H. TRAUTMANN. *On the Properties of the R2 Indicator*, in "GECCO'2012", Philadelphia, États-Unis, July 2012, p. 465-472 [*DOI :* 10.1145/2330163.2330230], http://hal.inria.fr/hal-00722060.

[38] I. CHAKROUN, N. MELAB. *An Adaptative Multi-GPU based Branch-and-Bound. A Case Study: the Flow-Shop Scheduling Problem.*, in "14th IEEE International Conference on High Performance Computing and Communications, HPCC 2012", Liverpool, Royaume-Uni, June 2012, http://hal.inria.fr/hal-00705868.

[39] F. CHICANO, F. DAOLIO, G. OCHOA, S. VEREL, M. TOMASSINI, E. ALBA. *Local Optima Networks, Landscape Autocorrelation and Heuristic Search Performance*, in "Parallel Problem Solving from Nature - PPSN XII", Taormina, Italie, C. A. COELLO COELLO, V. CUTELLO, K. DEB, S. FORREST, G. NICOSIA, M. PAVONE (editors), Lecture Notes in Computer Science, Springer Berlin Heidelberg, September 2012, vol. 7492, p. 337-347 [*DOI :* 10.1007/978-3-642-32964-7_34], http://hal.inria.fr/hal-00741842.

[40] F. DAOLIO, S. VEREL, G. OCHOA, M. TOMASSINI. *Local optima networks and the performance of iterated local search*, in "Proceedings of the fourteenth international conference on Genetic and evolutionary computation conference", Philadelphia, États-Unis, ACM, 2012, p. 369-376 [*DOI :* 10.1145/2330163.2330217], http://hal.inria.fr/hal-00741725.

[41] D. HOUDA, B. DERBEL. *On Neighborhood Tree Search*, in "Genetic and Evolutionary Computation Conference (GECCO'12)", Philadelphie, États-Unis, July 2012, http://hal.inria.fr/hal-00728531.

[42] Y. KESSACI, M. NOUREDINE, E.-G. TALBI. *An Energy-aware Multi-start Local Search Heuristic for Scheduling VMs on the OpenNebula Cloud Distribution*, in "HPCS 2012", Madrid, Espagne, July 2012, http://hal.inria.fr/hal-00749055.

[43] F. LEGILLON, A. LIEFOOGHE, E.-G. TALBI. *CoBRA: A cooperative coevolutionary algorithm for bi-level optimization*, in "IEEE Congress on Evolutionary Computation", Brisbane, Australie, 2012, p. 1–8 [*DOI :* 10.1109/CEC.2012.6256620], http://hal.inria.fr/hal-00732173.

[44] *Best Paper*
R. MACEDO, S. HANAFI, F. CLAUTIAUX, C. ALVES, J. M. VALÉRIO DE CARVALHO. *Generalized disaggregation algorithm for the vehicle routing problem with time windows and multiple routes*, in "ICORES 2012, 1st International Conference on Operations Research and Entreprise Systems, Vilamora, Portugal, 4-6 february, 2012", Portugal, 2012, p. 305-312, Best paper award, http://hal.inria.fr/hal-00751426.

[45] N. MELAB, I. CHAKROUN, M. MEZMAZ, D. TUYTTENS. *A GPU-accelerated Branch-and-Bound Algorithm for the Flow-Shop Scheduling Problem*, in "14th IEEE International Conference on Cluster Computing, Cluster'12", Beijin, Chine, September 2012, http://hal.inria.fr/hal-00723736.

[46] N. MITTON, D. SIMPLOT-RYL, M.-E. VOGE, L. ZHANG. *Energy efficient k-anycast routing in multi-sink wireless networks with guaranteed delivery*, in "11th International Conference on Ad-Hoc Networks and Wireless", Belgrade, Serbie, July 2012, http://hal.inria.fr/hal-00686691.

[47] K. SERIDI, L. JOURDAN, E.-G. TALBI. *Hybrid metaheuristic for multi-objective biclustering in microarray data*, in "2012 IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology, CIBCB 2012", San Diego, États-Unis, 2012, p. 222-228 [*DOI :* 10.1109/CIBCB.2012.6217234], http://hal.inria.fr/hal-00732459.

[48] K. SERIDI, L. JOURDAN, E.-G. TALBI. *Parallel Hybrid Metaheuristic for Multi-objective Biclustering in Microarray Data*, in "26th IEEE International Parallel and Distributed Processing Symposium Workshops", Shanghai, Chine, 2012, p. 625-633, http://hal.inria.fr/hal-00732450.

[49] S. VEREL. *Fitness landscapes and graphs: multimodularity, ruggedness and neutrality*, in "Proceedings of the fourteenth international conference on Genetic and evolutionary computation conference companion", Philadelphia, États-Unis, ACM, 2012, p. 1013–1034 [*DOI :* 10.1145/2330784.2330927], http://hal.inria.fr/hal-00744887.

