INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team DOLPHIN

Discrete multi-objective Optimization for Large scale Problems with Hybrid dIstributed techNiques

Lille - Nord Europe

Theme : Optimization, Learning and Statistical Methods

Activity Report

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2. Overall Objectives

2.1. Presentation

The goal of the DOLPHIN[1] project is the modelization 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 besummarized 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.

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

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 into account characteristics of the studied problem. While studying the problem in its multi-objective form, the analysis of the structure is another interesting way.

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 a given method is efficient? ii) why certain instances are 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, 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

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

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:
  - scheduling problems: Flow-shop scheduling problem;
  - routing problems: Vehicle routing problem (VRP), covering tour problem (CTP), etc;
  - mobile telecommunications: Design of mobile telecommunications networks (contract with France Telecom R&D) and design of access networks (contract with Mobinets);
  - genomics: Association rule discovery (data mining task) for mining genomic data, protein identification, docking and conformational sampling of molecules.
  - engineering design problems: Design of polymers.

  Some benchmarks and their associated optimal Pareto fronts or the 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

2nd of the ROADEF Challenge: François Clautiaux was a member of the team that was ranked 2nd among 29 teams for a challenge on disruption management in the airline industry (with S. Hanafi, C. Wilbaut and R. Mansi from Univ. Valenciennes). The problem was proposed by Amadeus society.

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

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 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 [62], [63], [61], [60].

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 cases: 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 [65]. The DOLPHIN research group has proposed two indicators: the *contribution* and the *entropy* [57]. 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.

These metrics and others (generational distance, spacing, etc) are integrated in the open software GUIMOO developed within the framework of the DOLPHIN project. This software is dedicated to the visualization of landscapes (2D and 3D) for multi-objective optimization and the performance analysis by the use of special metrics.

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 [56]. 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 to 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 [55], [52]. 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 almost 3 000 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, experiments are carried out 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://www.lifl.fr/OPAC at Benchmarks.

3.2.1. Cooperation of metaheuristics

In order to benifit 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 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

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

taxonomy of hybridization mechanisms may be found in [59]. It proposes to decompose these mechanisms into four classes:

- *LRH class - Low-level Relay Hybrid*: This class groups 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^* or on dynamic programming. However, those methods are limited to two objectives and are, most of the time, not able to be used on a complete large scale problem. Therefore, sub search spaces have to be defined in order to be able 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 [53].

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 those studies as follows:

- *Design of metaheuristics for the multi-objective optimization:* To improve metaheuristics, it becomes essential to integrate knowledge about the problem structure, that 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 evolve simultaneously cooperating methods 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 [54], [58].

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 such as 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 of 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 will allow 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.
>
> Recently, within a cooperation with SOGEP, the logistic and delivery subsidiary company of REDCATS (PINAULT PRINTEMPS REDOUTE), a new routing problem is under study. Indeed, the COLIVAD project consists in solving a logistic and transportation problem that has been reduced to a vehicle routing problem with additional constraints. First we are designing a method to solve exactly a bi-objective version of the problem in order to evaluate the interest of modifying the current process of delivery. We are also working on the resolution of a single-objective version of this problem to design an operational tool dedicated to the SOGEP problem.

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 infrastructures. Mobile network design appears of outmost importance and thus is a major issue in mobile telecommunication systems. The design of large cellular networks is a complex task with a great impact on the quality of service and the cost of the network. With the continuous and rapid growth of communication traffic, large scale planning becomes more and more difficult. Automatic or interactive optimization algorithms and tools would be very useful and helpful. Advances in this area will certainly lead to important improvements concerning the service quality and the deployment cost.

In this project, the solution of planification problems, in terms of modelization and resolution, are developed in a multi-criteria context associating financial criteria (cost of the network), technical criteria (coverage, availability), and marketing criteria (quality of service). Two complementary design problems are considered:

- Radio mobile network design: This work is realized in collaboration with France Telecom R&D. Engineering of radio mobile telecommunication networks involve two major problems: the design of the radio network and the frequency assignment. The design consists in positioning base stations (BS) on potential sites, in order to fulfill some objectives and constraints. The frequency planning sets up the frequencies used by BS with criteria of reusing. In this project, we address the first problem. Network design is a NP-hard combinatorial optimization problem. The BS problem deals with finding a set of sites for antennas from a set of pre-defined candidate sites, determining the type and the number of antennas, and setting up the configuration of different parameters of the antennas (tilt, azimuth, power, etc). A new formulation of the problem as a multi-objective constrained combinatorial optimization problem is considered. The model deals with specific objectives and constraints due to the engineering of cellular radio network. Reducing costs without sacrificing the quality of service are issues of concern. Most of the proposed models in the literature optimize a single objective (cover, cost, linear aggregation of objectives, etc.).
- Access network design: This work is realized in collaboration with Mobinets. The problem consists in minimizing the cost of the access network and maximizing its availability. Operators can only be competitive and economical if they have an optimized access network. Since the transmission costs are becoming high compared to the equipment costs, and the traffic demands are increasing with the introduction of new services, it is vital for operators to find cost-optimized transmission network

solutions at higher bit rates. Many constraints dealing with technologies and service providers have to be satisfied. All deployed important technologies (ex. GSM, UMTS) will be considered.

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 two problems have been modeled as classical datamining tasks. First it as been modeled as an association-rule mining problem. As the combinatoric of such problems is very high and the quality criteria not unique, we proposed to model the association-rule mining problem as a multi-objective combinatorial optimization problem. An evolutionary approach has been adopted in order to cope with large scale problems. Then, in order to make more efficient such approaches, a complementary datamining task has been studied: the feature selection problem. This problem is of multi-objective nature and a multi-objective approach has been proposed.

4.3.2. Protein identification

Another application deals with Proteomics. Proteomics consists of the global analysis of proteins. In fact, proteomics is very important to understand the biological mechanisms in the living cells, but also how different factors can influence them. The main goal of the proteomic is to identify experimental proteins. In this domain, we collaborate with the team of C. Rollando (research Director at CNRS) head director of the proteomic platform of the genopole of Lille.

Our objective is to automatically discover proteins and new protein variants from experimental spectrum. The protein variants and new protein identification is a complex problem. In fact, it cannot be summarized as a simple scoring of an experimental protein against protein databases, it needs additional processes to explore the huge space of potential solutions. For the protein variant, there are many modifications: insertion, deletion or substitution of an amino acid and also post-traductional modifications on it. So it is not practically feasible to generate all the possibilities of combination of modifications for a given size of protein (exponential complexity). The new protein identification problem is close because we cannot generate all possible proteins (with also modifications) in order to find the experimental one. For both a method of optimization is necessary.

4.3.3. Docking and conformational sampling

In molecular modelling, conformational sampling and docking procedures allow to 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 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) deploying those intrinsic distributed algorithms on computational Grids.

