



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

Activity Report 2016

**Project-Team DOLPHIN**

Parallel Cooperative Multi-criteria Optimization

IN COLLABORATION WITH: Centre de Recherche en Informatique, Signal et Automatique de Lille

RESEARCH CENTER  
**Lille - Nord Europe**

THEME  
**Optimization, machine learning and  
statistical methods**



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# Project-Team DOLPHIN

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## Keywords:

### Computer Science and Digital Science:

- 1.1.4. - High performance computing
- 1.1.5. - Exascale
- 3.1.4. - Uncertain data
- 6. - Modeling, simulation and control
- 7.1. - Parallel and distributed algorithms
- 7.3. - Optimization

### Other Research Topics and Application Domains:

- 1. - Life sciences
- 2.7. - Medical devices
- 4. - Energy
- 7. - Transport and logistics
- 8.1.1. - Energy for smart buildings

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## 2. Overall Objectives

### 2.1. Presentation

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

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

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

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

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

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

<sup>1</sup>Discrete multi-objective Optimization for Large scale Problems with Hybrid dIstributed techNiques.

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 <sup>2</sup>, which consists in: i) the generalization of the framework to single solution metaheuristics such as local search, tabu search and simulated annealing; ii) the design of metaheuristics for multi-objective optimization; iii) the design of hybrid methods; iv) the development of parallel and distributed models.

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

The experimentation of this framework by different users and applications outside the DOLPHIN project is considered. This is done in order to validate the design and the implementation issues of ParadisEO.

- **Validation:** the designed approaches are validated on generic and real-life MOPs, such as:
  1. Scheduling problems: Flow-shop scheduling problem.
  2. Routing problems: Vehicle routing problem (VRP), covering tour problem (CTP).
  3. mobile telecommunications: Design of mobile telecommunications networks (contract with France Telecom R&D) and design of access networks (contract with Mobinets).
  4. Genomics: Association rule discovery (data mining task) for mining genomic data, protein identification, docking and conformational sampling of molecules.
  5. Engineering design problems: Design of polymers.

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

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

## 3. Research Program

### 3.1. Hybrid multi-objective optimization methods

The success of metaheuristics is based on their ability to find efficient solutions in a reasonable time [54]. But with very large problems and/or multi-objective problems, efficiency of metaheuristics may be compromised. Hence, in this context it is necessary to integrate metaheuristics in more general schemes in order to develop even more efficient methods. For instance, this can be done by different strategies such as cooperation and parallelization.

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

Population-based methods, such as evolutionary algorithms, are well fitted for multi-objective problems, as they work with a set of solutions [50], [53]. To be convinced one may refer to the list of references on Evolutionary Multi-objective Optimization maintained by Carlos A. Coello <sup>4</sup>, which contains more than 5500 references. One of the objectives of the project is to propose advanced search mechanisms for intensification and diversification. These mechanisms have been designed in an adaptive manner, since their effectiveness is related to the landscape of the MOP and to the instance solved.

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

#### 3.1.1. Cooperation of metaheuristics

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

Hybrid metaheuristics have received considerable interest these last years in the field of combinatorial optimization. A wide variety of hybrid approaches have been proposed in the literature and give very good results on numerous single objective optimization problems, which are either academic (traveling salesman problem, quadratic assignment problem, scheduling problem, etc) or real-world problems. This efficiency is generally due to the combinations of single-solution based methods (iterative local search, simulated annealing, tabu search, etc) with population-based methods (genetic algorithms, ants search, scatter search, etc). A taxonomy of hybridization mechanisms may be found in [56]. It proposes to decompose these mechanisms into four classes:

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

<sup>3</sup>Graphical User Interface for Multi-Objective Optimization (<http://guimoo.gforge.inria.fr>).

<sup>4</sup><http://delta.cs.cinvestav.mx/~ccoello/EMOO/EMOObib.html>



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

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

### 3.1.2. Cooperation between metaheuristics and exact methods

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

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

Moreover, a part of the DOLPHIN project deals with studying exact methods in the multi-objective context in order: i) to be able to solve small size problems and to validate proposed heuristic approaches; ii) to have more efficient/dedicated exact methods that can be hybridized with metaheuristics. In this context, the use of parallelism will push back limits of exact methods, which will be able to explore larger size search spaces [51].

### 3.1.3. Goals

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

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

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

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

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

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

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

### 3.2.1. Parallel models

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

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

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

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

As these models have now been identified, our objective is to study them in the multi-objective context in order to use them advisedly. Moreover, these models may be merged to combine different levels of parallelism and to obtain more efficient methods [52], [55].

### 3.2.2. Goals

Our objectives focus on these issues are the following:

- *Design of parallel models for metaheuristics and exact methods for MOPs*: We will develop parallel cooperative metaheuristics (evolutionary algorithms and local search algorithms such as the Tabu search) for solving different large MOPs. Moreover, we are designing a new exact method, named PPM (Parallel Partition Method), based on branch and bound and branch and cut algorithms. Finally, some parallel cooperation schemes between metaheuristics and exact algorithms have to be used to solve MOPs in an efficient manner.
- *Integration of the parallel models into software frameworks*: The parallel models for metaheuristics will be integrated in the ParadisEO software framework. The proposed multi-objective exact methods must be first integrated into standard frameworks for exact methods such as COIN and BOB++. A *coupling* with ParadisEO is then needed to provide hybridization between metaheuristics and exact methods.
- *Efficient deployment of the parallel models on different parallel and distributed architectures 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. Smart grids

With the smart grid revolution, house energy consumption will play a significant role in the energy system. Home users are indeed responsible for a significant portion of the world's energy needs portion, but are totally

inelastic with respect to the market (i.e. the energy demand does not follow the price of the energy itself). Thus, the whole energy generation and distribution system performance can be improved by optimizing the house energy management. Those problems are concerned by multiple objectives such as cost and users' comfort, and multiple decision makers such as end-users and energy operators. We propose a home automation system that can monitor appliance scheduling in order to simultaneously optimize the total energy cost and the customer satisfaction.

The key challenge is to propose new optimization models and new hybrid optimization algorithms to the demand side management of smart grids in a context of uncertainty and in the presence of several conflicting objectives. Those complex optimization problems are also characterized by the presence of both continuous and discrete variables.

## 4.2. Transportation and logistics

- **Scheduling problems under uncertainty:** The flow-shop scheduling problem is one of the most well-known problems from scheduling. However, most of the works in the literature use a deterministic single-objective formulation. In general, the minimized objective is the total completion time (makespan). Many other criteria may be used to schedule tasks on different machines: maximum tardiness, total tardiness, mean job flowtime, number of delayed jobs, maximum job flowtime, etc. In the DOLPHIN project, a bi-criteria model, which consists in minimizing the makespan and the total tardiness, is studied. A bi-objective flow-shop problem with uncertainty on the duration, minimizing in addition the maximum tardiness, is also studied. It allows us to develop and test multi-objective (and not only bi-objective) optimization methods under uncertainty.
- **Routing problems under uncertainty:** The vehicle routing problem (VRP) is a well-known problem and it has been studied since the end of the fifties. It has a lot of practical applications in many industrial areas (ex. transportation, logistics, etc). Existing studies of the VRP are almost all concerned with the minimization of the total distance only. The model studied in the DOLPHIN project introduces a second objective, whose purpose is to balance the length of the tours. This new criterion is expressed as the minimization of the difference between the length of the longest tour and the length of the shortest tour. Uncertainty on the demands has also been introduced in the model.

