Activity Report 2018

Team BONUS

Big Optimization aNd Ultra-Scale computing

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Lille - Nord Europe

THEME
Optimization, machine learning and statistical methods

Table of contents

Team BONUS

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Keywords:

Computer Science and Digital Science:

A6.2.7. - High performance computing
A8.2.1. - Operations research
A8.2.2. - Evolutionary algorithms
A9.6. - Decision support
A9.7. - AI algorithmics

Other Research Topics and Application Domains:

B2. - Health
B4. - Energy
B7. - Transport and logistics

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2. Overall Objectives

2.1. Presentation

In the BONUS project, the context of optimization, where solving a problem consists in optimizing (minimizing or maximizing) one or more objective function(s) under some constraints, is considered. In this context, a problem can be formulated as follows:

$$\begin{array}{ll} \text{Min/Max} & F(\mathbf{x}) = (f_1(\mathbf{x}), f_2(\mathbf{x}), ..., f_m(\mathbf{x})) \\ \text{subject to} & \mathbf{x} \in S. \end{array}$$

where S is the feasible search space and $\mathbf{x}$ is the decision variable vector of dimension n.

Nowadays, in many research and application areas we are witnessing the emergence of the big era (big data, big graphs, etc). In the optimization setting, the problems are increasingly big in practice. Big optimization problems (BOPs) refer to problems composed of a large number of environmental input parameters and/or decision variables (*high dimensionality*), and/or *many objective functions* that may be *computationally expensive*. For instance, in smart grids, there are many optimization problems for which have to be considered a large number of consumers (appliances, electrical vehicles, etc.) and multiple suppliers with various energy sources. In the area of engineering design, the optimization process must often take into account a large number of parameters from different disciplines. In addition, the evaluation of the objective function(s) often consist(s) in the execution of an expensive simulation of a black-box complex system. This is for instance typically the case in aerodynamics where a CFD-based simulation may require several hours. On the other hand, to meet the high growing needs of applications in terms of computational power in a wide range of areas including optimization, high-performance computing (HPC) technologies have known a revolution during the last decade (see Top500 [1]). Indeed, HPC is evolving toward *ultra-scale supercomputers composed of millions of cores supplied in heterogeneous devices including multi-core processors with various architectures, GPU accelerators and MIC coprocessors*.

Beyond the "big buzzword", solving BOPs raises at least four major challenges: (1) tackling their high dimensionality; (2) handling many objectives; (3) dealing with computationally expensive objective functions; and (4) scaling on (ultra-scale) modern supercomputers. The overall scientific objectives of the BONUS project consist in addressing efficiently these challenges. On the one hand, the focus will be put on the design, analysis and implementation of optimization algorithms scalable to high-dimensional (in decision variables and/or objectives) and/or expensive problems. On the other hand, the focus will also be put on the design of optimization algorithms able to scale on heterogeneous supercomputers including several millions of processing cores. To achieve these objectives raising the associated challenges a program including three lines of research will be adopted (Fig. 1): *decomposition-based optimization, Machine Learning (ML)-assisted optimization and ultra-scale optimization*. These research lines are developed in the following section.

[1] Top500 international ranking (Edition of November 2018): https://www.top500.org/lists/2018/11/

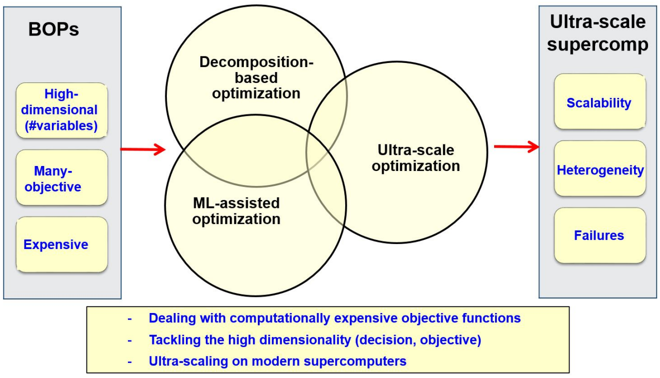

Figure 1. Research challenges/objectives and lines

From the software standpoint, our objective is to integrate the approaches we will develop in our *ParadisEO* [3] [2] framework in order to allow their reuse inside and outside the BONUS team. The major challenge will be to extend ParadisEO in order to make it *more collaborative* with other software including machine learning tools, other (exact) solvers and simulators. *From application point of view*, the focus will be put on two classes of applications: *complex scheduling and engineering design*.

3. Research Program

3.1. Decomposition-based Optimization

Given the large scale of the targeted optimization problems in terms of the number of variables and objectives, their decomposition into simplified and loosely coupled or independent subproblems is essential to raise the challenge of scalability. The first line of research is to *investigate the decomposition approach in the two spaces and their combination, as well as their implementation on ultra-scale architectures*. The motivation of the decomposition is twofold: first, the decomposition allows the parallel resolution of the resulting subproblems on ultra-scale architectures. Here also several issues will be addressed: the definition of the subproblems, their coding to allow their efficient communication and storage (checkpointing), their assignment to processing cores, etc. Second, decomposition is necessary for solving large problems that cannot be solved (efficiently) using traditional algorithms. Indeed, for instance with the popular NSGA-II algorithm the number of non-dominated solutions [3] increases drastically with the number of objectives leading to a very slow convergence to the Pareto front [4]. Therefore, decomposition-based techniques are gaining a growing interest. The objective of BONUS is to *investigate various decomposition schema and cooperation protocols between the subproblems* resulting from the decomposition to generate efficiently global solutions of good quality. Several challenges

[2] ParadisEO: http://paradiseo.gforge.inria.fr/

[3] A solution x dominates another solution y if x is better than y for all objectives and there exists at least one objective for which x is strictly better than y.

[4] A Pareto Front is the set of non-dominated solutions.

have to be addressed: how to define the subproblems (decomposition strategy), how to solve them to generate local solutions (local rules), and how to combine these latter with those generated by other subproblems and how to generate global solutions (cooperation mechanism), and how to combine decomposition strategies in more than one space (hybridization strategy)? These challenges, which are in the line with the CIS Task Force [5] on decomposition will be addressed in the decision as well as in the objective space.

The *decomposition in the decision space* can be performed following different ways according to the problem at hand. Two major categories of decomposition techniques can be distinguished: the first one consists in *breaking down the high-dimensional decision vector* into low-dimensional and easier-to-optimize blocks of variables. The major issue is how to define the subproblems (blocks of variables) and their cooperation protocol: randomly *vs.* using some learning (e.g. separability analysis), statically *vs.* adaptively, etc. *The decomposition in the decision space can also be guided by the type of variables i.e. discrete vs. continuous*. The discrete and continuous parts are optimized separately using cooperative hybrid algorithms [47]. *The major issue of this kind of decomposition is the presence of categorial variables in the discrete part [33]. The* BONUS *team is addressing this issue, rarely investigated in the literature*, within the context of vehicle aerospace engineering design. The second category consists in the *decomposition according to the ranges of the decision variables*. For continuous problems, the idea consists in iteratively subdividing the search (e.g. design) space into subspaces (hyper-rectangles, intervals, etc.) and select those that are most likely to produce the lowest objective function value. *Existing approaches meet increasing difficulty with an increasing number of variables and are often applied to low-dimensional problems. We are investigating this scalability challenge* (e.g. [10]). *For discrete problems, the major challenge is to find a coding (mapping) of the search space to a decomposable entity*. We have proposed an interval-based coding of the permutation space for solving big permutation problems. The approach opens perspectives we are investigating [7], in terms of ultra-scale parallelization, application to multi-permutation problems and hybridization with metaheuristics.