[50] T.-T. VU, B. DERBEL, A. ASIM, A. BENDJOUDI, N. MELAB. *Overlay-Centric Load Balancing: Applications to UTS and B&B*, in "CLUSTER - 14th IEEE International Conference on Cluster Computing", Beijing, Chine, IEEE, September 2012, http://hal.inria.fr/hal-00728700.

Conferences without Proceedings

[51] J. HAMON, C. DHAENENS, G. EVEN, J. JACQUES. *Feature selection for high dimensional regression using local search and statistical criteria*, in "International Conference on Metaheuristics and Nature Inspired Computing", Port El-Kantaoui, Tunisie, July 2012, http://hal.inria.fr/hal-00749708.

[52] J. HAMON, C. DHAENENS, J. JACQUES, G. EVEN. *Coopération entre Optimisation Combinatoire et Statistiques pour la Sélection animale*, in "13e congrès annuel de la Société française de Recherche Opérationnelle et d'Aide à la Décision", Angers, France, February 2012, http://hal.inria.fr/hal-00749727.

[53] J. JACQUES, J. TAILLARD, D. DELERUE, L. JOURDAN, C. DHAENENS. *Multi-objective local search for mining Pittsburgh classification rules*, in "International Conference on Metaheuristics and Nature Inspired Computing", Port El-Kantaoui, Tunisie, October 2012, http://hal.inria.fr/hal-00749712.

[54] Y. KESSACI, M. NOUREDINE, E.-G. TALBI. *A Multi-start Local Search Scheduler for an Energy-aware Cloud Manager*, in "META 2012", Sousse, Tunisie, October 2012, http://hal.inria.fr/hal-00749063.

Books or Proceedings Editing

[55] E.-G. TALBI (editor). *Hybrid metaheuristics*, Springer, 2013, 433, http://hal.inria.fr/hal-00750682.

Research Reports

[56] D. BROCKHOFF, Y. HAMADI, S. KACI. *Interactive Optimization With Weighted Hypervolume Based EMO Algorithms: Preliminary Experiments*, Inria, October 2012, n° RR-8103, http://hal.inria.fr/hal-00741730.

[57] J. HUMEAU, A. LIEFOOGHE, E.-G. TALBI, S. VEREL. *ParadisEO-MO: From Fitness Landscape Analysis to Efficient Local Search Algorithms*, Inria, 2012, n° RR-7871, http://hal.inria.fr/hal-00665421.

Other Publications

[58] D. C. PORUMBEL, F. CLAUTIAUX. *Convergent lower bounds for packing problems via restricted dual polytopes*, 2012, Internal report, http://hal.inria.fr/hal-00747375.

References in notes

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

[60] D. ARNOLD, D. VAN WART. *Cumulative Step Length Adaptation for Evolution Strategies Using Negative Recombination Weights*, in "Applications of Evolutionary Computing", M. GIACOBINI (editor), Lecture Notes in Computer Science, Springer, 2008, p. 545–554.

[61] A. AUGER, J. BADER, D. BROCKHOFF. *Theoretically Investigating Optimal μ-Distributions for the Hypervolume Indicator: First Results For Three Objectives*, in "Conference on Parallel Problem Solving from Nature (PPSN XI)", R. SCHAEFER (editor), LNCS, Springer, 2010, vol. 6238, p. 586–596.

[62] A. AUGER, J. BADER, D. BROCKHOFF, E. ZITZLER. *Investigating and Exploiting the Bias of the Weighted Hypervolume to Articulate User Preferences*, in "Genetic and Evolutionary Computation Conference (GECCO 2009)", New York, NY, USA, G. RAIDL (editor), ACM, 2009, p. 563–570.

[63] A. AUGER, J. BADER, D. BROCKHOFF, E. ZITZLER. *Theory of the Hypervolume Indicator: Optimal μ-Distributions and the Choice of the Reference Point*, in "Foundations of Genetic Algorithms (FOGA 2009)", New York, NY, USA, ACM, 2009, p. 87–102.

[64] A. AUGER, J. BADER, D. BROCKHOFF, E. ZITZLER. *Hypervolume-based Multiobjective Optimization: Theoretical Foundations and Practical Implications*, in "Theoretical Computer Science", 2012, vol. 425, p. 75–103.

[65] A. AUGER, D. BROCKHOFF, N. HANSEN. *Analyzing the Impact of Mirrored Sampling and Sequential Selection in Elitist Evolution Strategies*, in "Foundations of Genetic Algorithms (FOGA 2011)", ACM, 2011, p. 127–138.

[66] A. AUGER, D. BROCKHOFF, N. HANSEN. *Mirrored Sampling in Evolution Strategies With Weighted Recombination*, in "Genetic and Evolutionary Computation Conference (GECCO 2011)", ACM, 2011, p. 861–868.