## 4.3. Bioinformatics and Health care

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

### 4.3.1. Genomic and post-genomic studies

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

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

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

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

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

#### **4.3.2. Optimization for health care**

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

#### **4.3.3. Molecular sampling and docking on large hybrid clusters**

A Phd thesis is started in September 2015 in this context in collaboration with UMONS and University of Strasbourg. Flexible molecular docking is a very complex combinatorial optimization problem especially when two components (ligand and protein) involved in the mechanism are together flexible. To deal in a reasonable time with such highly combinatorial process approximate optimization methods and massively parallel computing are absolutely necessary. The focus of the Ph.D thesis is on the flexibility-aware modeling and the design and implementation of near-approached optimization methods for solving the docking problem on large hybrid clusters including GPU accelerators and MIC coprocessors.

## **5. Highlights of the Year**

### **5.1. Highlights of the Year**

- Patent with the company Beckman: the invention relates to the handling of samples of biological material. In one aspect, the invention relates to optimization techniques for aliquoting such biological samples in a manner which accounts for various conditions and requirements as they may exist when the samples are to be processed.

## **6. New Software and Platforms**

### **6.1. COCO**

COMparing Continuous Optimizers

KEYWORDS: Benchmarking - Numerical optimization - Black-box optimization - Stochastic optimization

SCIENTIFIC DESCRIPTION

COMparing Continuous Optimisers (COCO) is a tool for benchmarking algorithms for black-box optimisation. COCO facilitates systematic experimentation in the field of continuous optimization. COCO provides: (1) an experimental framework for testing the algorithms, (2) post-processing facilities for generating publication quality figures and tables, (3) LaTeX templates of articles which present the figures and tables in a single document.

The COCO software is composed of two parts: (i) an interface available in different programming languages (C/C++, Java, Matlab/Octave, R, Python) which allows to run and log experiments on multiple test functions testbeds of functions (noisy and noiseless) are provided (ii) a Python tool for generating figures and tables that can be used in the LaTeX templates.

## FUNCTIONAL DESCRIPTION

The Coco Platform provides the functionality to automatically benchmark optimization algorithms for unbounded, unconstrained optimization problems in continuous domains. Benchmarking is a vital part of algorithm engineering and a necessary path to recommend algorithms for practical applications. The Coco platform releases algorithm developers and practitioners alike from (re-)writing test functions, logging, and plotting facilities by providing an easy-to-handle interface in several programming languages. The Coco platform has been developed since 2007 and has been used extensively within the “Blackbox Optimization Benchmarking (BBOB)” workshop series since 2009. Overall, 140+ algorithms and algorithm variants by contributors from all over the world have been benchmarked with the platform so far and all data is publicly available for the research community). A new extension towards bi-objective problems will be used for the BBOB-2016 workshop at GECCO.

- Participants: Dimo Brockhoff, Arnaud Liefooghe, Thanh-Do Tran, Nikolaus Hansen, Anne Auger, Marc Schoenauer, Ouassim Ait Elhara, Asma Atamna, Tea Tusar and Dejan Tusar
- Partners: Université technique de Dortmund - Université technique de Prague
- Contact: Dimo Brockhoff
- URL: <https://github.com/numbbo/coco>

## 6.2. ParadisEO

KEYWORD: Metaheuristics, multi-objective optimization, Parallel metaheuristics

## SCIENTIFIC DESCRIPTION

ParadisEO (PARallel and DIStributed Evolving Objects) is a C++ white-box object-oriented framework dedicated to the flexible design of metaheuristics. 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)...) \* 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...) \* Paradiseo-MOEO provides tools for the design of Multi-objective metaheuristics (MO fitness assignment schemes, MO diversity assignment schemes, Elitism, Performance metrics, Easy-to-use standard evolutionary algorithms...) \* 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

## FUNCTIONAL DESCRIPTION

Paradiseo is a software framework for metaheuristics (optimisation algorithms aimed at solving difficult optimisation problems). It facilitates the use, development and comparison of classic, multi-objective, parallel or hybrid metaheuristics.

- Partners: Université Lille 1
- Contact: El-Ghazali Talbi
- URL: <http://paradiseo.gforge.inria.fr/>

## 6.3. VRPsolve

KEYWORDS: C++ - Mobile Computing, Transportation - Optimization

- Participants: Arnaud Liefooghe and Sebastien Verel
- URL: <http://gforge.inria.fr/projects/vrpsolve>

## 6.4. Platform Grid'5000

The Grid'5000 experimental platform is a scientific instrument to support computer science research related to distributed systems, including parallel processing, high performance computing, cloud computing, operating systems, peer-to-peer systems and networks. It is distributed on 10 sites in France and Luxembourg, including Lyon. Grid'5000 is a unique platform as it offers to researchers many and varied hardware resources and a complete software stack to conduct complex experiments, ensure reproducibility and ease understanding of results.

- Participants: F. Desprez, F. Huet, E. Jeannot, Y. Jegou, A. Lebre, L. Lefevre, F. Loui, D. Margery, N. Melab, J-M. Menaud, P. Neyron, L. Nussbaum, C. Perez, J-M. Pierson, O. Richard., S. Varette.
- Contact: Frédéric Desprez
- URL: <https://www.grid5000.fr/mediawiki/index.php/Grid5000:Home>

## 7. New Results

### 7.1. Optimization under uncertainty

Participants: El-Ghazali Talbi, Raca Todosijevic, Oumayma Bahri (external collaborators: Nahla BenAmor - Univ. Tunis, Tunisia, J. Puente, C. R. Vela, I. Gonzalez-Rodriguez - Univ. Oviedo Spain)

At the problem level, the sources of uncertainty are due to many factors such as the environment parameters of the model, the decision variables and the objective functions. Examples of such uncertainties can be the demand and travel times in vehicle routing problems, the execution time in scheduling problems, the wind or solar production in energy power systems, the price of resources in manufacturing, and the mechanical properties of a structure. Then, we need precise and efficient modeling and resolution approaches which are robust and non-sensitive to those uncertainties. The appeal of optimization under uncertainty is that its performance results remain relatively unchanged when exposed to uncertain data.

We have considered the fuzzy job shop, a job shop scheduling problem with uncertain processing times modelled as triangular fuzzy numbers. While the usual approaches to solving this problem involve adapting existing metaheuristics to the fuzzy setting, we have proposed instead to follow the framework of simheuristics from stochastic optimisation. More precisely, we integrate the simulation of possible realisations of the fuzzy problem with a genetic algorithm that solves the deterministic job shop. We test the resulting method, simGA, on a testbed of 23 benchmark instances and obtain results that suggest that this is a promising approach to solving problems with uncertainty by means of metaheuristics [38].