Within the framework of ANR DOCK and Decrypton projects, the focus is to propose with the collaboration of Institute of Biology at Lille (H. Dragos) multi-objective formulations of the conformational and docking problems. The goal is 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.

5. Software

5.1. ParadisEO

Participants: Jean-Charles Boisson, Jérémie Humeau, Laetitia Jourdan, Arnaud Liefooghe, Nouredine Melab, El-Ghazali Talbi [correspondent], Alexandru Tantar, Ali Khanafer, Mahmoud Fatene, Thé Van Luong, Mustepha Redouane Khouadija.

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

- Paradiseo-EO provides tools for the development of population-based metaheuristic (Genetic algorithm, Genetic programming, Particle Swarm Optimization (PSO), etc)
- Paradiseo-MO provides tools for the development of single solution-based metaheuristics (Hill-Climbing, Tabu Search, Simulated annealing, Iterative Local Search (ILS), Incremental evaluation, partial neighborhood, etc)
- Paradiseo-MOEO provides tools for the design of Multi-objective metaheuristics (MO fitness assignment shemes, MO diversity assignment shemes, Elitism, Performance metrics, Easy-to-use standard evolutionary algorithms, etc)
- Paradiseo-PEO provides tools for the design of parallel and distributed metaheuristics (Parallel evaluation, Parallel evaluation function, Island model)

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

- High level hybrid metaheuristics: coevolutionary and relay model
- Low level hybrid metaheuristics: coevolutionary and relay model

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 allow 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 PThreads.

This year, the goal was to renforce ParadisEO. Many works have been established:

- Add of several components in the different modules.
- Add of many tutorials to make easier utilisation of the framework.
- Improvement of the installation process on the different environments.

All the news are managed via the INRIA's Gforge project. A new version of ParadisEO is available since march 2009.

5.1.1. ParadisEO-EO and Particle Swarm Optimization integration

ParadisEO-EO is a template-based, ANSI-C++ compliant evolutionary computation library. It contains classes for almost any kind of evolutionary computation. EO was started by the Geneura Team at the University of Granada but the development team has been many times reinforced. Recently, we joined the developer staff to start a new contribution with ParadisEO. The goal was to create new classes and components increasing the compatibility between the framework (ParadisEO-EO) and its extensions (ParadisEO-MO, ParadisEO-MOEO and ParadisEO-PEO). Several technical features have also been improved from both sides. Furthermore, a set of classes allowing the implementation of any Particle Swarm Optimization (PSO) algorithm has been proposed to the EO community. It was successfully integrated and tested. ParadisEO proposes a full support for the PSO: sequential models (including many topologies, binary flight, etc), parallel and distributed models (evaluation function, island scheme, etc). A new implementation of PSO algorithm for dynamic routing problems (DTSP,DVRP, etc) is actually in progress and will be finalized before the end of the year. It covers both the sequential and parallel models.

5.1.2. Paradiseo-MOEO

Paradiseo-MOEO (Multi-Objective Evolving Objects) is the module dedicated to multi-objective optimization. It embeds some features and techniques for scalar, dominance- and indicator-based resolution. A genuine conceptual effort has been done to provide a set of classes allowing easing and speeding up the development of efficient programs in an incremental way while having a minimum programming effort. ParadisEO-MOEO provides a broad range of fine-grained components including fitness assignment strategies (the achievement functions, dominance rank, dominance count, dominance depth, indicator-based schemes and more), the most common diversity preservation mechanisms (sharing, nearest neighbour, crowding), some elitist-related features, as well as statistical tools and quality indicators (hypervolume, epsilon). Furthermore, some state-of-the-art evolutionary algorithms (such as NSGA-II, SPEA2 or IBEA) have been implemented into the library in a user-friendly way, only by using the fine-grained components of ParadisEO. This year, a new set of classes and templates have been integrated in a modular way into the framework in order to provide a wider range of features. For instance, we developed a new class of local search methods based on a population and on an arbitrary dominance relation (dominance-based multi-objective local search, DMLS). Furthermore, two new evolutionary algorithms have been integrated in a modular way onto the framework, namely MOGA and SEEA. At last, the UML design of archiving techniques has been entirely revised in order to confer a higher flexibility.

5.1.3. Paradiseo-MO

ParadisEO-MO (Moving Object) is the module dedicated to the design of popular solution-based metaheuristics such as hill climbing, simulated annealing, tabu search or iterated local search. This module is based on a clear separation of generic/dependent neighborhood concepts and thus can be seen as a white-box object-oriented with reusable components. During this year, a particular effort was made on the re-design and implementation of previous algorithms to enhance the performance in terms of effectiveness. In a similar manner, two new algorithms were also developed: threshold accepting and variable neighborhood search (VNS). In this latter, the other algorithms in ParadisEO-MO (including the mutation operators of ParadisEO-EO) can be used as different embedded neighborhoods. To validate this general approach, the current version of VNS has been already applied on the docking molecular problem and the obtained results are promising. Moreover, new tutorials are also provided including (1) a lesson to learn how to construct a local search from an existing application and (2) a lesson on the hybridization between ParadisEO-EO and ParadisEO-MO components in order to design hybrid metaheuristics.

5.1.4. Paradiseo-PEO and Paradiseo-G

The Parallel Evolving Objects (PEO) module of ParadisEO includes the well-known parallel and distributed models for metaheuristics. Due to the difficulty of running parallel applications, a particular focus was made on writing a complete set of documentation: source code documentation, a tutorial to configure the MPI/MPICH2 execution environment and new tutorials for exploiting existing parallel models. As an illustration, a technical introduction and 6 new lessons are provided to allow the design and the implementation of parallel metaheuristics for the quadratic assignment problem. Regarding the ParadisEO version on grids (ParadisEO-G), the adaptation and the deployment of the parallel models to the properties of grids (large scale, heterogeneous and dynamic nature of the resources and multi-administrative domain) must be handled efficiently. Therefore, a new system image based on the last version of Globus 4.2.1 (including GCC 4.3 and MPICH-G2) has been built allowing the deployment and the execution of parallel hybrid metaheuristics on grid. Experiments for the quadratic assignment problem have been performed on the computational Grid'5000 and the obtained results are promising in terms of scalability: the environment were successfully deployed and executed on 643 processors.

5.1.5. New technical features

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

- Compatibility with the new gcc version (4.3).
- Use of the new reporting server CDash.
- Switch-over to CMake 2.6 (compatibility with CMake 2.4 is maintained).
- Debug and improvement of the installation process.

5.1.6. Contributions and Documentations

Many investigations were made in this context in order to help users to manipulate the framework. The main contributions are:

- Cryptography: Permuted perceptron problem.
- Bioinformatics: Association Rules and Feature Selection.
- Continuous problems : ZDT and DTLZ problems.