The *decomposition in the objective space* consists in breaking down an original MaOP into a set of cooperative single-objective subproblems (SOPs). The decomposition strategy requires the careful definition of a scalarizing (aggregation) function and its weighting vectors (each of them corresponds to a separate SOP) to guide the search process towards the best regions. Several scalarizing functions have been proposed in the literature including weighted sum, weighted Tchebycheff, vector angle distance scaling, etc. These functions are widely used but they have their limitations. For instance, using weighted Tchebycheff might do harm diversity maintenance and weighted sum is inefficient when it comes to deal with nonconvex Pareto Fronts [40]. Defining a scalarizing function well-suited to the MaOP at hand is therefore a difficult and still an open question being investigated in BONUS [6], [5]. Studying/defining various functions and in-depth analyzing them to better understand the differences between them is required. Regarding the weighting vectors that determine the search direction, their efficient setting is also a key and open issue. They dramatically affect in particular the diversity performance. Their setting rises several issues mainly: how to determine their number according to the available computational ressources? when (statically or adaptively) and how to determine their values? *Weight adaptation is one of our main concerns that we are addressing especially from a distributed perspective.* They correspond to the main scientific objectives targeted by our bilateral ANR-RGC BigMO project with City University (Hong Kong). The other challenges pointed out in the beginning of this section concern the way to solve locally the SOPs resulting from the decomposition of a MaOP and the mechanism used for their cooperation to generate global solutions. To deal with these challenges, our approach is to design the decomposition strategy and cooperation mechanism keeping in mind the parallel and/or distributed solving of the SOPs. Indeed, we favor the local neighborhood-based mating selection and replacement to minimize the network communication cost while allowing an effective resolution [5]. The major issues here are how to define the neighborhood of a subproblem and how to cooperatively update the best-known solution of each subproblem and its neighbors.

To sum up, the objective of the BONUS *team is to come up with scalable decomposition-based approaches in the decision and objective spaces. In the decision space, a particular focus will be put on high dimensionality*

[5] IEEE CIS Task Force, created in 2017 on Decomposition-based Techniques in Evolutionary Computation.

and mixed-continuous variables which have received little interest in the literature. We will particularly continue to investigate at larger scales using ultra-scale computing the interval-based (discrete) and fractal-based (continuous) approaches. We will also deal with the rarely addressed challenge of mixed-continuous including categorial variables (collaboration with ONERA). In the objective space, we will investigate parallel ultra-scale decomposition-based many-objective optimization with ML-based adaptive building of scalarizing functions. A particular focus will be put on the state-of-the-art MOEA/D algorithm. This challenge is rarely addressed in the literature which motivated the collaboration with the designer of MOEA/D (bilateral ANR-RGC BigMO project with City University, Hong Kong). Finally, the joint decision-objective decomposition, which is still in its infancy [49], is another challenge of major interest.

3.2. Machine Learning-assisted Optimization

The Machine Learning (ML) approach based on metamodels (or surrogates) is commonly used, and also adopted in BONUS, to assist optimization in tackling BOPs characterized by time-demanding objective functions. The second line of research of BONUS is focused on ML-aided optimization to raise the challenge of expensive functions of BOPs using surrogates but also to assist the two other research lines (decomposition-based and ultra-scale optimization) in dealing with the other challenges (high dimensionality and scalability).

Several issues have been identified to make efficient and effective surrogate-assisted optimization. First, infill criteria have to be carefully defined to adaptively select the adequate sample points (in terms of surrogate precision and solution quality). The challenge is to find the best trade-off between exploration and exploitation to efficiently refine the surrogate and guide the optimization process toward the best solutions. The most popular infill criterion is probably the *Expected Improvement* (EI) [43] which is based on the expected values of sample points but also and importantly on their variance. This latter is inherently determined in the kriging model, this is why it is used in the state-of-the-art *efficient global optimization* (EGO) algorithm [43]. However, such crucial information is not provided in all surrogate models (e.g. ANN) and needs to be derived. In BONUS, we are currently investigating this issue. Second, it is known that surrogates allow one to reduce the computational burden for solving BOPs with time-demanding function(s). However, using parallel computing as a complementary way is often recommended and cited as a perspective in the conclusions of related publications. Nevertheless, *despite being of critical importance parallel surrogate-assisted optimization is weakly addressed in the literature*. For instance, in the introduction of the survey proposed in [42] it is warned that because the area is not mature yet the paper is more focused on the potential of the surveyed approaches than on their relative efficiency. *Parallel computing is required at different levels that we are investigating*.

Another issue with surrogate-assisted optimization is related to high dimensionality in decision as well as in objective space: it is often applied to low-dimensional problems. *The joint use of decomposition, surrogates and massive parallelism is an efficient approach to deal with high dimensionality. This approach adopted in* BONUS *has received little effort in the literature.* In BONUS, we are considering a generic framework in order to enable a flexible coupling of existing surrogate models within the state-of-the-art decomposition-based algorithm MOEA/D. This is a first step in leveraging the applicability of efficient global optimization into the multi-objective setting through parallel decomposition. Another issue which is a consequence of high dimensionality is the mixed (discrete-continuous) nature of decision variables which is frequent in real-world applications (e.g. engineering design). *While surrogate-assisted optimization is widely applied in the continuous setting it is rarely addressed in the literature in the discrete-continuous framework.* In [33], we have identified different ways to deal with this issue that we are investigating. Non-stationary functions frequent in real-world applications (see Section 4.1) is another major issue we are addressing using the concept of deep GP.

Finally, as quoted in the beginning of this section, ML-assisted optimization is mainly used to deal with BOPs with expensive functions but it will also be investigated for other optimization tasks. Indeed, ML will be useful to assist the decomposition process. In the decision space, it will help to perform the separability analysis (understanding of the interactions between variables) to decompose the vector of variables. In the objective space, ML will be useful to assist a decomposition-based many-objective algorithm in dynamically selecting a scalarizing function or updating the weighting vectors according to their performances in the previous steps of the optimization process [5]. Such a data-driven ML methodology would allow us to understand what makes a problem difficult or an optimization approach efficient, to predict the algorithm performance [4], to select the most appropriate algorithm configuration [8], and to adapt and improve the algorithm design for unknown optimization domains and instances. Such an autonomous optimization approach would adaptively adjust its internal mechanisms in order to tackle cross-domain BOPs.

In a nutshell, to deal with expensive optimization the BONUS *team will investigate the surrogate-based ML approach with the objective to efficiently integrate surrogates in the optimization process. The focus will especially be put on high dimensionality (e.g. using decomposition) with mixed discrete-continuous variables which is rarely investigated. The kriging metamodel (Gaussian Process or GP) will be considered in particular for engineering design (for more reliability) addressing the above issues and other major ones including mainly non stationarity (using emerging deep GP) and ultra-scale parallelization (highly needed by the community). Indeed, a lot of work has been reported on deep neural networks (deep learning) surrogates but not on the others including (Deep) GP. On the other hand, ML will be used to assist decomposition: importance/interaction between variables in the decision space, dynamic building (selection of scalarizing functions, weight update, ...) of scalarizing functions in the objective space, etc.*

3.3. Ultra-scale Optimization

The third line of our research program that accentuates our difference from other (project-)teams of the related Inria scientific theme is the ultra-scale optimization. *This research line is complementary to the two others, which are sources of massive parallelism* and with which it should be combined to solve BOPs. Indeed, ultra-scale computing is necessary for the effective resolution of the large amount of subproblems generated by decomposition of BOPs, parallel evaluation of simulation-based fitness and metamodels, etc. These sources of parallelism are attractive for solving BOPs and are natural candidates for ultra-scale supercomputers [6]. However, their efficient use raises a big challenge consisting in managing efficiently a massive amount of irregular tasks on supercomputers with multiple levels of parallelism and heterogeneous computing resources (GPU, multi-core CPU with various architectures) and networks. Raising such challenge requires to tackle three major issues, scalability, heterogeneity and fault-tolerance, discussed in the following.