### 7.2. Indicator-based Multiobjective Optimization

Participants: Bilel Derbel, Arnaud Liefoghe (external collaborators: Matthieu Basseur, Adrien Goëffon, Univ. Angers, France)

A large spectrum of quality indicators has been proposed so far to assess the performance of discrete Pareto set approximations in multiobjective optimization. Such indicators assign, to any solution set, a real-value reflecting a given aspect of approximation quality. This is an important issue in multiobjective optimization, not only to compare the performance and assets of different approximate algorithms, but also to improve their internal selection mechanisms. In [37], we adopt a statistical analysis to experimentally investigate by how much a selection of state-of-the-art quality indicators agree with each other for a wide range of Pareto set approximations from well-known two- and three-objective continuous benchmark functions. More particularly, we measure the correlation between the ranking of low-, medium-, and high-quality limited-size approximation sets with respect to inverted generational distance, additive epsilon, multiplicative epsilon, R2, R3, as well as hypervolume indicator values. Since no pair of indicators obtains the same ranking of approximation sets, we confirm that they emphasize different facets of approximation quality. More importantly, our statistical analysis allows the degree of compliance between these indicators to be quantified.

Subset selection constitutes an important stage of any evolutionary multiobjective optimization algorithm when truncating the current approximation set for the next iteration. This appears to be particularly challenging when the number of solutions to be removed is large, and when the approximation set contains many mutually non-dominating solutions. In particular, indicator-based strategies have been intensively used in recent years for that purpose. However, most solutions for the indicator-based subset selection problem are based on a very simple greedy backward elimination strategy. We experiment additional heuristics that include a greedy forward selection and a greedy sequential insertion policies, a first-improvement hill-climbing local search, as well as combinations of those. We evaluate the effectiveness and the efficiency of such heuristics in order to maximize the enclosed hypervolume indicator of candidate subsets during a hypothetical evolutionary process, or as a post-processing phase. Our experimental analysis, conducted on randomly generated as well as structured two-, three- and four-objective mutually non-dominated sets, allows us to appreciate the benefit of these approaches in terms of quality, and to highlight some practical limitations and open challenges in terms of computational resources.

### 7.3. Decomposition-based Multiobjective Optimization

Participants: Bilel Derbel, Arnaud Liefooghe (external collaborators: Hernan Aguirre and Kiyoshi Tanaka, Shinshu Univ., Japan; Qingfu Zhang, City Univ., Hong Kong)

It is generally believed that local search (LS) should be used as a basic tool in multi-objective evolutionary computation for combinatorial optimization. However, not much effort has been made to investigate how to efficiently use LS in multi-objective evolutionary computation algorithms. In [28], we study some issues in the use of cooperative scalarizing local search approaches for decomposition-based multiobjective combinatorial optimization. We propose and study multiple move strategies in the MOEA/D framework. By extensive experiments on a new set of bi-objective traveling salesman problems with tunable correlated objectives, we analyze these policies with different MOEA/D parameters. Our empirical study has shed some insights about the impact of the Ls move strategy on the anytime performance of the algorithm.

### 7.4. Learning and Adaptation for Landscape-aware Algorithm Design

Participants: Bilel Derbel, Arnaud Liefooghe (external collaborators: Hernan Aguirre, Fabio Daolio, Miyako Sagawa and Kiyoshi Tanaka, Shinshu Univ., Japan; Cyril Fonlupt, Christopher Jankee and Sébastien Verel, Univ. Littoral, France)

In [13], we attempt to understand and to contrast the impact of problem features on the performance of randomized search heuristics for black-box multi-objective combinatorial optimization problems. At first, we measure the performance of two conventional dominance-based approaches with unbounded archive on a benchmark of enumerable binary optimization problems with tunable ruggedness, objective space dimension, and objective correlation ( $\rho$ MNK-landscapes). Precisely, we investigate the expected runtime required by a global evolutionary optimization algorithm with an ergodic variation operator (GSEMO) and by a neighborhood-based local search heuristic (PLS), to identify a  $(1 + \epsilon)$ -approximation of the Pareto set. Then, we define a number of problem features characterizing the fitness landscape, and we study their intercorrelation and their association with algorithm runtime on the benchmark instances. At last, with a mixed-effects multi-linear regression we assess the individual and joint effect of problem features on the performance of both algorithms, within and across the instance classes defined by benchmark parameters. Our analysis reveals further insights into the importance of ruggedness and multi-modality to characterize instance hardness for this family of multi-objective optimization problems and algorithms.

Designing portfolio adaptive selection strategies is a promising approach to gain in generality when tackling a given optimization problem. However, we still lack much understanding of what makes a strategy effective, even if different benchmarks have been already designed for these issues. In [35], we propose a new model based on fitness cloud allowing us to provide theoretical and empirical insights on when an on-line adaptive strategy can be beneficial to the search. In particular, we investigate the relative performance and behavior of two representative and commonly used selection strategies with respect to static (off-line) and purely random approaches, in a simple, yet sound realistic, setting of the proposed model.



In evolutionary multi-objective optimization, variation operators are crucially important to produce improving solutions, hence leading the search towards the most promising regions of the solution space. In [39], we propose to use a machine learning modeling technique, namely random forest, in order to estimate, at each iteration in the course of the search process, the importance of decision variables with respect to convergence to the Pareto front. Accordingly, we are able to propose an adaptive mechanism guiding the recombination step with the aim of stressing the convergence of the so-obtained offspring. By conducting an experimental analysis using some of the WFG and DTLZ benchmark test problems, we are able to elicit the behavior of the proposed approach, and to demonstrate the benefits of incorporating machine learning techniques in order to design new efficient adaptive variation mechanisms.

## **7.5. Feature Selection using Tabu Search with Learning Memory: Learning Tabu Search**

Participants: C. Dhaenens, L. Jourdan, M-E. Kessaci

Feature selection in classification can be modeled as a combinatorial optimization problem. One of the main particularities of this problem is the large amount of time that may be needed to evaluate the quality of a subset of features. We propose to solve this problem with a tabu search algorithm integrating a learning mechanism. To do so, we adapt to the feature selection problem, a learning tabu search algorithm originally designed for a railway network problem in which the evaluation of a solution is time-consuming. Experiments conducted show the benefit of using a learning mechanism to solve hard instances of the literature [hal-01370396v1].

## **7.6. MO-ParamILS: A Multi-objective Automatic Algorithm Configuration Framework**

Participants: C. Dhaenens, L. Jourdan, M-E. Kessaci

Automated algorithm configuration procedures play an increasingly important role in the development and application of algorithms for a wide range of computationally challenging problems. Until very recently, these configuration procedures were limited to optimising a single performance objective, such as the running time or solution quality achieved by the algorithm being configured. However, in many applications there is more than one performance objective of interest. This gives rise to the multi-objective automatic algorithm configuration problem, which involves finding a Pareto set of configurations of a given target algorithm that characterises trade-offs between multiple performance objectives. In this work, we introduced MO-ParamILS, a multiobjective extension of the state-of-the-art single-objective algorithm configuration framework ParamILS, and demonstrated that it produces good results on several challenging bi-objective algorithm configuration scenarios compared to a base-line obtained from using a state-of-the-art single-objective algorithm configurator. [hal-01370392].

## **7.7. Parallel optimization methods revisited for multi-core and many-core (co)processors**

Participants: J. Gmys and N. Melab

This contribution is a joint work with M. Mezmaç, E. Alekseeva and D. Tuytens from University of Mons (UMONS) and T. C. Pessoa and F. H. De Carvalho Junior from Universidade Federal Do Ceará (UFC), Brazil.