New tutorials:

- HowToDoContribution, pre-completed package to help a user to solve his/her own problem.
- Tutorials to explain new algorithms: VNS and Hybrid algorithm.
- The tutorials concerning PEO are improved.
- Quick Start Guide explains how to use ParadisEO with Visual Studio.
- An exercice and a tutorial are proposed to discover ParadisEO solving a simple problem.

5.2. Docking@Grid

Participants: Jean-Charles Boisson, Laetitia Jourdan, Arnaud Liefooghe, Nouredine Melab, El-Ghazali Talbi [correspondent], Alexandru Tantar.

Docking@GRID is a software dedicated to the flexible conformational sampling and docking on the computational grid. The goal of the software is to help users to perform such processes in a friendly way. In other words, the software provides a web portail for remote job submission, importation/preparation of proteins, access to protein data bank, visualization, efficient sampling and docking. The project could be later integrated into the larger platform of chemioinformatics tools under construction around the site of the "Chimiothèque Nationale"-project of the CNRS (Prof. Hibert, Strasbourg). This platform, designed as a portail for the display of the collections of molecules synthesized in French academic labs might offer predicted affinities of these compounds with respect to various biologically interesting targets, in order to facilitate compound selection.

The current version considers only sampling and visualization of conformations. A registration step requiring a reduced amount of information is demanded in order to access the provided resources. The software offers a hierarchical perspective, allowing us to group different tasks into projects. A new project can be created by accessing the Ligands/ActiveSite section - following this initial phase, the project is displayed in a hierarchical manner. After creating the project, the user has the possibility of creating a new molecule file by employing the Msketch application (Chemaxon), which is provided in the form of a Java applet. Following this process, a conformational sampling step can be applied on the specified file. The sampling process relies on a hybrid genetic hierarchical algorithm executed in a distributed environment and making use of different parallelization strategies. The underlying framework is ParadisEO-G which is a Globus based version of the ParadisEO framework. The parallelization of the algorithm is transparently achieved by making use of the ParadisEO models - asynchronous island model, parallel evaluation of the population and parallel synchronous multi-start model. As middle-ware an MPICH-based distribution of MPI is used, the execution being performed on a dedicated set of machines.The results are displayed at the end of the sampling process, a notification mail being sent in case the processing step takes longer than 5 seconds. The obtained conformations may be visualized using the MView tool (Chemaxon). Each conformation can be further subjected to rigid transformations (translations, rotations), animations can also be constructed, etc.

Eight models have been designed for the flexible docking problem. These models were validated on instances of the CCDC-Astex dataset thanks a multi-objective genetic algorithm (GA) based on IBEA (Indicator Based Evolutionnary Algorithm). The best results were obtained with configurations of the GA using local searches as mutation operator on models based our own new criteria (surface and robustness). Based on this work, a collaboration with biophysicians of the Interdisciplinary Research Institute of Lille (IRI) has permitted to propose a docking approach for quantifying the molecular recognition of lysine acetylation patterns by a bromodomain of a chromatin remodeler. We find that the different acetylation patterns are characterized by distinct binding energies which are not simply related to the number of acetyl groups present on the histone tail. The results support the view that the combinatorial positioning of enzymatic modifications may underlie a code which can play a role in the recruitment of remodeling molecules. Biophysical consequences of such a code on transcriptional initiation are highlighted in the context of a recently proposed kinetic proofreading scheme of chromatin remodeling. All this work have been detailed in a paper entitled “Reading the histone code: a protein-docking approach” and recently submitted in the HFSP journal (Human Frontier Science Program) which publishes high quality, innovative research at the frontier of biology with an emphasis on interdisciplinary research at the interface between the life sciences and the more quantitative sciences. This kind of approach opens the path to other docking approach guiding the understanding of biological systems without directly designing in vitro or vivo studies which are long and expensives and not always possible depending of the studied living organisms.

6. New Results

6.1. Parallel adaptive hybrid metaheuristics for molecular conformational sampling

Participants: Alexandru Adrian Tantar, Nouredine Melab, El-Ghazali Talbi.

Conformational sampling for protein structure prediction and molecular docking is a highly multi-modal and combinatorial problem in terms of landscape and search space size. Solving efficiently and effectively such problems requires the design of hybrid intensification-diversification metaheuristics together with the use of parallel large scale computing.

First, the problem has been formulated as an energy minimization combinatorial optimization problem. Then, a new approach has been proposed for dynamic and adaptive building of parallel grid-based hybrid metaheuristics. The selection of the combined variation and local search operators of the built metaheuritics is based on an adaptive probabilistic model. The probabilities of applying the different operators are dynamically updated according to their efficiency during the previous steps of the evolution process. To allow the deployment of such approach for building hybrid metaheuristics on computational grids, a strongly asynchronous design has been adopted and a checkpointing mechanism has been proposed. The whole approach has been implemented using ParadisEO-G, which is a coupling of ParadisEO and Globus developped by the team.

In order to validate the proposed energy-based modeling of the problem and the proposed approach, large experiments have been performed on the Grid5000 using 964 processing cores distributed over 6 clusters belonging to Sophia-Antiplois, Lyon and Orsay. The obtained results demonstrate the effectiveness and efficiency of the approach. Indeed, a significant improvement, in terms of energy minimization, is obtained on some benchmarks (proteins from Protein Data Bank) compared to the Autodock reference tool for molecular docking.

6.2. Parallel Hybrid Optimisation for permutation-based problems on computational grids

Participants: Malika Mehdi, Nouredine Melab, El-Ghazali Talbi.

In this work, we propose to re-use some concepts used in tree-based exact methods (e.g., branch and bound) in order to efficiently manage large spaces in metaheuristics. In fact, in tree-based exact methods an explicit handling of all the search space is possible thanks to the enumeration strategies in a tree representing the search space. In metaheuristics it is more and more difficult to diversify the search in large benchmarks due to the absence of a global guiding strategy. The major idea of this work is to use the tree structure in metaheuristics in order to : (1) generate diversified and well distributed initial populations for population-based metaheuristics and then (2) to define a conceptual and software framework for the cooperation of optimisation methods in a computational grid, be it heuristics or exact. For application we use the quadratic 3-dimensional assignment problem (Q3AP). This problem arises in an important wireless communication design problem whose solution can significantly increase throughput and reduce the cost for providing reliable digital transmission over noisy, fading or jammed communication channels.

6.3. Large scale Peer-to-Peer Branch and Bound for permutation-based optimization problems

Participants: Mathieru Djama, Bilel Derbel, Nouredine Melab.

Solving optimally very large problem instances requires a huge amount of computational resources. Parallel Branch-and-Bound (B&B) algorithm is among the most popular tree exploration-based methods for solving optimally combinatorial optimization problems. Recently, Mezmaz et al. have proposed a Farmer-Worker Grid-based parallel B&B approach. The approach makes use of an original coding of the tree nodes and sub-trees that allows us to optimize communication and storage costs induced by the work distribution and checkpointing operations. However, the approach is limited in terms of scalability.