The *scalability* issue requires, on the one hand, the definition of scalable data structures for efficient storage and management of the tremendous amount of subproblems generated by decomposition [45]. On the other hand, achieving extreme scalability requires also the optimization of communications (in number of messages, their size and scope) especially at the inter-node level. For that, we target the design of asynchronous locality-aware algorithms as we did in [41], [48]. In addition, efficient mechanisms are needed for granularity management and coding of the work units stored and communicated during the resolution process.

Heterogeneity means harnessing various resources including multi-core processors within different architectures and GPU devices. The challenge is therefore to design and implement hybrid optimization algorithms taking into account the difference in computational power between the various resources as well as the resource-specific issues. On the one hand, to deal with the heterogeneity in terms of computational power, we adopt in BONUS the dynamic load balancing approach based on the Work Stealing (WS) asynchronous paradigm [7] at the inter-node as well as at the intra-node level. We have already investigated such approach, with various victim selection and work sharing strategies in [48], [7]. On the other hand, hardware resource specific-level optimization mechanisms are required to deal with related issues such as thread divergence and memory optimization on GPU, data sharing and synchronization, cache locality, and vectorization on multi-core processors, etc. These issues have been considered separately in the literature including our works [9], [1]. Indeed, in most of existing works related to GPU-accelerated optimization only a single CPU core is used. This leads to a

[6]In the context of BONUS, supercomputers are composed of several massively parallel processing nodes (inter-node parallelism) including multi-core processors and GPUs (intra-node parallelism).

[7]A WS mechanism is mainly defined by two components: a victim selection strategy which selects the processing core to be stolen and a work sharing policy which determines the part and amount of the work unit to be given to the thief upon WS request.

huge resource wasting especially with the increase of the number of processing cores integrated into modern processors. Using jointly the two components raises additional issues including data and work partitioning, the optimization of CPU-GPU data transfers, etc.

Another issue the scalability induces is the *increasing probability of failures* in modern supercomputers [46]. Indeed, with the increase of their size to millions of processing cores their MTBF tends to be shorter and shorter [44]. Failures may have different sources including hardware and software faults, silent errors, etc. In our context, we consider failures leading to the loss of work unit(s) being processed by some thread(s) during the resolution process. The major issue, which is particularly critical in exact optimization, is how to recover the failed work units to ensure a reliable execution. Such issue is tackled in the literature using different approaches: algorithm-based fault tolerance, checkpoint/restart (CR), message logging and redundancy. The CR approach can be system-level, library/user-level or application-level. Thanks to its efficiency in terms of memory footprint, adopted in BONUS [2], the application-level approach is commonly and widely used in the literature. This approach raises several issues mainly: what is critical information which defines the state of the work units and allows to resume properly their execution? when, where and how (using which data structures) to store it efficiently? how to deal with the two other issues: scalability and heterogeneity?

The last but not least major issue which is another roadblock to exascale is the programming of massive-scale applications for modern supercomputers. *On the path to exascale, we will investigate the programming environments and execution supports able to deal with exascale challenges: large numbers of threads, heterogeneous resources, etc.* Various exascale programming approaches are being investigated by the parallel computing community and HPC builders: extending existing programming languages (e.g. DSL-C++) and environments/libraries (MPI+X, etc.), proposing new solutions including mainly PGAS-based environments (Chapel, UPC, X10, etc.). It is worth noting here that our objective is not to develop a programming environment nor a runtime support for exascale computing. Instead, we aim to collaborate with the research teams (inside or outside Inria) having such objective.

To sum up, we put the focus on the design and implementation of efficient big optimization algorithms dealing jointly (uncommon in parallel optimization) with the major issues of ultra-scale computing mainly the scalability up to millions of cores using scalable data structures and asynchronous locality-aware work stealing, heterogeneity addressing the multi-core and GPU-specific issues and those related to their combination, and scalable GPU-aware fault tolerance. A strong effort will be devoted to this latter challenge, for the first time to the best of our knowledge, using application-level checkpoint/restart approach to deal with failures.

4. Application Domains

4.1. Introduction

For the validation of our findings we obviously use standard benchmarks to facilitate the comparison with related works. In addition, we also target real-world applications in the context of our collaborations and industrial contracts. From the *application* point of view two classes are targeted: *complex scheduling* and *engineering design*. The objective is twofold: proposing new models for complex problems and solving efficiently BOPs using jointly the three lines of our research program. In the following, are given some use cases that are the focus of our current industrial collaborations.

4.2. Big optimization for complex scheduling

Three application domains are targeted: energy, health and transport and logistics. In the **energy** field, with the smart grid revolution (multi-)house energy management is gaining a growing interest. The key challenge is to make elastic with respect to the energy market the (multi-)house energy consumption and management. *This kind of demand-side management will be of strategic importance for energy companies in the near future.* In collaboration with the EDF energy company we are working on the formulation and solving of optimization problems on demand-side management in smart micro-grids for single- and multi-user frameworks. These complex problems require taking into account multiple conflicting objectives and constraints and many (deterministic/uncertain, discrete/continuous) parameters. A representative example of such BOPs that we are addressing is the scheduling of the activation of a large number of electrical and thermal appliances for a set of homes optimizing at least three criteria: maximizing the user's confort, minimizing its energy bill and minimzing peak consumption situations. In the **health** care domain, we are collaborating with the Beckman & Coulter company on the design and planning of large medical laboratories. This is a hot topic resulting from the mutualisation phenomenon which makes bigger these laboratories. As a consequence, being responsible for analyzing medical tests ordered by physicians on patient's samples, these laboratories receive large amounts of prescriptions and tubes making their associated workflow more complex. Our aim is therefore to design and plan any medical laboratory to minimize the costs and time required to perform the tests. More exactly, the focus is put on the multi-objective modeling and solving of large (e.g. dozens of thousands of medical test tubes to be analyzed) strategic, tactical and operational problems such as the layout design, machine selection and confguration, assignment and scheduling. Finally, in **transport and logistics**, within the context of our potential collaboration (being set up) with the EXOTEC company we target the optimization of the robotic logistics of 3D warehouses. More exactly, the problem consists in efficient complex scheduling without collision of thousands of missions realized by a fleet of dozens of robots and several operators in a 3D logistics warehouse. The problem is identified in the literature as the parts-to-picker based order processing in a rack-moving mobile robots environment.