On the road to exascale, coprocessors are increasingly becoming key building blocks of High Performance Computing platforms. In addition to their energy efficiency, these many-core devices boost the performance of multi-core processors. During 2016, we first have revisited the design and implementation of parallel Branch-and-Bound (B&B) algorithms using the work stealing paradigm on GPU accelerators [16][40], multi-GPU systems [17], multi-core processors [15] and MIC (Xeon Phi) coprocessors [20]. The challenge is to take into account the high irregular nature of the B&B algorithm and the hardware characteristics of GPU, Xeon Phi and multi-core (co)processors. Several work stealing strategies have been investigated while addressing several issues: host-device data transfer, thread divergence and data placement on the hierarchy of memories of the GPU and vectorization on Xeon Phi. The proposed approaches have been extensively experimented considering permutation-based optimization problems (e.g. FSP). The results reported in the cited papers demonstrate the efficiency of the many-core approaches compared to their multi-core counterpart. An extension of the proposed approaches to large hybrid clusters, including multi-core and many-core (co)processors is already started in [27].

The second part of the contribution consists in proposing a new hyper-heuristic (generalized GRASP) together with its parallelization for multi-core processors [11]. A cost function based on a bounding operator (used in B&B) is integrated to GRASP for the first time. Multi-core computing is used to investigate 315 GRASP configurations. In order to improve the performance of the local search procedure used in GRASP, we have proposed in [33] an original vectorization of the cost function of the makespan of FSP on Xeon Phi coprocessors. The reported results show that speed-ups up to 4.5 can be achieved compared to a non-vectorized approach.

## 8. Bilateral Contracts and Grants with Industry

### 8.1. Bilateral Contracts with Industry

- Beckman (2015-2018): the goal of this contract concerns the strategic and operational planning for medical laboratories (Phd of Sohrab Faramarzi).
- Strat&Logic (2012-2016): the objective of this CIFRE contract is the optimization of economic decisions in a competitive business management simulator (Phd of S. Dufourny).
- PIXEO (2014-2018): the objective of this bilateral project is the predictive models and knowledge extraction for insurance web comparator (Phd of A-L. Bedenel).
- Alicante (2014-2017): the objective of this CIFRE contract is the design of new optimization methods to extract knowledge from hospital data (Phd of M. Vandromme)
- Intel (2015-2016) Bilateral academic and research partnership between Université Lille 1 and Intel. In this context, Intel provides Lille 1 with training and technical support for the dissemination of its activities related to High Performance Computing.
- Nvidia (2016) Nvidia GPU Research Center, (see: <https://developer.nvidia.com/academia/centers/universit%C3%A9-lille-1>).

### 8.2. Bilateral Grants with Industry

- Intel 2015-2016 Intel has supported with a budget equivalent to 22Keuros the acquisition of a cluster of 2 multi-core servers and 8 Intel Xeon Phi coprocessors. The objective is to develop research and teaching on multi and many-core computing on coprocessors. The hybrid cluster has been deployed in 2016.

## 9. Partnerships and Cooperations

### 9.1. Regional Initiatives

- CPER “data” (2015-2020): co-leader of a workpackage “Research infrastructures”. The objective is to support research related to data science including high performance computing for combinatorial optimization using the Grid’5000 grid infrastructure.
- ELSAT (2015-2019) of CPER (Contrat Plan Etat Région) : transversal research action “Planning and scheduling of maintenance logistics in transportation”.

## 9.2. National Initiatives

### 9.2.1. ANR

- ANR project Modèles Numériques “NumBBO - Analysis, Improvement and Evaluation of Numerical Blackbox Optimizers” (2012-2016) in collaboration with Inria Saclay, TAO team, Ecole des Mines de St. Etienne, CROCUS team, and TU Dortmund University, Germany (2012-2016).
- ANR project TECSAN (Technologies pour la Santé) “ClinMine - Optimisation de la prise en Charge des Patients à l’Hôpital”, in collaboration with University Lille 1, Université Lille 2, Inria, CHRU Lille, CHICL, Alicante (7 partners) (2014-2017) - Coordinator -
- Bilateral ANR/RGC France/Hong Kong PRCI “Big Multiobjective Optimization” (2016-2021) in collaboration with City University of Hong Kong.
- PGM0 project “Towards a Complexity Theory for Black-Box Optimization”, together with Carola Doerr (CNRS, LIP6), Benjamin Doerr (Ecole Polytechnique), Anne Auger, Nikolaus Hansen (both Inria Saclay), Timo Koetzing (University of Jena, Germany), Johannes Lengler (ETH Zurich, Switzerland), and Jonathan Rowe (The University of Birmingham, UK), (2014-2016)
- PGM0 project “Demand side management in smart grids”, together with EDF, (2015-2017).

## 9.3. European Initiatives

### 9.3.1. FP7 & H2020 Projects

Program: H2020

Project acronym: SYNERGY

Project title: Synergy for Smart Multi-Objective Optimisation

Duration: 02 2016 - 01 2019

Coordinator: Jožef Stefan Institute (JSI), Ljubljana, Slovenia

Other partners: University of Lille (France), Cologne University of Applied Sciences (Germany)

Abstract: Many real-world application areas, such as advanced manufacturing, involve optimisation of several, often time-consuming and conflicting objectives. For example, they require the maximisation of the product quality while minimising the production cost, and rely on demanding numerical simulations in order to assess the objectives. These, so-called multi-objective optimisation problems can be solved more efficiently if parallelisation is used to execute the simulations simultaneously and if the simulations are partly replaced by accurate surrogate models.

### 9.3.2. Collaborations with Major European Organizations

University of Luxembourg: (Luxembourg)

Energy aware scheduling in Cloud computing systems

University of Oviedo: (Spain)

Optimization under uncertainty for fuzzy flow shop scheduling

University of Elche and University of Murcia: (Spain)

Matheuristics for DEA

## 9.4. International Initiatives

### 9.4.1. Inria International Labs

- LIRIMA Afrique: Equipe associée avec l'EMI (Ecole Mohammadia d'Ingénieurs), Morocco

### 9.4.2. Inria Associate Teams Not Involved in an Inria International Labs

#### 9.4.2.1. MOHA

Title: Mixed Multi-objective Optimization using Hybrid Algorithms: Application to smart grids

International Partner (Institution - Laboratory - Researcher):

Ecole Mohammadia d'Ingénieurs (Morocco) - LERMA (Laboratoire d'Etudes et de Recherches en Mathématiques Appliquées) - Rachid Ellaia

Start year: 2016

See also: <https://ocm.univ-lille1.fr/talbi/momh>

The key challenge of this project is to propose new optimization models and new hybrid algorithms to the demand side management of smart grids in a context of uncertainty and in the presence of several conflicting objectives.