In this work, we define a new Peer-to-Peer approach for parallel B&B harnessing a huge amount of computational resources for solving very large combinatorial problems. Our approach is based on a structured Pastry-like overlay network that allows us to improve the scalability of the previous approach while maintaing the communication costs low. The approach includes different mechanisms dealing with the following major issues: dynamic load distribution, global information sharing and automatic termination detection. The proposed approach has been applied for solving the Flow-Shop scheduling problem. The experimentation has been conducted on the Grid5000 nation-wide French experimental grid. First results, in a static context (with non-volatile resources), show a scalability up to 1300 cores dispatched on three different sites of the grid as well as a communication cost reduction (as communications are no longer centralized towards a single machine) and a greater number of nodes of the explored search tree.

6.4. Re-design of Parallel Local Search Models on GPU

Participants: Thé Van Luong, Nouredine Melab, El-Ghazali Talbi.

The use of GPU-based parallel computing for local search (LS) algorithms is not straighforward. Indeed, several scientific challenges mainly related to the hierarchical memory management have to be faced. The major issues are the efficient distribution of data processing between CPU and GPU, the thread synchronization, the optimization of data transfer between the different memories, the capacity constraints of these memories, etc. Our objective is to deal with such issues for the re-design of parallel LS models to allow solving of large scale optimization problems on GPU architectures. We propose a new general methodology for building efficient parallel LS methods on GPU. This methodology is based on a three-level decomposition of the GPU hierarchy allowing a clear separation between generic and problem-dependent LS features. Several challenges are deal with: (1) the distribution of the search process among the CPU and the GPU minimizing the data transfer between them ; (2) finding the efficient mapping of the hierarchical LS parallel models on the hierarchical GPU. The mapping of the neighborhood of the currently processed solution to GPU threads is particularly challenging. Three well-known problem solution encodings (thus three neighborhood structures quoted above) are considered ; (3) using efficiently the coalescing and texture memory in the context of LS algorithms.

6.5. A parallel version for PhyloMOEA using the ParadisEO framework

Participants: El-Ghazali Talbi, Laetitia Jourdan, Waldo Cancino.

PhyloMOEA proposes the multi-objective phylogenetic reconstruction using the maximum parsimony and maximum likelihood criteria. We adopt here two of the three levels of parallelism proposed for population-based metaheuristics: (1) Algorithmic-level, where independent or collaborative algorithms are running in parallel (2) Iteration-level, in this model, each iteration of metaheuristic is parallelized in order to speedup the algorithm and reduce the search time and (3) Solution-level, focused on the parallelization of a single solution.

The first step for parallelizing PhyloMOEA was carried out at iteration level using a master/slave scheme. The solution level parallelism implemented in PhyloMOEA distributes the ML site calculations across several threads. As OpenMP is well-suited for automatic loop parallelization, it was the natural choice to develop the multi-thread version of the likelihood function. Note that, solution and iteration levels can be hybridized to take advantage of multi-core node clusters.

Results from both parallel PhyloMOEA versions using several benchmark DNA datasets show sub-linear speedup in most of the cases. Nevertheless, the execution time reduction compared to the serial version was significant.

6.6. Using decomposition methods and hybrid methods for solving a bin-packing problem with conflicts

Participants: Ali Khanafer, François Clautiaux, El-Ghazali Talbi.

We have considered the two-dimensional bin packing problem with conflicts. Given a set of items, an unlimited number of bins and a conflict/compatibility graph, the goal is to find a conflict-free packing of the items minimizing the number of bins used. We have shown that the notion of tree-decomposition can be used to improve some heuristics of the literature in terms of computing time and results.

A method for using a tree-decomposition of the compatibility graph was proposed, and several issues were dealt with. The framework we proposed can be used to design an hybrid resolution method, using heuristics or exact methods. Computational experiments show that the proposed approach is competitive and lead to improved results for many instances of a benchmark derived from the literature.

6.7. A new distance measure based on the exchange operator for the ACVRP

Participants: Marie-Eléonore Marmion, Laetitia Jourdan, Clarisse Dhaenens.

We define a distance between ACVRP (Asymetric Capacitated Vehicle Routing Problem) solutions and propose an algorithm to compute it. This distance will be necessary to make landscape analysis.

A representation close to the permutation representation and the exchange operator were chosen. Then a distance, called the exchange-distance, was defined by the exchange operator as the minimal number of applications of the operator necessary to move from an ACVRP solution to another one. With this theoretical definition of the exchange-distance, a robust algorithm was searched to compute it. Four algorithms were suggested and tested. Experimentations showed that the *on-hold greedy* algorithm computes the exact distance, and so it could be used in order to work on distance between the ACVRP solutions.Since this study gives a reliable distance based on the exchange operator between feasible ACVRP solutions, the next step is to realize a landscape analysis using it.

6.8. Generic algorithms for constrained spanning trees optimization

Participants: Jérôme Brongniart, Clarisse Dhaenens, El-Ghazali Talbi.

Optimisation of constrained spanning tree problems often appear in real world problems such as networks design, biology or transportation. Even if efficient exact and heuristic methods exist for some classical constrained spanning tree problems, such as the diameter constrained or the capacitated minimum spanning tree problems, these dedicated methods can hardly take into account multiple and realistic constraints.
Generic methods for spanning tree based optimization problems, mainly based on edge swaps where an edge of the current solution is permuted with a non-tree edge, allow us to perform more complex constraints checking. But it appears that the computational cost of checking the validity of the edge swaps can be prohibitive, due to the non-local nature of the additional requirements tackled in these problems.
Hence, in order to reduce this computational time, we have developed a dynamic edge swap structure which permits the update of the tree information needed for checking the main constraints studied in the literature. This structure allows to design a set of generic methods (Branch and Bound, local searches and genetic algorithms) for a large set of requirement using a constraint programming paradigm.

6.9. Adaptive Metaheuristics for Dynamic Vehicle Routing Problem

Participants: Mostepha Redouane Khouadjia, Laetitia Jourdan, El-Ghazali Talbi.

Combinatorial optimization problems are usually modeled in a static fashion. In this kind of problems, all data are known in advance, i.e. before the optimization process has started. However, in practice, many problems are dynamic, and change while the optimization is in progress. For example, in the Dynamic Vehicle Routing Problem (DVRP), new orders arrive when the working day plan is in progress. In this case, routes must be reconfigured dynamically while executing the current simulation. The DVRP is an extension of a conventional routing problem, its main interest being its connection to many real word applications (repair services, courier mail services, dial-a-ride services, etc.). We proposed solving methods based on Particle Swarm Optimization (PSO) and Variable Neighborhood Search (VNS) paradigms. The performance of both approaches is evaluated using a new set of benchmarks. We measured the behavior of both methods in terms of dynamic adaptation indicators. Our Adaptive Particle Swarm Optimization (APSO) was compared with some other metaheuristics. The experimental results showed that the APSO approach was able to find high quality solutions when compared to other techniques, and to introduce new best solutions for well-known problem instances. The obtained results demonstrate the efficiency of our approach to solve the treated problem.