4.3. Big optimization for engineering design

The focus is for now put on the aerospace vehicle design, a complex multidisciplinary optimization process, we are exploring in collaboration with ONERA. The objective is to find the vehicle architecture and characteristics that provide the optimal performance (flight performance, safety, reliability, cost, etc.) while satisfying design requirements [39]. A representative topic we are investigating, and will continue to investigate throughout the lifetime of the project given its complexity, is the design of launch vehicles that involves at least 4 tightly coupled disciplines (aerodynamics, structure, propulsion and trajectory). Each discipline may rely on time-demanding simulations such as Finite Element analyses (structure) and Computational Fluid Dynamics analyses (aerodynamics). Surrogate-assisted optimization is highly required to reduce the time complexity. In addition, the problem is high-dimensional (dozens of parameters and more than 3 objectives) requiring different decomposition schema (coupling *vs.* local variables, continuous *vs.* discrete even categorial variables, scalarization of the objectives). Another major issue arising in this area is the non-stationarity of the objective functions which is generally due to the abrupt change of a physical property that often occurs in the design of launch vehicles. In the same spirit than deep learning using neural networks, we use Deep Gaussian Processes to deal with non-stationary multi-objective functions. Finally, the resolution of the problem using only one objective takes 1 week using a multi-core processor. Therefore, *in addition to surrogates ultra-scale computing is required at different levels to speed up the search and improve the reliability which is a major requirement in aerospace design.* This example shows that we need to use the synergy between the 3 lines of our research program to tackle such BOPs.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

- Patent with Beckman & Coulter on the optimization of large medical laboratories (Prof. E-G. Talbi, S. Faramarzi-oghani, M. Bué).

6. New Software and Platforms

6.1. Platforms

6.1.1. Grid'5000 testbed: extension with GPUs at Lille

KEYWORDS: Experimental testbed, large-scale computing, high-performance computing, GPU computing, cloud computing, big data

FUNCTIONAL DESCRIPTION: Grid'5000 is a project initiated in 2003 by the French government to promote scientific research on large scale distributed systems. The project is later supported different research organizations including Inria, CNRS, the french universities, Renater which provides the wide-area network, etc. The overall objective of Grid'5000 was to build by 2007 a nation-wide experimental testbed composed of at least 5000 processing units and distributed over several sites in France. From a scientific point of view, the aim was to promote scientific research on large-scale distributed systems.

Grid'5000 was installed at the center of IT resources including supercomputing resources of Université de Lille 1 and opened to users in 2005. Since March 2017, the Grid'5000 site has moved to the premises on Inria Lille within the context of the phase 1 of the CPER data program (see Section 9.1) with a completely new hardware equipment. As a scientific leader of the testbed for the Lille's site, N. Melab has been strongly involved in the extension (phase 2 of CPER data) of the platform with 16 computing serveurs, 16 Nvidia GPUs (12 P100 and 4V100), 2 storage serveurs 200TB and 2 administration servers. Grid'5000 at Lille is used by more than 150 users including 100 external ones. The testbed is used for research as well as for teaching allowing a high scientific production (publications, PhD theses, etc.) and over 30 master students to get started with parallel and distributed programming.

- Participants: N. Melab, external collaborators: D. Delabroy, T. Peltier, L. Nussbaum.
- Contact: Nouredine Melab.
- URL: https://www.grid5000.fr/mediawiki/index.php/Grid5000:Home

7. New Results

7.1. Decomposition-based optimization

- **A set-oriented decomposition algorithm for multi-objective optimization.**
  Participants: B. Derbel and A. Liefooghe, external collaborators: H. Aguirre and K. Tanaka, Shinshu University (JAPAN); S. Verel, Univ. Littoral (FRANCE); Q. Zhang, City University (HONG KONG)

  The working principles of the well-established multi-objective evolutionary algorithm MOEA/D relies on the iterative and cooperative improvement of a number of single-objective sub-problems obtained by decomposition. Besides the definition of sub-problems, selection and replacement are, like in any evolutionary algorithm, the two core elements of MOEA/D. We argue that these two components are however loosely coupled with the maintained population. Thereby, in [24], we propose to re-design the working principles of MOEA/D by adopting a set-oriented perspective, where a many-to-one mapping between sub-problems and solutions is considered. Selection is then performed by defining a neighborhood relation among solutions in the population set, depending on the corresponding sub-problem mapping. Replacement is performed following an elitist mechanism allowing the population to have a variable, but bounded, cardinality during the search process. By conducting a comprehensive empirical analysis on a range of combinatorial multi- and many-objective nk-landscapes, we show that the proposed approach leads to significant improvements, especially when dealing with an increasing number of objectives. Our findings indicate that a set-oriented design can constitute a sound alternative for strengthening the practice of multi- and many-objective evolutionary optimization based on decomposition.

- **Parallel Pareto local search for multi-objective optimization.**
  Participants: B. Derbel and A. Liefooghe, external collaborators: J. Shi and J. Sun, Xi'an Jiaotong University (CHINA); Q. Zhang, City University (HONG KONG)

  Pareto Local Search (PLS) is a simple, yet effective optimization approach dedicated to multi-objective combinatorial optimization. It can however suffer from a high computational cost, especially when the size of the Pareto optimal set is relatively large. Recently, incorporating decomposition in PLS had revealed a high potential, not only in providing high-quality approximation sets, but also in speeding-up the search process. In [30], using the bi-objective Unconstrained Binary Quadratic Programming (bUBQP) problem as an illustrative benchmark, we demonstrate some shortcomings in the resulting decomposition-guided Parallel Pareto Local Search (PPLS), and we propose to revisit the PPLS design accordingly. For instances with a priori unknown Pareto front shape, we show that a simple pre-processing technique to estimate the scale of the Pareto front can help PPLS to better balance the workload. Furthermore, we propose a simple technique to deal with the critically-important scalability issue raised by PPLS when deployed over a large number of computing nodes. Our investigations show that the revisited version of PPLS provides a consistent performance, suggesting that decomposition-guided PPLS can be further generalized in order to improve both parallel efficiency and approximation quality.
- **Archivers for the representation of the set of approximate solutions for MOPs.**
  Participants: E-G. Talbi, external collaborators: O. Schutze, C. Hernandez (Computer Science Department, Cinvestav, MEXICO), Q. Sun, Y. Naranjani (School of Engineering University of California, USA), R. Xiong (Department of Mechanics, University Tianjin, CHINA)

  In this work we have addressed the problem of computing suitable representations of the set of approximate solutions of a given multi-objective optimization problem via stochastic search algorithms. For this, we have proposed different archiving strategies for the selection of the candidate solutions maintained by the generation process of the stochastic search process, and investigate them further on analytically and empirically. For all archivers we have provided upper bounds on the approximation quality as well as on the cardinality of the limit solution set. A comparative study on some test problems in order to visualize the effect of all novel archiving strategies has also been carried out [18].

7.2. ML-assisted optimization

FIve major contributions related to ML-assisted optimization have been achieved and summarized in the following. As pointed out previously in our research program, one of the major issues in surrogate-assisted optimization is how to integrate efficiently and effectively the surrogates in the optimization process. This issue is addressed in first three contributions. Another major aspect addressed in the fourth contribution is the investigation of surrogates within the context of combinatorial optimization. The focus of the fifth contribution is put on the landscape analysis applied within the context of multi-objective optimization.