Those complex optimization problems are also characterized by the presence of both continuous and discrete variables. We need to design new efficient optimization algorithms combining state of the art exact and metaheuristic algorithms from the global optimization and combinatorial optimization communities

#### 9.4.2.2. s3-bbo

Title: Threefold Scalability in Any-objective Black-Box Optimization (s3-bbo)

International Partner (Institution - Laboratory - Researcher):

Shinshu University, Japan

Duration: 2015-2017

See also: <http://francejapan.gforge.inria.fr/doku.php?id=associateteam>

The main scientific goals of this collaboration is to theoretically derive, analyze, design, and develop scalable evolutionary and other stochastic local search algorithms for large-scale optimization considering three different axes of scalability: (i) decision space, (ii) objective space, and (iii) availability of distributed and parallel computing resources. This research will allow us to design, control, predict, analyze and optimize parameters of recent complex, large-scale, and computationally expensive systems, providing the basic support for problem solution and decision-making in a variety of real world applications. For single-objective continuous optimization, we want to theoretically derive variants of the state-of-the-art CMA-ES with linear time and space complexity scalings with respect to the number of variables. We will exploit the information geometry framework to derive updates using parametrization of the underlying family of probability distribution involving a linear number of components. The challenges are related to finding good representations that are theoretically tractable and meaningful. For the design of robust algorithms, implementing the derived updates, we plan to follow the same approach as for the design of CMA-ES. For multi- and many-objective optimization, we will start by characterizing and defining new metrics and methodologies to analyze scalability in the objective space and in terms of computational resources. The first challenge is to accurately measure the impact of adding objectives on the search behavior and on the performance of evolutionary multi- and many- objective optimization (EMyO) algorithms. The second challenge is to investigate the new opportunities offered by large-scale computing platforms to design new effective algorithms for EMyO optimization. To this end, we plan to follow a feature-based performance analysis of EMyO algorithms, to design new algorithms using decomposition-based approaches, and to investigate their mapping to a practical parallel and distributed setting.

### **9.4.3. Inria International Partners**

#### *9.4.3.1. Declared Inria International Partners*

- Memorandum of Understanding between Shinshu University (Japan) and Inria, signed on March 2014

#### *9.4.3.2. Informal International Partners*

- University of Coimbra, Portugal
- University of Manchester, U.K.
- Collaboration with Université de Mons (UMONS). The collaboration consists mainly in the joint supervision of the Ph.D thesis of Jan Gmys started in 2014.

### **9.4.4. Participation in Other International Programs**

- JSPS-MEXT project on Evolutionary multi-objective optimization, landscape analysis, and search performance, with Shinshu University, Japan (2013—2016)

## **9.5. International Research Visitors**

### **9.5.1. Visits of International Scientists**

- Hernan Aguirre, Shinshu University, Japan
- Fabio Daolio, University of Stirling, U.K.
- Luis Paquete, University of Coimbra, Portugal
- Kiyoshi Tanaka, Shinshu University, Japan
- Saúl Zapotecas-Martínez, Shinshu University, Japan
- Qingfu Zhang, City University, Hong Kong
- Dr. Myriam Delgado (Federal University of Technology of Paraná, Brazil), 1 week, April 2016
- Prof. Fred Glover (University of Colorado, USA), 1 month, Nov 2016
- Dr Lakhdar Loukil from Université d’Oran, Algeria (January 18-22, 2016).

#### *9.5.1.1. Internships*

- Oliver Cuate, CINVESTAV, Mexico
- Miyako Sagawa, Shinshu University, Japan

### **9.5.2. Visits to International Teams**

#### *9.5.2.1. Sabbatical programme*

- E-G. Talbi has a one-year sabbatical program for 2016 and 2017.

#### *9.5.2.2. Research Stays Abroad*

- E-G. Talbi: University of Florida, USA, 1 month, 2016.
- E-G. Talbi: University of Colorado, USA, 1 month, 2016.

## **10. Dissemination**

### **10.1. Promoting Scientific Activities**

#### **10.1.1. Scientific Events Organisation**

##### *10.1.1.1. General Chair, Scientific Chair*

- N. Melab: Chair of the HPCS'2016 workshop (Parallel Optimization using / for Multi and Many-core High Performance Computing) organized in conjunction with HPCS'2016, Innsbruck, Austria, June 7<sup>th</sup> 2015.
- N. Melab: Chair of 5 simulation and HPC-related seminars at Lille 1 oct-dec. 2016 (CENAERO, Intel, Atos-Bull, FFT, UPMC).
- E-G. Talbi: General chair of META'2016 Int. Conf. on Metaheuristics and Nature Inspired Computing, Marrakech, Morocco, Oct 2016, 105 participants.
- E-G. Talbi, Program co-chair of HM'2016 Int. Conf on Hybrid Metaheuristics, Exeter, UK, May 2016.

#### *10.1.1.2. Member of the Organizing Committees*

- D. Brockhoff: co-organizer of the Surrogate-Assisted Multi-Criteria Optimization workshop at the Lorentz Center in Leiden, The Netherlands, Feb/Mar 2016
- D. Brockhoff: co-organizer of the Blackbox Optimization Benchmarking workshop (BBOB-2016) at GECCO in Denver, CO, USA
- CEC 2016 special session entitled "Advances in Decomposition-based Evolutionary Multiobjective Optimization", Vancouver, Canada, organized by Saul Zapotecas Martinez, Bilel Derbel, Qingfu Zhang, Carlos A. Coello Coello, July 2016
- E-G. Talbi: organisation of META'2016 Int. Conf. on Metaheuristics, Marrakech, Morocco, Oct 2016.

### **10.1.2. Scientific Events Selection**

#### *10.1.2.1. Chair of Conference Program Committees*

- E-G. Talbi, HM'2016
- E-G. Talbi, META'2016

#### *10.1.2.2. Member of the Conference Program Committees*

- CEC -IEEE Congress on Evolutionary Computation 2016
- CIBCB - IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology 2016
- GECCO conference 2016
- HM 2016
- ICORES 2016
- LION Conference 2016
- MICAI 2016
- MIM 2016
- MOD 2016
- PPSN 2016
- ROADEF 2016
- GECCO conference 2016
- IEEE Congress on Evolutionary Computation (CEC), Vancouver, Canada, July 24-29, 2016
- The ACM Genetic and Evolutionary Computation Conference (GECCO), Denver, Colorado, USA, July 20-24, 2016
- IEEE International Workshop on Nature Inspired Distributed Computing (IPDPS/NIDISC'2016), Chicago, Illinois, USA, May 23-27, 2016
- IEEE Intl. Workshop on Parallel Computing and Optimization (IPDPS/PCO), Chicago, Illinois, USA, May 23-27, 2016

- Grid'5000 winter school, Grenoble, France, February 2-5, 2016
- Colloque sur l'Optimisation et les Systèmes d'information (COSI), Sétif, Algérie, May 30 - June 1, 2016
- Intl. Conf. on Contemporary Computing (IC3), Noida, India, Aug. 11-13, 2016
- The 2nd Intl. Conf. on Cloud Computing Technologies and Applications (CloudTech), Marrakesh, Morocco, May 24-26, 2016.
- 8th IEEE Intl. Conf. on Cloud Computing Technology and Science (CloudCom), Luxembourg, Dec. 12-15, 2016
- PPSN 2016: 14th International Conference on Parallel Problem Solving from Nature (Edinburgh, UK, 2016)
- GECCO 2016: Genetic and Evolutionary Computation Conference, Evolutionary Combinatorial Optimization and Metaheuristics (ECOM) track (Denver, USA, 2016)
- CEC 2016: IEEE Congress on Evolutionary Computation (Vancouver, Canada, 2016)
- EvoCOP 2016: 16th European Conference on Evolutionary Computation in Combinatorial Optimization (Porto, Portugal, 2016)

#### 10.1.2.3. Reviewer

- Dimo Brockhoff: CEC'2016, GECCO'2016 (EMO track), PPSN'2016, FOGA'2017, EMO'2017

### 10.1.3. Journal

#### 10.1.3.1. Member of the Editorial Boards

- L. Jourdan: Review Editor Frontiers in Big Data
- N. Melab: Guest Editor (in collaboration with M. Mezmaç) of a special on Multi/Many-core computing for parallel Metaheuristics in Wiley Concurrency and Computation: Practice and Experience, April 2016.
- N. Melab: Guest Editor (in collaboration with A. Zomaya and I. Chakroun) of a special on Parallel Optimization using/for Multi and Many-core High Performance Computing in Journal of Parallel and Distributed Computing (JPDC), 2016.
- E-G. Talbi : Editor of the Journal « Computers and Industrial Engineering (CAIE, Elsevier)» Area «Computational Intelligence».