6.10. Dominance-based Local Search Approaches

Participants: Arnaud Liefooghe, Jérémy Humeau, Salma Mesmoudi, Laetitia Jourdan, El-Ghazali Talbi.

We investigated simple local search approaches for approximating the efficient set of multiobjective combinatorial optimization problems. We focused on algorithms that maintain an archive of non-dominated solutions and improve them all by means of a neighborhood structure and of an arbitrary dominance relation (e.g., Pareto-dominance). Such methods are referred to as dominance-based multiobjective local search (DMLS). We first provided a concise overview of existing algorithms, and we proposed a model trying to unify them through a fine-grained decomposition. The main problem-independent search components of dominance relation, solution selection, neighborhood exploration and archiving have been identified. We illustrated the ability of this unified model by investigating a number of dominance-based local search approaches as direct instantiations of it. This fine-grained decomposition has latter been used for the implementation of DMLS algorithms into the ParadisEO-MOEO framework. Then, a number of state-of-the-art and original strategies were experimented on solving a permutation flowshop scheduling problem and a traveling salesman problem, both on a two- and a three-objective formulation. The experiments conducted revealed that DMLS algorithms are easily scalable, and can successfully find a good approximation of the efficient set for different problem types and sizes. Moreover, some useful guidelines have been highlighted with respect to the choice of the main DMLS-related design issues.

6.11. Multi-objective optimization in uncertain environments

Participants: Arnaud Liefooghe, Laetitia Jourdan, Dalia Sulieman, El-Ghazali Talbi.

Nowadays, there is a growing demand for solving real-world optimization problems, which are frequently characterized by a host of uncertainties. This uncertainty may come from different sources, such as objective functions, decision variables or environmental parameters. Within a reasonable effort, metaheuristics can be effectively applied to solve stochastic and dynamic problems from different uncertain formulations.

In the project, we treat two aspects of multi-objective optimization in uncertain environments.
The first one is to modelize mono-objective stochastic optimization problem in a multiobjective manner by adding a robustness criterion. We have studied the vehicle routing problem with stochastic demands (VRPSD) and proposed two new models using a new robustness measure based on the entropy. The model was solved thanks to classical multi-objective metaheuristics and provided robust solutions.
The second aspect focuses on directly solving multiobjective stochastic problems. This area is relatively studied in the single-objective case, and very limited in a multi-objective context. Handling uncertainty in this case often results on a sampling approach, so that a pair-wise comparison of solutions results in a comparison of objective vector sets. Some new approaches have been proposed for solving stochastic multi-objective optimization problems, together with an application on a bi-objective flowshop scheduling problem with stochastic processing times. We have also pointed out that performance assessment is a fundamental issue that has not been correctly addressed until now. Indeed, performance assessment of multi-objective metaheuristics is already a hard task in the deterministic case, and even more once uncertainty is taken into account.

7. Contracts and Grants with Industry

7.1. Vekia

(2009-2010): Direct research contract with Vekia society. Scheduling and timetabling in the distribution of goods.

7.2. Intecum

(2009-2010): Direct technology transfer contract with Intecum society. Packing boxes into containers.

7.3. CEA

(2006-2009): The cooperation with the CEA intervenes in the ANR project ”DOCK” (Docking on Grids).

8. Other Grants and Activities

8.1. Regional Actions

- Members of the project GOLE (warehouse management)

8.2. National actions

- ANR DOCK (Docking on Grids) (2006-2009): collaboration with IBL (Institut de Biologie de Lille) and CEA (Grenoble). The challenge in this project is a new model and grid-enabled optimization algorithm for the structure prediction and docking of molecules.
- ANR CHOC (Challenges on Combinatorial Optimization on Grids) (2006-2009): collaboration with Prism (Univ. of Versailles), MOAIS (INRIA Rhones-Alpes), GILCO (Grenoble). he project deals with the design and implementation of grid-enable software frameworks for exact and metaheuristic optimization algorithms.
- PPF (Bioinformatics) (2006-2009): This national program within the university of Lille (USTL) deals with solving bioinformatics and computational biology problems using combinatorial optimization techniques.
- CONS-PACK project (study of constrained packing problems) 2007-2009: collaboration with Université de Technologie de Compiègne and Ecole des Mines de Nantes, supported by GDR RO (GDR on Operational Research). This project explores the multi-objective modeling of cutting and packing problems.
- CONS-PACK Project (GDR recherche opérationnelle): project on bin packing problems with École des Mines de Nantes and Université de Technologie de Compiègne.

8.3. International actions

- INRIA project 3+3 Méditerrannée PERFORM (2006-2009) involving the University of Malaga (Spain), University of Constantine (Algeria), and University of Tunis (Tunisia). This project deals with multi-objective optimization.
- NEGST (NExt Grid Systems and Techniques - 2006-2009): International Collaboration and Promotion on interoperability and advanced technologies of Grid. Program between CNRS (France) and Japan on optimization on Grids.
- Project CNRS/FCT with the university of Braga (Portugal) on packing problems.

8.4. Visits and researcher invitations

The project had visitors during the year 2009:

- David Quintana (Universidad Carlos III, Madrid), three months.
- Pedro Isasi (Universidad Carlos III, Madrid), one month.
- Claudio Alves (University of Braga), two weeks.

9. Dissemination

9.1. Services to the scientific community

9.1.1. Research Management

- Co-fondator and chair of the group META (Metaheuristics: Theory and Applications, http://www.lifl.fr/~talbi/META). This group is associated with the ROADEF (French Operations Research Society), and the CNRS research groups GDR ALP and MACS.
- Chair of the group PM2O (Multi-objective Mathematical Programming, http://www.lifl.fr/PM2O). This group is associated with the ROADEF (French Operations Research Society), and the CNRS research group GDR RO (Operations Research).
- Secretary of ROADEF (the French Operational Research Society - http://www.roadef.org).
- Direction of the CIB (Bioinformatics Center) of the Genopole of Lille.
- Scientific Committee of the Genopole of Lille.
- Steering Committee of the INRIA nation-wide ADT Aladdin-Grid5000.
- Co-leader of an ALADDIN working group on scalability of Grid-enabled algorithms and applications.
- Member of the Scientific Committee of High-Performance Computing of Université de Lille1.
- Coordinator of the High Performance Computing collaborative research action at LIFL.
- Leader of the PPF "High Performance Computing" at Université de lille1.