- **Efficient Global Optimization Using Deep Gaussian Processes.**
  Participants: A. Hebbal, E-G. Talbi and N. Melab, external collaborators: L. Brevault and M. Balesdent from ONERA (Palaiseau, Paris)

  Efficient Global Optimization (EGO) is widely used for the optimization of computationally expensive black-box functions. EGO is based on a surrogate modeling technique using Gaussian Processes (kriging). However, due to the use of a stationary covariance, kriging is not well suited for approximating non stationary functions. Non stationarity is generally due to the abrupt change of a physical property that often occurs in the design of launch vehicles, subject of our collaboration with ONERA. This leads to a variation of the objective function with a completely different smoothness along the input space. In the spirit of deep learning using neural networks, we have investigated in [25] the integration of Deep Gaussian processes (DGP) in EGO framework to deal with non stationarity. Numerical experimentations are performed on analytical problems to highlight the different aspects of DGP and EGO. The experimental results show that the coupling EGO-DGP outperforms EGO-GP with a significant margin. Furthermore, the study has also highlighted some challenging issues to be investigated including: the integration of DGP in multi-objective EGO, the configuration of the network and revisiting the training model. Ultra-scale optimization at different levels is particularly important given the large number of hyperparameters of the training model.

- **Efficient global optimization of constrained mixed variable problems.**
  Participants: E-G. Talbi, external collaborators: Julien Pelamatti, Loïc Brevault, Mathieu Balesdent (ONERA) Yannick Guerin (CNES)

  Due to the increasing demand for high performance and cost reduction within the framework of complex system design, numerical optimization of computationally costly problems is an increasingly popular topic in most engineering fields [33]. In this work, several variants of the Efficient Global Optimization algorithm for costly constrained problems depending simultaneously on continuous decision variables as well as on quantitative and/or qualitative discrete design parameters are proposed. The adaptation that is considered is based on a redefinition of the Gaussian Process kernel as a product between the standard continuous kernel and a second kernel representing the covariance between the discrete variable values. Several parameterizations of this discrete kernel, with their respective strengths and weaknesses, have been investigated. The novel algorithms are tested on a number of analytical test-cases and an aerospace related design problem, and it is shown that they require fewer function evaluations in order to converge towards the neighborhoods of the problem optima when compared to more commonly used optimization algorithms [38].

- **Adaptive Evolution Control using Confident Regions for Surrogate-assisted Optimization.**
  Participants: G. Briffoteaux and N. Melab, external collaborators: M. Mezmaz and D. Tuyttens from Université de Mons (BELGIUM)

  The challenge of the efficient/effective integration of surrogates in the optimization process is to find the best trade-off between the quality (in terms of quality/precision) of the generated solutions and the efficiency (in terms of execution time) of the resolution. In [22], we have investigated the evolution control that alternates between the real function (simulator) and the surrogate within the multi-objective optimization process. We propose an adaptive evolution control mechanism based on the distance-based concept of confident regions (hyperspheres). The approach has been integrated into an ANN-assisted NSGA-2 and experimented using the ZDT4 multi-modal benchmark function. The reported results show that the proposed approach outperforms two other existing ones.

- **A surrogate model for combinatorial optimization.**
  Participants: B. Derbel and A. Liefooghe, external collaborators: H. Aguirre and K. Tanaka, Shinshu University (JAPAN), S. Verel, Univ. Littoral (FRANCE)

  Extensive efforts so far have been devoted to the design of effective surrogate models for expensive black-box continuous optimization problems. There are, however, relatively few investigations on the development of methodologies for combinatorial domains. In [31], we rely on the mathematical foundations of discrete Walsh functions in order to derive a surrogate model for pseudo-boolean optimization functions. Specifically, we model such functions by means of Walsh expansion. By conducting a comprehensive set of experiments on nk-landscapes, we provide empirical evidence on the accuracy of the proposed model. In particular, we show that a Walsh-based surrogate model can outperform the recently-proposed discrete model based on Kriging.

- **Landscape analysis for multi-objective optimization.**
  Participants: B. Derbel and A. Liefooghe, external collaborators: H. Aguirre and K. Tanaka, Shinshu University (JAPAN); M. López-Ibánez, Univ. Manchester (UK); L. Paquete, Univ. Coimbra, Portugal; S. Verel, Univ. Littoral (FRANCE)

Pareto local optimal solutions (PLOS) are believed to highly influence the dynamics and the performance of multi-objective optimization algorithms, especially those based on local search and Pareto dominance. In [28], we introduce a PLOS network (PLOS-net) model as a step toward the fundamental understanding of multi-objective landscapes and search algorithms. Using a comprehensive set of instances, PLOS-nets are constructed by full enumeration, and selected network features are further extracted and analyzed with respect to instance characteristics. A correlation and regression analysis is then conducted to capture the importance of the PLOS-net features on the runtime and effectiveness of two prototypical Pareto-based heuristics. In particular, we are able to provide empirical evidence for the relevance of the PLOS-net model to explain algorithm performance.

Additionally, we know that local search algorithms naturally stop at a local optimal set (LO-set) under given definitions of neighborhood and preference relation among subsets of solutions, such as set-based dominance relation, hypervolume or epsilon indicator. It is an open question how LO-sets under different set preference relations relate to each other. In [29], we report an in-depth experimental analysis on multi-objective nk-landscapes. Our results reveal that, whatever the preference relation, the number of LO-sets typically increases with the problem non-linearity, and decreases with the number of objectives. We observe that strict LO-sets of bounded cardinality under set-dominance are LO-sets under both epsilon and hypervolume, and that LO-sets under hypervolume are LO-sets under set-dominance, whereas LO-sets under epsilon are not. Nonetheless, LO-sets under set-dominance are more similar to LO-sets under epsilon than under hypervolume. These findings have important implications for multi-objective local search. For instance, a dominance-based approach with bounded archive gets more easily trapped and might experience difficulty to identify an LO-set under epsilon or hypervolume. On the contrary, a hypervolume-based approach is expected to perform more steps before converging to better approximations.

7.3. Large scale GPU-centric optimization

Participants: J. Gmys, T. C. Pessoa and N. Melab, external collaborators: M. Mezmaz, D. Tuyttens from University of Mons (BELGIUM) and F.H. De Carvalho Junior from Universidade Federal Do Cearà (BRAZIL)

Nowadays, accelerator-centric architectures offer orders-of-magnitude performance and energy improvements. The interest of those parallel resources has been recently accentuated by the advent of deep learning making them definitely key-building blocks of modern supercomputers. During the year 2018, in collaboration with A. Zomaya (The Univ. of Sydney) and I. Chakroun (IMEC, Leuven) N. Melab has (guest-)edited a special issue on this hot topic (editorial in [16]). In addition, we have put the focus on the investigation of these specific devices within the context of parallel optimization. In the following, two major contributions are reported: (1) Many-core Branch-and-Bound for GPU accelerators and MIC coprocessors; (2) Cuda Dynamic Parallelism (CDP) for backtracking.

- **Many-core Branch-and-Bound for GPU accelerators and MIC coprocessors.** Solving large optimization problems results in the generation of a very large pool of subproblems and the time-intensive evaluation of their associated lower bounds. Generating and evaluating those subproblems on coprocessors raises several issues including processor-coprocessor data transfer optimization, vectorization, thread divergence, etc. In [15], [32], we have investigated the offload-based parallel design and implementation of B&B algorithms for coprocessors addressing these issues. Two major many-core architectures are considered and compared: Nvidia GPU and Intel MIC. The proposed approaches have been experimented using the Flow-Shop scheduling problem and two hardware configurations equivalent in terms of energy consumption: Nvidia Tesla K40 and Intel Xeon Phi 5110P. The reported results show that the GPU-accelerated approach outperforms the MIC offload-based one even in its vectorized version. Moreover, vectorization improves the efficiency of the MIC offload-based approach with a factor of two.