#### 10.1.3.2. Reviewer - Reviewing Activities

- IEEE Transactions on Evolutionary Computation, Evolutionary Computation, Journal of Heuristics, Artificial Intelligence Journal
- Applied Soft Computing
- Computers in Biology and Medicine
- Computers & Industrial Engineering
- Computers & Operations Research
- EJOR European Journal of Operational Research
- IEEE Transaction on Evolutionary Computation
- International Journal of Metaheuristics
- International Journal of Molecular Sciences
- International Journal of Production research
- International Transactions in Operational
- JOH Journal of Heuristics
- JOCO Journal of Combinatorial Optimization
- JPDC Journal of Parallel and Distributed Computing

- Nature Scientific Report
- Soft Computing (SOCO)
- Transactions on Computational Biology and Bioinformatics
- ACM Computing Surveys
- Computation and Concurrency: Practice and Experience (CCPE)
- Parallel Processing Letters
- Parallel Computing
- Journal of Parallel and Distributed Computing (JPDC)
- 4OR: A Quarterly Journal of Operations Research (Springer)
- ASOC: Applied Soft Computing (Elsevier)
- CAIE: Computers & Industrial Engineering (Elsevier)
- ITOR: International Transactions in Operational Research (Wiley)
- NEUCOM: Neurocomputing (Elsevier)

#### **10.1.4. Invited Talks**

- D. Brockhoff: invited talk on multiobjective optimization, MEXICO/Mascot-Num meeting, Nov 2016, Nantes
- D. Brockhoff: invited tutorial at GECCO'2016 on Evolutionary Multiobjective Optimization, Jul 2016, Denver, CO, USA
- B.Derbel and A. Liefoghe: Designing and understanding EMO algorithms, Invited talk, City University, Hong Kong, November 2016
- A. Liefoghe: Fitness landscape analysis, problem features and performance prediction for multi-objective optimization, Workshop on Landscape-aware heuristic search (PPSN 2016), Edinburgh, UK, September 2016 (joint work with Fabio Daolio, Sébastien Verel, Hernan Aguirre, and Kiyoshi Tanaka)
- L. Jourdan, "Combinatorial optimization for Bioinformatics", invited talk (1day), summer school of Bioinformatics, Angers, 2016
- L. Jourdan, "The emerging use of Optimization methods for Datamining in Big Data", invited talk, summer school of Cyber-Physical Systems (CPS), Toulouse, 2016.
- L. Jourdan, "Modélisation et optimisation multi-objectif pour l'extraction de connaissances Le cas des applications médicales", Mars 2016, Séminaire Expert, Worldline.
- C. Dhaenens "Exemple de collaboration réussie entre l'entreprise et le monde de la recherche", CCI Grand Lille, Fev. 2016.
- N. Melab: Tutorial on Grid'5000, Arcus international project "E2D2", May 2016, Université Lille 1.
- E-G. Talbi: Multi-objective metaheuristics, Invited seminar, Colorado State University, Fort Collins, Colorado, USA, Mar 2016.
- E-G. Talbi: Optimization under uncertainty, Invited seminar, Univeridad Elche, Elche, Spain, Apr 2016.
- E-G. Talbi: Parallel evolutionary algorithms for multi-objective optimization, Keynote speaker BIOMA'2016 7th Int. Conf. on Bioinspired Optimization Methods and their Applications, Bled, Slovenia, May 2016.
- E-G. Talbi: Parallel metaheuristics, Invited seminar, CINVESTAV, Mexico, Sept 2016.
- E-G. Talbi: Combining metaheuristics with mathematical programming and data mining, Keynote speaker, NEO'2016 Int. Workshop on Numerical and Evolutionary Optimization, Tlalneptla, Mexico, Sept 2016.



- E-G. Talbi: A survey of hybrid metaheuristics with exact methods and machine learning, Tutorial, META'2016 Int. Conf. on Metaheuristics and Nature Inspired computing, Marrakech, Morocco, Oct 2016.

### **10.1.5. Leadership within the Scientific Community**

- L. Jourdan : Co-president of the working group “ATOM: Multi-objective optimization”, GDR RO.
- L. Jourdan, A. Liefoghe : Secretary of the association “Artificial Evolution” (EA).
- C. Dhaenens: member of the scientific council of GDR RO (Operations research)
- C. Dhaenens: nominated member at Co-NRS, section 6 (National committee of CNRS)
- N. Melab: scientific leader of Grid'5000 (<https://www.grid5000.fr>) at Lille, Since 2004
- N. Melab: Chargé de Mission of High Performance Computing and Simulation at Université Lille 1, Since 2010
- E-G. Talbi : Co-president of the working group “META: Metaheuristics - Theory and applications”, GDR RO and GDR MACS.
- E-G. Talbi : Co-Chair of the IEEE Task force on Cloud Computing within the IEEE Computational Intelligence Society.

### **10.1.6. Scientific Expertise**

- D. Brockhoff: external reviewer of a research proposal for the National Science Centre Poland
- N. Melab: Member of the advisory committee for the IT and management engineer training at Faculté Polytechnique de Mons
- E-G. Talbi : Expert for Qatar Foundation QNRF projects, 2016.

### **10.1.7. Research Administration**

- C. Dhaenens: Vice-head of CRISAL laboratory (Centre de Recherche en Informatique, Signal et Automatique de Lille), common to CNRS, University of Lille and Ecole Centrale de Lille, 430 people.
- L. Jourdan: member of the Bureau du Département de domaine Informatique pour l'école doctorale SPI, University of Lille
- N. Melab: Member of the steering committee of “Maison de la Simulation” at Université Lille 1
- E-G. Talbi, Coordinator of the International Relationships of Inria Lille Nord Europe.