9.1.2. Participation to Working Groups

- EURO-PAREO (European working group on Parallel Processing in Operations Research).
- EURO-EU/ME (European working group on Metaheuristics).
- EURO-ESICUP (European Working Group on Cutting and Packing).
- ECCO (European Chapter on Combinatorial Optimization).
- ERCIM (European Research Consortium for Informatics and Mathematics) working group on Soft Computing.
- JET national group on evolutionary computation.
- PM2O national group on Multi-objective Mathematical Programming.
- META national group on Metaheuristics: Theory and Applications.
- KSO national group on cutting and packing.

9.1.3. Editions

- Special Issue (Cooperative Combinatorial Optimization) in the European Journal of Operational Research (Elsevier).
- Special Issue (Selection Articles of ROADEF 2006) in RAIRO Oper. Res. (EDP Sciences).

9.1.4. Organizations of sessions, workshops and conferences

- Organization of "3èmes Journées Aladdin-Grid5000" in Lille, Dec. 3-4-7 2009
- Organization of the Workshop on Parallel Optimization in Emerging Computing Environments (POECE'2010) in conjunction wirh AICCSA'2010.

9.1.5. Editorial boards

- Editorial board of the International Journal of Data Mining, Modelling and Management

9.1.6. Reviews

- Review of a research project:
  - Evaluation of a four year project for the ANR (Agence Nationale de la Recherche)
  - Evaluation of a four year project for the Israel Scientific Foundation
- Review of journal papers:
  - 4OR: A Quarterly Journal of Operations Research (Springer)
  - Expert Systems: The Journal of Knowledge Engineering (Wiley-Blackwell)
  - Distributed Computing Journal (Springer)
  - Networks (Wiley)
- Review of conference papers:
  - 27th International Symposium on Theoretical Aspects of Computer Science (STACS'09, LNCS, Springer)

9.1.7. Program Committees

- International Conferences on Evolutionary Computation:
  - The Genetic and Evolutionary Computation Conference (GECCO'09)
  - 5th International Conference on Evolutionary Multi-Criterion Optimization (EMO'09)
  - Doctoral Symposium on Engineering Stochastic Local Search Algorithms (SLS-DS'09).
- International conferences on Operations Research and Production Management
  - Workshop on Bin Packing and Placement Problems (CP'09).
- International conferences on distributed and parallel computing
  - International Symposium on Parallel and Distributed Computing (ISPDC'09) .
  - High Performance Computing and Simulation Conference (HPC&S'09).
  - International Symposium on Parallel and Distributed Computing (NIDISC'09, in conj. with IPDPS'09).

9.1.8. Phd and HdR committees

Nouredine Melab was jury member of the following PhD thesis:

- Jean-Claude Charr. "Calcul parallèle et distribué sur architectures pair à pair". PhD thesis from Université de Franche-Comté, defended on September 16th, 2009. Jury : N. Abdennadher, C. Perez , N. Melab (Examiner), L. Philippe, R. Couturier and D. Laiymani
- Arnaud Fontaine. "Classification d'ARN codants et non codants. PhD thesis from Université de Lille1, defended on March 30th, 2009. Jury : T. Schiex, C. Thermes, N. Melab (President) F. Leclerc, F. Tahi, H. Touzet
- Pascal Wehrle. "Modèle multidimensionnel et OLAP sur architecture de grille". PhD thesis from INSA de Lyon, defended on January 1st, 2009. Jury : H. Kosch, F. Ravat, J. Darmont, N. Melab (President), M. Miguel, A. Tchounikine.

Clarisse Dhaenens was jury member of the following PhD thesis:

- Frédéric Dugardin. "Ordonnancement multi-objectif des lignes rentrantes", PhD thesis from Université Technologique de Troyes, defended on december 8th, 2009. Jury : Lionel Amodeo, Abdelhakim Artiba, Stéphane Dauzère-Pérès, Bernard Descotes-Genon, Clarisse Dhaenens, Abdelaziz Hamzaoui, Farouk Yalaoui.
- Jean-Laurent Hippolyte. "Algorithme génétique décentralisé appliqué à la conception optimale de machines électriques", PhD thesis from Université de Franche-Comté defended on december 10th, 2009. Jury : C. Bloch, D. Chamagne, P. Chatonnay, C. Dhaenens (Examiner), C. Espanet, F. Guinard, M.C Portman, G. Wimmer.

François Clautiaux was jury member for the following thesis:

- Selma Khebbache. "Les Problèmes de découpe et de placement à deux dimensions et leurs applications", defended at Université de Technologie de Troyes. Jury: P. Lacomme, M. Sevaux, F. Clautiaux, A. Dolgui, C. Prins, A. Yalaloui.
- Raid Mansi. "Approches hybrides pour des variantes du sac dos et applications", defended at Université de Valenciennes et du Hainaut-Cambrésis. Jury: G. Plateau, G. Savard, P. Chrtienne, J. Teghem, M. Vasquez, F. Clautiaux, L. Brotcorne, C. Wilbaut, S. Hanafi.

François Clautiaux was also foreign referee for the european label of the PhD thesis of Antonio LaTorre de la Fuente: "A framework for hybrid dynamic evolutionary algorithms: multiple offspring sampling (MOS)".

9.2. Teaching

- Postgraduate (IEEA, Université Lille 1): “Optimization methods” (L. Jourdan).
- Postgraduate (IEEA, Université Lille 1): “GRID computing”, (N. Melab, B. Derbel).
- Undergraduate (IEEA, Université Lille 1): “Distributed Systems” (N. Melab, B. Derbel).
- Undergraduate (IEEA, Université Lille 1): “Operations Research” (N. Melab).
- Undergraduate (Polytech’Lille): “Operations Research” (C. Dhaenens).
- Undergraduate (Polytech’Lille): “Graphs and combinatorics” (C. Dhaenens).
- Undergraduate (Polytech’Lille): “Data mining” (E-G. Talbi).
- Undergraduate (Polytech’Lille): “Advanced Optimization” (L. Jourdan).
- Undergraduate (Polytech’Lille): “Production Management” (C. Dhaenens).
- Undergraduate (IUT, Université Lille 1): “Graphs and Modeling” (F. Clautiaux).

10. Bibliography

Major publications by the team in recent years

[1] F. CLAUTIAUX, A. JOUGLET, J. CARLIER, A. MOUKRIM. *A New Constraint Programming Approach for the Orthogonal Packing Problem*, in "Computers and Operations Reseach", vol. 35, n^{o} 3, 2008, p. 944-959.

[2] 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", vol. 13, 2007, p. 455-469.

[3] J. LEMESRE, C. DHAENENS, E.-G. TALBI. *An exact parallel method for a bi-objective permutation flowshop problem*, in "European Journal of Operational Research", vol. 177, n^{o} 3, 2007, p. 1641-1655.

[4] A. LIEFOOGHE, L. JOURDAN, E. G. TALBI. *Metaheuristics and cooperative approaches for the bi-objective ring star problem*, in "Computers and Operations Research", 2009, To appear.