- **Dynamic Configuration of CUDA Runtime Variables for CDP-based Divide-and-Conquer Algorithms.** CUDA Dynamic Parallelism (CDP) is an extension of the GPGPU programming model proposed to better address irregular applications and recursive patterns of computation. However, processing memory-demanding problems by using CDP is not straightforward, because of its particular memory organization. We have proposed in [23] (extension of [13]) an algorithm to deal with such an issue which dynamically calculates and configures the CDP runtime variables and the GPU heap on the basis of an analysis of the partial backtracking tree. We have implemented the algorithm for solving permutation problems and experimented on two test-cases: N-Queens and the Asymmetric Travelling Salesman Problem. The proposed algorithm allows different CDP-based backtracking from the literature to solve memory-demanding problems, adaptively with respect to the number of recursive kernel generations and the presence of dynamic allocations on GPU.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

Our current industrial contracts and granted projects are completely at the heart of the BONUS project. They are summarized in the following.

- *Beckman & Coulter (2015-2018, California, USA)*: the goal of this contract is the strategic and operational planning of large medical laboratories (Phd of S. Faramarzi-Oghani). More exactly, the focus is put on the multi-objective modeling and solving of large (e.g. dozens of thousands of medical test tubes to be analyzed) strategic, tactical and operational problems such as the layout design, machine selection and confguration, assignment and scheduling. The project deals also with the coupling between optimization and simulation for performance assessment.
- *EDF (2015-2019, Paris)*: this project deals with demand-side management in smart grids with EDF, a major electrical power player in France. The Energy Management System (EMS) in the home receives the market and system signals and controls the loads, Heating, Ventilation and Air Conditioning systems (HVAC), storages and local generation units according to the user preferences. A large number of home users and appliances and several conflicting objectives have to be considered.
- *ONERA & CNES (2016-2020, Paris)*: the focus of this project with major European players in vehicle aerospace is put on the design of aerospace vehicles, a high-dimensional expensive multidisciplinary problem. Such problem needs the use of the research lines of BONUS to be tackled effectively and efficiently. Two jointly supervised Phd students (J. Pelamatti and A. Hebbal) are involved in this project.
- *In contact with EXOTEC (2018-2019, Lille)*: This project deals with the optimization of logistics flows of robots. More exactly, the problem consists in efficient complex scheduling without collision of thousands of missions realized by a fleet of dozens of robots and several operators in a 3D logistics warehouse.

9. Partnerships and Cooperations

9.1. Regional Initiatives

- *CPER Data (2015-2019)*: in this project, that promotes research and software development related to advanced data science, the BONUS team is the scientific leader (N. Melab) of one of the three research lines of the project "Optimization and High-Performance Computing". In this context, a two-year (2018-2019) engineer (J-Y. Ji) is supported to develop a software demonstrator on decomposition-based big optimization. In addition, the team is co-leader of the workpackage/lever

"Research infrastructures" related to the Grid'5000 nation-wide experimental testbed. This allowed to extend the testbed at Lille with a GPU-powered cluster highly important for the BONUS project. In addition, two engineers have been hired for the system & network administration of the testbed, user support and development.

- *CPER ELSAT (2015-2019)*: in this project, focused on ecomobility, security and adaptability in transport, the BONUS team is involved in the transversal research line: planning and scheduling of maintenance logistics in transportation. The team got support for a one-year (2017-2018) post-doc position (M. Rahimi).

9.2. National Initiatives

9.2.1. ANR

- *Bilateral ANR/RGC France/Hong Kong PRCI* (2016-2021), "Big Multi-objective Optimization" in collaboration with City University of Hong Kong

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 optimization of several, often time-consuming and conflicting objectives. For example, they require the maximization of the product quality while minimizing the production cost, and rely on demanding numerical simulations in order to assess the objectives. These, so-called multi-objective optimization problems can be solved more efficiently if parallelization is used to execute the simulations simultaneously and if the simulations are partly replaced by accurate surrogate models.

9.3.2. Collaborations in European Programs, Except FP7 & H2020

Program: COST CA15140

Project acronym: ImAppNIO

Project title: Improving applicability of nature-inspired optimization by joining theory and practice

Duration: 2016-2019

Coordinator: Thomas Jansen

Abstract: The main objective of the COST Action is to bridge this gap and improve the applicability of all kinds of nature-inspired optimisation methods. It aims at making theoretical insights more accessible and practical by creating a platform where theoreticians and practitioners can meet and exchange insights, ideas and needs; by developing robust guidelines and practical support for application development based on theoretical insights; by developing theoretical frameworks driven by actual needs arising from practical applications; by training Early Career Investigators in a theory of nature-inspired optimisation methods that clearly aims at practical applications; by broadening participation in the ongoing research of how to develop and apply robust nature-inspired optimisation methods in different application areas.

9.3.3. Collaborations with Major European Organizations

MARO: University of Mons (BELGIUM), Parallel surrogate-assisted optimization, large-scale exact optimization

University of Ceara (BRAZIL), Large-scale GPU-accelerated tree-based optimization

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 Coimbra and University of Lisbon (PORTUGAL), Exact and heuristic multi-objective search

University of Manchester (UNITED KINGDOM), Local optimality in multi-objective optimization

University of Elche and University of Murcia (SPAIN), Matheuristics for DEA

9.4. International Initiatives

9.4.1. Inria International Labs

International Laboratory for Research in Computer Science and Applied Mathematics
Associate Team involved in the International Lab:

9.4.1.1. 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.

9.4.1.2. Other IL projects

Title: Frontiers in Massive Optimization and Computational Intelligence

International Partner (Institution - Laboratory - Researcher): Shinshu University (JAPAN)

Start year: 2017

See also: https://sites.google.com/view/lia-modo/

Abstract: The aim of MODO is to federate French and Japanese researchers interested in the dimensionality, heterogeneity and expensive nature of massive optimization problems. The team receives a yearly support for international exchanges and shared manpower (joint PhD students).

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

Title: Three-fold decomposition in multi-objective optimization (D^3MO)

International Partner (Institution - Laboratory - Researcher): University of Exeter, UK

Start year: 2018

9.4.3. Inria International Partners

9.4.3.1. Informal International Partners

- Collaboration with Université de Mons (UMONS). The collaboration consists mainly in the joint supervision of two Phds (M. Gobert and G. Briffoteaux)
- University of Elche, Spain

9.4.4. Participation in Other International Programs

Title: **Evolutionary many-objective optimization: application to smart cities and engineering design**

International Partner (Institution - Laboratory - Researcher): CINVESTAV-IPN (MEXICO)

Start year: 2016

Abstract: The project is co-funded by ECOS Nord (FRANCE) and ANUIES (MEXICO). Abstract to be extended ...