## **10.2. Teaching - Supervision - Juries**

### **10.2.1. Teaching**

- Master : Dimo Brockhoff, Introduction to Optimization, 18h ETD, M2 Apprentissage, Information et Contenu, U. Paris-Saclay, France
- Master : Dimo Brockhoff, Advanced Optimization, 18h ETD, M2 Apprentissage, Information et Contenu, U. Paris-Saclay, France
- Master : Dimo Brockhoff, Introduction to Optimization, 54h ETD, MSc in Data Sciences & Business Analytics, CentraleSupélec/ESSEC, France
- Master : Laetitia Jourdan, Business Intelligence, 30h, M1, University of Lille 1, France
- Master : Laetitia Jourdan, Datamining, 60h , M1, University of Lille 1, France
- Master : Laetitia Jourdan, Datawarehouse, 30h, M1, University of Lille 1, France
- Licence: Laetitia Jourdan : Informatique, 48h, L1 University of Lille 1, France
- Master: Laetitia Jourdan : Responsable of Master MIAGE Formation en Alternance, ,University of Lille 1, France

- Licence: Laetitia Jourdan: Co-responsible of Licence 1 Computer Science, University of Lille 1, France
- Engineering school : Clarisse Dhaenens, Graphs and Combinatorics, 80 HeqTD, Polytech Lille, University Lille 1, France
- Engineering school : Clarisse Dhaenens, Operations Research, 70 HeqTD, Polytech Lille, University Lille 1, France
- Engineering school : Clarisse Dhaenens, Algorithmics and programming, 45 HeqTD, Polytech Lille, University Lille 1, France
- Engineering school : Clarisse Dhaenens, responsible of the 5th year of statistics and computer science department.
- Engineering school : Marie-Eléonore Kessaci, Graphs and Combinatorics, 44 HeqTD, Polytech Lille, University Lille 1, France
- Engineering school : Marie-Eléonore Kessaci, Algorithmics and programming, 51 HeqTD, Polytech Lille, University Lille 1, France
- Engineering school : Marie-Eléonore Kessaci, Databases, 71 HeqTD, Polytech Lille, University Lille 1, France
- Engineering school : Marie-Eléonore Kessaci, Mathematics, 20 HeqTD, Polytech Lille, University Lille 1, France
- Engineering school : Marie-Eléonore Kessaci, responsible of the 3th year of statistics and computer science department.
- Master lecture: N. Melab, Supercomputing, 24h, Master 2, Université Lille 1, France
- Master lecture: N. Melab, Operations Research, 78h, Master 1, Université Lille 1, France
- Master leading: N. Melab, Co-head (with C. Chainais) of the master 2 of advanced scientific computing, U. Lille 1
- Licence: A. Liefoghe, Algorithmic and Data structure, 36h ETD, L2, Université de Lille 1, France
- Licence: A. Liefoghe, Algorithmic for Operations Research, 36h ETD, L3, Université de Lille 1, France
- Master: A. Liefoghe, Databases, 30h ETD, M1, Université de Lille 1, France
- Master: A. Liefoghe, Advanced Object-oriented Programming, 53h ETD, M2, Université de Lille 1, France
- Master: A. Liefoghe, Combinatorial Optimization, 10h ETD, M2, Université de Lille 1, France
- Master: A. Liefoghe, Multi-criteria Decision Aid and Optimization, 25h ETD, M2, Université de Lille 1, France
- A. Liefoghe is supervising the Master 2 MIAGE IPI-NT
- Master : Bilel Derbel, Combinatorial Optimization, 35h, M2, University Lille 1, France
- Master : Bilel Derbel, Grid Computing, 16h, M2, University Lille 1, France
- Master : Bilel Derbel, Parallel and Distributed Programming, 35h, M1, University Lille 1, France
- Master : Bilel Derbel, Algorithms and Applications, 28h, M1, University Lille 1, France
- Engineering school : El-Ghazali Talbi, Advanced optimization, 36h, Polytech'Lille, University Lille 1, France
- Engineering school : El-Ghazali Talbi, Data mining, 36h, Polytech'Lille, University Lille 1, France
- Engineering school : El-Ghazali Talbi, Operations research, 60h, Polytech'Lille, University Lille 1, France
- Engineering school : El-Ghazali Talbi, Graphs, 25h, Polytech'Lille, University Lille 1, France

### 10.2.2. Supervision

- PhD in progress: Gauvain Marquet, Mono-objective decomposition for multi-objective optimization, University Lille 1, Sep. 2014, Bilel Derbel and El-Ghazali Talbi
- PhD in progress: Maxence Vandromme, Datamining et optimisation combinatoire adaptés à la prévention et à l'orientation de patients, début : 1/06/2014, CIFRE with Alicante Co-direction : Clarisse Dhaenens and Laetitia Jourdan
- PhD in progress : Sylvain Dufourny, Optimisation de décisions économiques concurrentielles dans un simulateur de gestion d'entreprise, Novembre 2012, Clarisse Dhaenens
- PhD in progress : Aymeric Blot, Réagir et s'adapter à son environnement : Concevoir des méthodes autonomes pour l'optimisation combinatoire à plusieurs objectifs, september 2015, co-directed Laetitia Jourdan and Marie-Eléonore Marmion
- PhD in progress : Lucien Mousin, Exploiter la connaissance pour mieux optimiser, october 2015, co-directed Clarisse Dhaenens and Marie-Eléonore Marmion
- PhD in progress : AnneLise Bedenel, Classification supervisée et non supervisée en présence de descripteurs évoluant dans le temps. Application à la comparaison d'assurances en ligne, co-directed Laetitia Jourdan and Christophe Biernacki (Modal Inria Team)
- PhD (cotutelle in progress): Jan GMYS, Parallel Branch-and-Bound for solving permutation problems on multi- and many-core clusters, Nouredine Melab (Université Lille 1) and Daniel Tuytens (UMONS, Belgium), Defense end of 2017
- PhD in progress : A. Q. Nguyen, Green scheduling on cloud computing systems, 11/2012, El-Ghazali Talbi and Pascal Bouvry
- PhD in progress : Oumayma Bahri, Fuzzy multi-objective optimization, 11/2013, El-Ghazali Talbi and Nahla Ben-Omar
- PhD in progress : Sohrab Faramarzi, Optimization of medical lab, 02/2016, El-Ghazali Talbi

### 10.2.3. Juries

- C. Dhaenens: PhD Thesis: B. Tounsi, "Contributions à la chaîne logistique e-commerce : Intégration dans l'e-fulfillment et tarification de services de livraison", Université Lille 1, Dec. 2016.
- C. Dhaenens: HDR : L. Boudjeloud, "Approches coopératives et semi-interactives pour le traitement de données massives et temporelles", Université de Lorraine, Dec. 2016.
- L. Jourdan: PhD Thesis: Métaheuristiques hybrides distribuées et massivement parallèles, de Omar ABDELKAFI Université de Haute Alsace, November 7th 2016 (Présidente de Jury)
- L. Jourdan: PhD Thesis: Le routage avec transbordement et collaboration, de Nicolas Danloup, Université de Béthune Artois, December 1st 2016 (Présidente de Jury) Hyperheuristics in Logistics, de Kassem DANACH, Ecole Centrale Lille, December 21st 2016 (Présidente de Jury).
- L. Jourdan: PhD Thesis: Contribution à la synthèse et l'optimisation multi-objectif par essais particuliers de lois de commande robuste RST de système dynamique, de 'Riadh Madiouni', de l'Université Paris Est - Créteil, June 20th 2016 (Rapporteur)
- L. Jourdan: PhD Thesis: A dynamic programming operator for metaheuristics to solve vehicle routing problems with optional visits, de 'Leticia VARGAS' du LAAS-CNRS, June 24th 2016. (Rapporteur)
- L. Jourdan: PhD Thesis: Conception d'alliages par optimisation combinatoire multiobjectifs : thermodynamique prédictive, fouille de données, algorithmes génétiques et analyse décisionnelle de 'Edern Menou' Université de Nantes, October 19th 2016. (Rapporteur)
- HDR: Sebastien Verel, "Apport à l'analyse des paysages de fitness pour l'optimisation mono-objective et multi-objective", Université du Littoral - Côte d'Opale, December 12th, 2016.
- PhD thesis: Ania Kaci, "Conception d'une architecture extensible pour le calcul massivement parallèle", Université Paris-Est, December 14th, 2016.