[5] N. MELAB, S. CAHON, E.-G. TALBI. *Grid computing for parallel bioinspired algorithms*, in "Journal of Parallel and Distributed Computing (JPDC)", vol. 66, n^{o} 8, Aug. 2006, p. 1052–1061.

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

[7] J.-M. PIERSON, J. GOSSA, P. WEHRLE, Y. CARDENAS, S. CAHON, M. E. SAMAD, L. BRUNIE, C. DHAENENS, A. HAMEURLAIN, N. MELAB, M. MIQUEL, F. MORVAN, E.-G. TALBI, A. TCHOUNIKINE. *GGM: Efficient Navigation and Mining in Distributed Genomedical Data*, in "IEEE Transactions on Nanobioscience", vol. 6, n^{o} 2, 2007, p. 110-116.

[8] E.-G. TALBI. *Parallel Combinatorial Optimization*, Wiley, 2006.

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

[10] 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.", vol. 23, n^{o} 3, 2007, p. 398–409.

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

Year Publications

Doctoral Dissertations and Habilitation Theses

[12] A. LIEFOOGHE. *Métaheuristiques pour l'optimisation multiobjectif: Approches coopératives, prise en compte de l'incertitude et application en logistique*, Université Lille 1 – Sciences et Technologies, France, 2009, Ph. D. Thesis.

[13] A.-A. TANTAR. *Métaheuristiques parallèles coopératives pour le problème d'échantillonnage de protéines sur grilles de calcul*, Université des Sciences et Technologie de Lille, 2009, Ph. D. Thesis.

[14] E. TANTAR. *Landscape analysis in multi-objective combinatoriel optimization*, Université des Sciences et Technologie de Lille, 2009, Ph. D. Thesis.

Articles in International Peer-Reviewed Journal

[15] A. BENDJOUDI, N. MELAB, E.-G. TALBI. *Peer-to-peer design and implementation of a parallel branch and bound algorithm for grids*, in "International Journal of Grid and Utility Computing (IJGUC)", vol. 1, n^{o} 2, 2009, p. 159-168.

[16] F. CLAUTIAUX, C. ALVES, J. VALÉRIO DE CARVALHO. *A survey of dual-feasible functions and superadditive functions*, in "Annals of Operations Research", 2009, To appear.

[17] F. CLAUTIAUX, A. MOUKRIM, J. CARLIER. *Improving Lower Bounds for a Two-Dimensional Bin-Packing Problem by Generating New Data-Dependent Dual-Feasible Functions*, in "International Journal of Production Research", vol. 47, n^o 2, 2009, p. 537-560.

[18] B. DERBEL, M. MOSBAH, A. ZEMMARI. *Sublinear Fully Distributed Partition with Applications*, in "Theory of Computing Systems", 2009, To appear.

[19] J. GARCÍA-NIETO, E. ALBA, L. JOURDAN, E.-G. TALBI. *Sensitivity and specificity based multiobjective approach for feature selection: Application to cancer diagnosis*, in "Inf. Process. Lett.", vol. 109, n^o 16, 2009, p. 887-896 ES .

[20] L. JOURDAN, M. BASSEUR, E.-G. TALBI. *Hybridizing exact methods and metaheuristics: A taxonomy*, in "European Journal of Operational Research", vol. 199, n^o 3, 2009, p. 620-629.

[21] L. JOURDAN, O. SCHUTZE, T. LEGRAND, E.-G. TALBI, J.-L. WOJKIEWICZ. *An Analysis of the Effect of Multiple Layers in the Multi-Objective Design of Conducting Polymer Composites*, in "Journal Materials and Manufacturing Processes", vol. 24, n^o 3, March 2009, p. 350-357.

[22] N. JOZEFOWIEZ, F. SEMET, E.-G. TALBI. *An evolutionary algorithm for the vehicle routing problem with route balancing*, in "European Journal of Operational Research (EJOR)", vol. 195, n^o 3, 2009, p. 761-769.

[23] A. LIEFOOGHE, L. JOURDAN, E.-G. TALBI. *Metaheuristics and cooperative approaches for the bi-objective ring star problem*, in "Computers and Operations Research", 2009, To appear.

[24] L. LOUKIL, M. MEHDI, N. MELAB, E.-G. TALBI, P. BOUVRY. *Parallel Hybrid Genetic Algorithms for solving Q3AP on Computational Grid*, in "International Journal of Foundations of Computer Science", 2009, To appear.

[25] M. MEHDI, M. MEZMAZ, N. MELAB, E.-G. TALBI, P. BOUVRY. *Peer to peer computing for large tree exploration-based exact optimization*, in "International Journal on Grid and Utility Computing", vol. 1, n^o 3, 2009, p. 252-260.

International Peer-Reviewed Conference/Proceedings

[26] G. DE-ITA, C. GUILLÉN, A. KHANAFER. *Efficient Computation of the Degree of Belief for a Subclass of Two Conjuctive Forms*, in "Fifth Latin American Workshop on Non-Monotonic Reasoning (LANMR 2009)", 2009, To appear.

[27] B. DERBEL, C. GAVOILLE, D. PELEG, L. VIENNOT. *Local Computation of Nearlly Additive Spanners*, in "23th Symposium on Distributed Computing (DISC'09), LNCS", 2009, p. 176-190.

[28] J. C. HERNANDEZ, J. E. TAPIADOR, P. PERIS-LOPEZ, J. A. CLARK, E.-G. TALBI. *Metaheuristic traceability attack against SLMAP, an RFID lightweight authentification protocol*, in "Nature Inspired Distributed Computing Workshop in conjunction with IEEE Int. Symposium on Parallel and Distributed Processing", 2009.

[29] D. HORVATH, L. BRILLET, S. ROY, S. CONILLEAU, A.-A. TANTAR, J.-C. BOISSON, N. MELAB, E.-G. TALBI. *Local vs. global search strategies in evolutionary GRID-based conformational sampling & docking*,

in "IEEE Congress on Evolutionary Computation in Bioinformatics and Computational Biology (CEC'09)", May 2009, p. 247-254.

[30] A. LIEFOOGHE, L. JOURDAN, E.-G. TALBI. *A unified model for evolutionary multi-objective optimization and its implementation in a general purpose software framework*, in "IEEE Symposium on Computational Intelligence in Multi-Criteria Decision-Making (MCDM'09)", April 2009, p. 88-95.

[31] A. LIEFOOGHE, S. MESMOUDI, J. HUMEAU, L. JOURDAN, E.-G. TALBI. *A Study on Dominance-Based Local Search Approaches for Multiobjective Combinatorial Optimization, LNCS*, in "Second International Workshop on Engineering Stochastic Local Search Algorithms (SLS)", 2009, p. 120-124.