Title: **Bridging the gap between exact methods and heuristics for multi-objective search (MOCO-Search)**

International Partner (Institution - Laboratory - Researcher): University of Coimbra and University of Lisbon, Portugal

Start year: 2018

Website: http://sites.google.com/view/moco-search/

Abstract: This international project for scientific cooperation (PICS), funded by CNRS and FCT, aims to fill the gap between exact and heuristic methods for multi-objective optimization. The goal is to establish the link between the design principles of exact and heuristic methods, to identify features that make a problem more difficult to be solved by each method, and to improve their performance by hybridizing search strategies. Special emphasis is given to rigorous performance assessment, benchmarking, and general-purpose guidelines for the design of exact and heuristic multi-objective search.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Kiyoshi Tanaka, Shinshu University (JAPAN), March 2018 and November 2018
- Hernan Aguirre, Shinshu University (JAPAN), Invited Professor Univ Lille, from March 2018 until April 2018
- Kalyan Deb, University of Michiga (USA), Oct 2018
- Rachid Ellaia, EMI University of Rabat, Morocco, April 2018

9.5.1.1. Internships

- Alexandre Jesus, University of Coimbra (Portugal)

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. General Chair, Scientific Chair

- E-G. Talbi (Conference program chair): Intl. Conf. on Metaheuristics and Nature Inspired Computing (META'2018), Marrakech, Morocco, Oct. 2018.
- N. Melab (Workshop co-chair): Intl. Workshop on the Synergy of Parallel Computing, Optimization and Simulation (HPCS/PaCOS'2018), Orléans, FRANCE, Jul. 16-20, 2018.

- E-G. Talbi (General Chair): 8th Intl. Conf. on Bioinspired Optimization Methods and their Applications (BIOMA'2018), Paris, FRANCE, May 16-18, 2018.
- E-G. Talbi (Workshop co-chair): Intl. Workshop on Optimization and Learning: Challenges and Applications (OLA'2018), Alicante, SPAIN, Feb. 26-28, 2018.
- E-G. Talbi (steering committee): 8th IEEE Workshop Parallel Distributed Computing and Optimization (IPDPS/PDCO'2018), Vancouver, CANADA, May 21-25, 2018.
- N. Melab: Chair of 4 simulation and HPC-related seminars at Université de Lille, Oct-Dec. 2018 (CENAERO-BELGIUM, IBM, UCL-BELGIUM, ONERA).
- B. Derbel and A. Liefooghe (workshop co-chairs): 1st International Workshop on Computational Intelligence for Massive Optimization (CIMO 2018), Nagano, Japan, July 2018 (with H. Aguirre, K. Tanaka and S. Verel).
- B. Derbel (workshop co-chair): Decomposition Techniques in Evolutionary Optimization (DTEO), workshop at GECCO 2018, Kyoto, Japan, July 2018 (with K. Li, X. Li, S. Zapotecas, Q. Zhang and H. Li).
- A. Liefooghe (workshop co-chair): Landscape-aware heuristic search (LAHS), workshop at GECCO 2018, Kyoto, Japan, July 2018 (with N. Veerapen, S. Verel and G. Ochoa).
- B. Derbel (special session co-chair): Advances in Decomposition-based Evolutionary Multi-objective Optimization (ADEMO), special session at WCCI/CEC 2018, Rio, Brazil, July 2018 (with S. Zapotecas and Q. Zhang).
- B. Derbel and A. Liefooghe (special session co-chairs): Multi-/many-objective optimization and learning, special session at BIOMA 2018, Paris, France, May 2018 (with H. Aguirre, B. Filipič, T. Tušar, and S. Verel).

10.1.1.2. Member of the Organizing Committees

- N. Melab and E-G. Talbi: Synergy Summer School on Efficient Multi-objective Optimization, Ljubljana, Slovenia, Aug. 27-31, 2018.
- E-G. Talbi: The first international Metaheuristics Summer School – MESS 2018, Acireale-Sicily, Italy, Jul. 21-25, 2018.

10.1.2. Scientific Events Selection

10.1.2.1. Chair of Conference Program Committees

- N. Melab (Program co-chair): 8th Intl. Conf. on Bioinspired Optimization Methods and their Applications (BIOMA'2018), Paris, France, May 16-18, 2018.
- A. Liefooghe (program co-chair): EvoCOP 2018: 18th European Conference on Evolutionary Computation in Combinatorial Optimisation (Parma, Italy, 2018).
- A. Liefooghe (proceedings chair): GECCO 2018: Genetic and Evolutionary Computation Conference (Kyoto, Japan, 2018).

10.1.2.2. Member of the Conference Program Committees

- IEEE Congress on Evolutionary Computation (CEC), Rio de Janeiro, BRAZIL, Jul. 8-13, 2018.
- The ACM Genetic and Evolutionary Computation Conference (GECCO), Kyoto, JAPAN, July 15-19, 2018.
- The 2018 International Conference on High Performance Computing & Simulation (HPCS), Orleans, FRANCE, July 16–20, 2018.
- IEEE Intl. Workshop on Parallel/Distributed Computing and Optimization (IPDPS/PDCO), Vancouver, Britich Columbia, CANADA, May 21-25, 2018.
- IEEE Intl. on High-Performance Optimization in Industry (HPOI), Ljubljana, SLOVENIA, October 8, 2018.

- Colloque sur l'Optimisation et les Systèmes d'information (COSI), Oran, ALGERIE, Oct. 22-24, 2018.
- The 4^{th} Intl. Conf. on Cloud Computing Technologies and Applications (CloudTech), Brussels, BELGIUM, Nov. 26-28, 2018.
- EvoCOP'2018, 18^{th} European Conference on Evolutionary Computation in Combinatorial Optimization, Parma, ITALY, April 4–6, 2018.
- 15th International Conference on Parallel Problem Solving from Nature (PPSN), Coimbra, Portugal, September 2018
- Genetic and Evolutionary Computation Conference (GECCO), Kyoto, Japan, July 2018.
- IEEE Congress on Evolutionary Computation (WCCI-CEC), Rio, Brazil, July 2018.
- 18th European Conference on Evolutionary Computation in Combinatorial Optimisation (EvoCOP), Parma, Italy, April 2018.

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- N. Melab: Guest and Managing 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), Vol. 112, 2018.
- P. Korosec, N. Melab and E-G. Talbi. Guest Editor of LNCS Proceedings of 8^{th} Intl. Conf., BIOMA 2018, Paris, France, May 16-18, 2018. *Springer Lecture Notes in Computer Science (LNCS)*, Vol. 10835, 2018.
- B. Derbel: Associate Editor, IEEE Transactions on Systems, Man and Cybernetics: Systems (IEEE).
- A. Liefooghe, M. López-Ibánez: Editors of LNCS Proceedings of the 18th European conference on evolutionary computation in combinatorial optimization (EvoCOP 2018), Lecture Notes in Computer Science (LNCS), vol. 10782, Parma, Italy, 2018.
- E-G. Talbi: Co-editor (with C. Ribeiro) of a special issue in International Transactions on Operational Research (ITOR) on Optimization and Learning, 2018.

10.1.3.2. Reviewer - Reviewing Activities

- Journal of Heuristics (Springer)
- IEEE Transactions on Parallel and Distributed Systems
- IEEE Transactions on Cybernetics
- Evolutionary Computation (MIT)

10.1.4. Invited Talks

- N. Melab: High-performance Computing, Invited Speaker (1h30), Synergy Summer School, Ljubljana, SLOVENIA, Aug. 28^{th}, 2018.
- N. Melab: Introduction to High-performance Computing, Invited Tutorial (1h40), the 7^{th} Intl. Conf. on Metaheuristics and Nature Inspired Computing (META'18), Marrakech, MOROCCO, Oct. 27-31, 2018.
- E-G. Talbi: Bridging the gap between metaheuristics and machine learning, Invited seminar, PUCV Universidad, Santiago, Chile, Mar 2018.
- E-G. Talbi: How machine learning can help metaheuristics, Invited keynote, LOPAL'2018 International Conference on Learning and Optimization Algorithms: Theory and Applications, Rabat, Marrakech, May 2018.
- E-G. Talbi: Synergy between metaheuristics and machine learning, Tutorial, BIOMA'2018 International Conference on Bioinspired Optimization and their Applications, Paris, France, May 2018.