- PhD thesis: Escobar Fernando, “High Performance Computing Architectures based on Reconfigurable Platforms for Scientific Applications, Université de Mons, March 30th, 2016.
- PhD thesis: K. Lefrouni, “Contrôle de congestion dans les réseaux de communication”, EMI – Université Mohammed V Rabat, Maroc, Jan 2016.
- PhD thesis: S. Nielsen, “Diversity preserving genetic algorithms – Application to the inverted folding problem and analogous formulated benchmarks”, University of Luxembourg, Luxembourg, Feb 2016.
- PhD thesis: K. E. Vazquez Ortiz, “Advanced methods to solve the maximum parsimony problem”, Université d’Angers, France, June 2016.
- PhD thesis: Urrego Agudelo Lilliam, “A novel method for the approximation of risk of blackout in operational conditions”, Université Paris-Est, Créteil, Nov 2016.

### 10.3. Popularization

- Clarisse Dhaenens, Fanny Dufossé, Laetitia Jourdan, Marie-Eléonore Marmion: Operational research - for 2nde during integration week (June 2016)
- Laetitia Jourdan, Marie-Eléonore: Computer Unplugged, Numériqu’elle Day (November 2016)
- Laetitia Jourdan: Computer Unplugged, Primary School (December 2016)

## 11. Bibliography

### Major publications by the team in recent years

- [1] J.-C. BOISSON, L. JOURDAN, E.-G. TALBI. *Metaheuristics based de novo protein sequencing: A new approach*, in "Applied Soft Computing", 2011, vol. 11, n<sup>o</sup> 2, pp. 2271-2278
- [2] C. DHAENENS, J. LEMESRE, E.-G. TALBI. *K-PPM: A new exact method to solve multi-objective combinatorial optimization problems*, in "European Journal of Operational Research", 2010, vol. 200, n<sup>o</sup> 1, pp. 45-53
- [3] J. FIGUEIRA, A. LIEFOOGHE, E.-G. TALBI, A. P. WIERZBICKI. *A parallel multiple reference point approach for multi-objective optimization*, in "European Journal of Operational Research", 2010, vol. 205, n<sup>o</sup> 2, pp. 390 - 400
- [4] N. JOZEFOWIEZ, F. SEMET, E.-G. TALBI. *Target Aiming Pareto Search and its application to the vehicle routing problem with route balancing*, in "Journal of Heuristics", 2007, vol. 13, pp. 455-469
- [5] A. KHANAFER, F. CLAUTIAUX, E.-G. TALBI. *New lower bounds for bin packing problems with conflicts*, in "European Journal of Operational Research", 2010, vol. 2, n<sup>o</sup> 206
- [6] A. LIEFOOGHE, L. JOURDAN, E.-G. TALBI. *A software framework based on a conceptual unified model for evolutionary multiobjective optimization: ParadisEO-MOEO*, in "European Journal of Operational Research", 2010
- [7] A. LIEFOOGHE, L. PAQUETE, J. FIGUEIRA. *On local search for bi-objective knapsack problems*, in "Evolutionary Computation", 2013, vol. 21, n<sup>o</sup> 1, pp. 179-196 [DOI : 10.1162/EVCO\_A\_00074], <http://hal.inria.fr/hal-00676625>

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- [9] M.-É. MARMION, L. JOURDAN, C. DHAENENS. *Fitness Landscape Analysis and Metaheuristics Efficiency*, in "Journal of Mathematical Modelling and Algorithms in Operations Research", 2013, vol. 12, n<sup>o</sup> 1, pp. 3-26 [DOI : 10.1007/s10852-012-9177-5], <http://hal.inria.fr/hal-00807352>
- [10] E.-G. TALBI. *Metaheuristics: From Design to Implementation*, Wiley, 2009

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### Articles in International Peer-Reviewed Journals

- [11] E. ALEKSEEVA, M. MEZMAZ, D. TUYTTENS, N. MELAB. *Parallel multi-core hyper-heuristic GRASP to solve permutation flow-shop problem: Hyper-heuristique GRASP parallèle multi-coeur pour la résolution du flow-shop de permutation*, in "Concurrency and Computation: Practice and Experience", April 2016 [DOI : 10.1002/CPE.3835], <https://hal.inria.fr/hal-01419060>
- [12] D. C. CATTARUZZA, N. ABSI, D. FEILLET. *Vehicle routing problems with multiple trips*, in "4OR: A Quarterly Journal of Operations Research", 2016, forthcoming, <https://hal-emse.ccsd.cnrs.fr/emse-01250603>
- [13] F. DAOLIO, A. LIEFOOGHE, S. VEREL, H. AGUIRRE, K. TANAKA. *Problem Features vs. Algorithm Performance on Rugged Multi-objective Combinatorial Fitness Landscapes*, in "Evolutionary Computation", 2016 [DOI : 10.1162/EVCO\_A\_00193], <https://hal.archives-ouvertes.fr/hal-01380612>
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- [15] J. GMYS, R. LEROY, M. MEZMAZ, N. MELAB, D. TUYTTENS. *Work Stealing with Private Integer-Vector-Matrix Data Structure for Multi-core Branch-and-Bound Algorithms*, in "Concurrency and Computation: Practice and Experience", 2016 [DOI : 10.1002/CPE.3771], <https://hal.inria.fr/hal-01248336>
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- [21] E.-G. TALBI. *Combining metaheuristics with mathematical programming, constraint programming and machine learning*, in "Annals of Operations Research", 2016, vol. 240, n<sup>o</sup> 1, pp. 171-215, <https://hal.inria.fr/hal-01423492>
- [22] T.-T. VU, B. DERBEL. *Parallel Branch-and-Bound in Multi-core Multi-CPU Multi-GPU Heterogeneous Environments*, in "Future Generation Computer Systems", March 2016, vol. 56, pp. 95–109 [DOI : 10.1016/J.FUTURE.2015.10.009], <https://hal.inria.fr/hal-01249124>

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- [23] O. BAHRI, E.-G. TALBI, N. BENAMOR. *Robust routes for the fuzzy multi-objective vehicle routing problem*, in "MIM'2016 8th IFAC Conference on Manufacturing Modelling Management and Control", Troyes, France, 2016, <https://hal.inria.fr/hal-01423498>
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- [25] M. BASSEUR, B. DERBEL, A. GOEFFON, A. LIEFOOGHE. *Experiments on greedy and local search heuristics for d-dimensional hypervolume subset selection*, in "Genetic and Evolutionary Computation Conference (GECCO 2016)", Denver, United States, 2016, <https://hal.archives-ouvertes.fr/hal-01302283>
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