[32] L. LOUKIL, M. MEHDI, N. MELAB, E.-G. TALBI, P. BOUVRY. *A parallel hybrid genetic algorithm-simulated annealing for solving Q3AP on computational grid*, in "Proceedings of the IEEE International Symposium on Parallel&Distributed Processing (IPDPS'09)", 2009, p. 1-8.

[33] M. MEHDI, N. MELAB, E.-G. TALBI, P. BOUVRY. *Interval island model initialization for permutation-based problems*, in "IEEE Proc. of the Genetic and Evolutionary Computation Conference (GECCO'09)", ACM, 2009, p. 1919-1920.

[34] J. TAVARES, S. MESMOUDI, E.-G. TALBI. *On the efficiency of local search methods for the molecular docking problem*, in "7th European Conference on Evolutionary Computation, Machine Learning and Data Mining in Bioinformatics", 2009, p. 104-115.

Workshops without Proceedings

[35] J.-C. BOISSON, S. MESMOUDI, L. JOURDAN, T. EL-GHAZALI. *ParadisEO-MO : une plateforme pour le développement de métaheuristiques à base de solution unique*, in "Dixième congrès de la Société Française de Recherche Opérationnelle et d'Aide à la décision (ROADEF 2009)", 2009, p. 208-209.

[36] J. BRONGNIART, C. DHAENENS, E.-G. TALBI. *Un algorithme générique pour le calcul d'arbres couvrants sous contraintes*, in "10ème congrès de la Société Française de Recherche Opérationnelle et Aide à la Décision (ROADEF'09)", Nancy, 2009.

[37] A. KHANAFER, F. CLAUTIAUX, E.-G. TALBI. *A Tree-Decomposition Based Tabu Search for Bin Packing Problems with Conflicts*, in "Metaheuristics International Conference (MIC 2009), Hamburg, Germany", 2009.

[38] A. KHANAFER, F. CLAUTIAUX, E.-G. TALBI. *Le Problème de Bin Packing avec Conflits – Nouvelles Bornes Inférieures*, in "Recherche Opérationnelle et d'Aide à la Décision (ROADEF 2009), Nancy, France", 2009.

[39] A. KHANAFER, F. CLAUTIAUX, E.-G. TALBI. *New Lower Bounds for the Bin Packing Problem with Conflicts*, in "6th ESICUP Meeting, Valencia, Spain", 2009.

[40] T. V. LUONG, N. MELAB, E.-G. TALBI. *Algorithmes de recherche locale sur GPU*, in "NP-PAR'09 : 6ème Réunion du Groupe de Travail sur la Résolution Parallèle des Problèmes NP-Complets", 2009.

[41] T. V. LUONG, N. MELAB, E.-G. TALBI. *Local Search Algorithms on Graphics Processing Units*, in "Journée jeunes chercheurs sur les Multiprocesseurs et Multicoeurs", 2009.

[42] R. MANSI, S. HANAFI, C. WILBAUT, F. CLAUTIAUX. *Oscillation Strategy for Disruption Management in the Airline Industry*, in "8th Metaheuristic International Conference, (MIC'09)", 2009.

Scientific Books (or Scientific Book chapters)

[43] A. LIEFOOGHE, L. JOURDAN, T. LEGRAND, J. HUMEAU, E.-G. TALBI. *ParadisEO-MOEO: A software framework for evolutionary multi-objective optimizaiton*, in "Advances in Multi-objective Nature Inspired Computing", Springer, 2010, p. 87-117.

[44] F. PAMELARD, G. EVEN, C. APOSTOL, C. PREDA, C. DHAENENS, V. FAFEUR, R. DESMET, O. MELNYK. *PASE: a web-based platform for peptide / protein microarray experiments*, in "Peptide Microarrays", M. CRETICH (editor), Methods in Molecular Biology, vol. 570, Humana Press, 2009, p. 413-430.

[45] E.-G. TALBI. *Metaheuristics: from design to implementation*, Wiley, USA, 2009.

[46] A.-A. TANTAR, N. MELAB, E.-G. TALBI. *An Analysis of Dynamic Mutation Operators for Conformational Sampling*, in "Biologically-Inspired Optimisation Methods", Studies in computational intelligence, Vol 210, Springer, 2009, p. 291-323.

[47] E. TANTAR, A.-A. TANTAR, N. MELAB, E.-G. TALBI. *Landscape Analysis in Adaptive Metaheuristics for Grid Computing*, in "Parallel Programming, Models and Applications in Grid and P2P Systems", Advances in Parallel Computing, IOS Press, 2009, p. 313-344.

Research Reports

[48] B. DERBEL, E.-G. TALBI. *A Note on Distributed Coloring in the SINR Model*, n° RR-7058 (Hal Inria), INRIA - LIFL - USTL, 2009, http://hal.archives-ouvertes.fr/inria-00408670, Technical report.

[49] J. FIGUEIRA, A. LIEFOOGHE, E.-G. TALBI, A. WIERZBICKI. *A Parallel Multiple Reference Point Approach for Multi-objective Optimization*, n° RR-6938, INRIA, 2009, http://hal.inria.fr/inria-00385079/en/, Technical reportPTPL.

[50] A. LIEFOOGHE, L. JOURDAN, E.-G. TALBI. *A Unified Model for Evolutionary Multiobjective Optimization and its Implementation in a General Purpose Software Framework: ParadisEO-MOEO*, n° RR-6906, INRIA, 2009, http://hal.inria.fr/inria-00376770/en/, Technical report.

[51] T. V. LUONG, N. MELAB, E.-G. TALBI. *Parallel Local Search on GPU*, n° RR-6915, Institut National de Recherche en Informatique et Automatique (INRIA), 2009, http://hal.inria.fr/inria-00380624/en/, Technical report.

References in notes

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

[53] 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, Ph. D. Thesis.

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

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

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

[57] 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, Ph. D. Thesis.

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

[59] E.-G. TALBI. *A Taxonomy of Hybrid Metaheuristics*, in "Journal of Heuristics", vol. 8, n° 5, 2002, p. 541–564.

[60] B. WEINBERG, E.-G. TALBI. *NFL theorem is unusable on structured classes of problems*, in "Proceedings of the 2004 Congress on Evolutionary Computation (CEC), Portland, Oregon, USA", vol. 1, IEEE Service Center, June 2004, p. 220–226.

[61] B. WEINBERG, E.-G. TALBI. *On Search Space Symmetry in Partitionning Problems*, in "Proceedings of the Fourth European Conference on Evolutionary Computation in Combinatorial Optimization (EvoCop), Coimbra, Portugal", LNCS, vol. 3004, Springer Verlag, April 2004, p. 230–240.

[62] 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, 2005, p. 625–638, ISBN: 1584884754.

[63] 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, Ph. D. Thesis.

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

[65] 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", vol. 7, April 2003, p. 117–132.