[67] A. AUGER, N. HANSEN. *A Restart CMA Evolution Strategy With Increasing Population Size*, in "Congress on Evolutionary Computation (CEC 2005)", Piscataway, NJ, USA, IEEE Press, 2005, vol. 2, p. 1769–1776.

[68] 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.

[69] K. BRINGMANN, T. FRIEDRICH. *The Maximum Hypervolume Set Yields Near-optimal Approximation*, in "Genetic and Evolutionary Computation Conference (GECCO 2010)", J. BRANKE (editor), ACM, 2010, p. 511–518.

[70] K. BRINGMANN, T. FRIEDRICH. *Tight Bounds for the Approximation Ratio of the Hypervolume Indicator*, in "Conference on Parallel Problem Solving from Nature (PPSN XI)", R. SCHAEFER (editor), LNCS, Springer, 2010, vol. 6238, p. 607–616.

[71] D. BROCKHOFF, A. AUGER, N. HANSEN, D. V. ARNOLD, T. HOHM. *Mirrored Sampling and Sequential Selection for Evolution Strategies*, in "Conference on Parallel Problem Solving from Nature (PPSN XI)", R. SCHAEFER (editor), LNCS, Springer, 2010, vol. 6238, p. 11–21.

[72] D. BROCKHOFF, T. WAGNER, H. TRAUTMANN. *R2 Indicator Based Multiobjective Search*, 2012, submitted to the Evolutionary Computation journal.

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

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

[75] T. FRIEDRICH, C. HOROBA, F. NEUMANN. *Multiplicative Approximations and the Hypervolume Indicator*, in "Genetic and Evolutionary Computation Conference (GECCO 2009)", G. RAIDL (editor), ACM, 2009, p. 571–578.

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

[77] N. HANSEN, A. AUGER, S. FINCK, R. ROS. *Real-Parameter Black-Box Optimization Benchmarking 2009: Experimental Setup*, Inria Saclay—Ile-de-France, May 2009, n^{o} RR-6828.

[78] N. HANSEN, A. AUGER, R. ROS, S. FINCK, P. POSÍK. *Comparing results of 31 algorithms from the black-box optimization benchmarking BBOB-2009*, in "GECCO workshop on Black-Box Optimization Benchmarking (BBOB'2010)", J. BRANKE (editor), ACM, July 2010, p. 1689–1696.

[79] M. P. HANSEN, A. JASZKIEWICZ. *Evaluating The Quality of Approximations of the Non-Dominated Set*, Institute of Mathematical Modeling, Technical University of Denmark, 1998, IMM Technical Report IMM-REP-1998-7.

[80] N. HANSEN, A. OSTERMEIER. *Completely Derandomized Self-Adaptation in Evolution Strategies*, in "Evolutionary Computation", 2001, vol. 9, n^{o} 2, p. 159–195.

[81] N. HANSEN, A. OSTERMEIER. *Adapting arbitrary normal mutation distributions in evolution strategies: the covariance matrix adaptation*, in "Congress on Evolutionary Computation (CEC 1996)", Piscataway, NJ, USA, IEEE, 1996, p. 312–317.

[82] H. MEUNIER. *Algorithmes évolutionnaires parallèles pour l'optimisation multi-objectif de réseaux de télécommunications mobiles*, Université des Sciences et Technologies de Lille, France, June 2002.

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

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

[85] H. TRAUTMANN, T. WAGNER, D. BROCKHOFF. *R2-EMOA: Focused Multiobjective Search Using R2-Indicator-Based Selection*, 2012, submitted as short paper to Learning and Intelligent Optimization Conference (LION 2013).

[86] T. WAGNER, H. TRAUTMANN, D. BROCKHOFF. *Preference Articulation by Means of the R2 Indicator*, in "Conference on Evolutionary Multi-Criterion Optimization (EMO 2013)", 2013, accepted for publication.

[87] B. WEINBERG, E.-G. TALBI. *A cooperative parallel metaheuristic applied to the graph coloring problem*, in "Handbook of Bioinspired Algorithms and Applications", USA, Editors: S. Olariu and A.Y. Zomaya, CRC Press, USA, 2005, p. 625–638, ISBN: 1584884754.

[88] B. WEINBERG. *Analyse et résolution approchées de problèmes d'optimisation combinatoire : application au problème de coloration de graphe*, Université des Sciences et Technologies de Lille, France, September 2004.

[89] S. WRIGHT. *The roles of mutation, imbreeding, crossbreeding and selection in evolution*, in "Proc. of the sixth Congress on Genetics", 1932, p. 356–366.

[90] E. ZITZLER, L. THIELE, M. LAUMANNS, C. M. FONSECA, V. G. FONSECA. *Performance Assessment of Multiobjective Optimizers: an Analysis and Review*, in "IEEE Transactions on Evolutionary Computation", April 2003, vol. 7, p. 117–132.