- E-G. Talbi: Parallel and distributed evolutionary algorithms, Invited tutorial, IEEE WCCI World Congress on Computational Intelligence, Rio de Janeiro, Brazil, July 2018.
- E-G. Talbi: Optimization for machine learning, Invited seminar, Universidad Elche, Spain, Dec 2018.

10.1.5. Leadership within the Scientific Community

- N. Melab: scientific leader of Grid'5000 (https://www.grid5000.fr) at Lille, since 2004
- 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
- A. Liefooghe: co-secretary of the association "Artificial Evolution" (EA)

10.1.6. Scientific Expertise

- N. Melab: Reviewer expert for AAPG ANR, CES 23 (B.7, Axe 4), JCJC, FRANCE, 2018
- N. Melab: Member of the advisory committee for the IT and maganement engineer training at Faculté Polytechnique de Mons, BELGIUM

10.1.7. Research Administration

- N. Melab: Member of the steering committee of "Maison de la Simulation" at Université de Lille
- E-G. Talbi, Coordinator of the International Relationships of Inria Lille Nord Europe

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

- International Master lecture: N. Melab, Supercomputing, 24h ETD, M2, Université de Lille, FRANCE
- Master lecture: N. Melab, Operations Research, 72h ETD, M1, Université de Lille, FRANCE
- Master leading: N. Melab, Co-head (with B. Merlet) of the international Master 2 of advanced scientific computing, Université de Lille, FRANCE
- Licence: A. Liefooghe, Algorithmic and Data structure, 36h ETD, L2, Université de Lille, FRANCE
- Licence: A. Liefooghe, Algorithmic for Operations Research, 36h ETD, L3, Université de Lille, FRANCE
- Master: A. Liefooghe, Databases, 30h ETD, M1, Université de Lille, FRANCE
- Master: A. Liefooghe, Advanced Object-oriented Programming, 53h ETD, M2, Université de Lille, FRANCE
- Master: A. Liefooghe, Combinatorial Optimization, 10h ETD, M2, Université de Lille, FRANCE
- Master: A. Liefooghe, Multi-criteria Decision Aid and Optimization, 25h ETD, M2, Université de Lille, FRANCE
- Master leading: A. Liefooghe, superviser of the Master 2 MIAGE IPI-NT
- Master: Bilel Derbel, Combinatorial Optimization, 35h, M2, Université de Lille, FRANCE
- Master: Bilel Derbel, Grid Computing, 16h, M2, Université de Lille, FRANCE
- Master: Bilel Derbel, Parallel and Distributed Programming, 35h, M1, Université de Lille, FRANCE
- Master: Bilel Derbel, Algorithms and Applications, 28h, M1, Université de Lille, FRANCE
- Engineering school: El-Ghazali Talbi, Advanced optimization, 36h, Polytech'Lille, Université de Lille, FRANCE
- Engineering school: El-Ghazali Talbi, Data mining, 36h, Polytech'Lille, Université de Lille, FRANCE

- Engineering school: El-Ghazali Talbi, Operations research, 60h, Polytech'Lille, Université de Lille, FRANCE
- Engineering school: El-Ghazali Talbi, Graphs, 25h, Polytech'Lille, Université de Lille, FRANCE
- Master leading: B. Derbel, head of the Master MIAGE, Université de Lille, FRANCE
- Licence: O. Abdelkafi, Computer Science, 46.5 ETD, L1, Université de Lille, FRANCE
- Licence: O. Abdelkafi, Web Technologies, 36 ETD, L1, Université de Lille, FRANCE
- Licence: O. Abdelkafi, Unix system introduction, 6 ETD, L2, Université de Lille, FRANCE
- Licence: O. Abdelkafi, Web Technologies, 24 ETD, L2 S3H, Université de Lille, FRANCE
- Licence: O. Abdelkafi, object-oriented programming, 36 ETD, L2, Université de Lille, FRANCE
- Licence: O. Abdelkafi, Relational Databases, 36h ETD, L3, Université de Lille, FRANCE
- Licence: O. Abdelkafi, Algorithmic for Operations Research, 36h ETD, L3, Université de Lille, FRANCE

10.2.2. Supervision

- PhD defended: Sohrab Faramarzi, Optimization of medical laboratories, Defended on Dec. 17$^{\text{th}}$, El-Ghazali Talbi
- PhD in progress: Z. Garroussi, Demand side management in smart grids: Multi-objective models, El-Ghazali Talbi and Rachid Ellaia (EMI, Morocco)
- PhD in progress: J. Pelamatti, Multi-disciplinary design of aerospace vehicles, Jan 2017, El-Ghazali Talbi
- PhD in progress: Ali Hebbal, Surrogate-assisted multi-objective evolutionary algorithms, Oct 2017, El-Ghazali Talbi and Nouredine Melab
- PhD in progress (cotutelle): Maxime Gobert, Surrogate-assisted multi-objective evolutionary algorithms, Oct 2017, Nouredine Melab (Université de Lille) and Daniel Tuyttens (Université de Mons, BELGIUM)
- PhD in progress (cotutelle): Guillaume Briffoteaux, Surrogate-assisted multi-objective evolutionary algorithms, Oct 2017, Nouredine Melab (Université de Lille) and Daniel Tuyttens (Université de Mons, BELGIUM)
- PhD in progress: Geoffrey Pruvost, Machine learning and decomposition techniques for large-scale multi-objective optimization, Oct 2018, Bilel Derbel and Arnaud Liefooghe
- PhD in progress: Nicolas Berveglieri, Meta-models and machine learning for massive expensive optimization, Oct 2018, Bilel Derbel and Arnaud Liefooghe
- PhD in progress: Alexandre Jesus, Algorithm selection in multi-objective optimization, Bilel Derbel and Arnaud Liefooghe (University of Lille), Luís Paquete (University of Coimbra, PORTUGAL)

10.2.3. Juries

- N. Melab: PhD thesis of Yahya Al Dhuraibi, Flexible Framework for Elasticity in Cloud Computing, Université de Lille (FRANCE), Dec. 10$^{\text{th}}$ 2018.
- N. Melab: PhD thesis of Muhammad Umer Wasim, Design and Implementation of Legal Protection for Trade Secrets in Cloud Brokerage Architectures relying on Blockchains, University of Bologna (ITALY), Apr. 2018.
- N. Melab: PhD thesis of Maruf Ahmed, On Improving The Performance and Resource Utilization of Consolidated Virtual Machines: Measurement, Modeling, Analysis and Prediction, The University of Sydney (AUSTRALIA), Aug. 2018.
- B. Derbel: PhD thesis of Christopher Jankee, Optimisation par métaheuristique adaptative distribuée en environnement de calcul parallèle, Université du Littoral Côte d'Opale (FRANCE), Aug. 2018.

10.3. Popularization

10.3.1. Internal or external Inria responsibilities

- N. Melab: Nominated again as Chargé de Mission of High Performance Computing and Simulation at Université de Lille, since 2010.
- E-G. Talbi: International relations coordinator for Inria Lille Nord Europe, since 2016.
- N. Melab. Member of the Working Group on software and technological demonstrators, since end 2017.

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Articles in International Peer-Reviewed Journals

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