IN PARTNERSHIP WITH:
Université de Lille

Activity Report 2019

Project-Team BONUS

Big Optimization aNd Ultra-Scale Computing

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

Table of contents

Project-Team BONUS

Creation of the Team: 2017 July 01, updated into Project-Team: 2019 June 01

Keywords:

Computer Science and Digital Science:

A1.1.1. - Multicore, Manycore
A1.1.2. - Hardware accelerators (GPGPU, FPGA, etc.)
A1.1.5. - Exascale
A8.2.1. - Operations research
A8.2.2. - Evolutionary algorithms
A9.6. - Decision support
A9.7. - AI algorithmics

Other Research Topics and Application Domains:

B3.1. - Sustainable development
B3.1.1. - Resource management
B7. - Transport and logistics
B8.1.1. - Energy for smart buildings

1. Team, Visitors, External Collaborators

Research Scientist

Jan Gmys [University of Mons, Belgium, Researcher]

Faculty Members

Nouredine Melab [Team leader, Université de Lille, Professor, HDR]
Omar Abdelkafi [Université de Lille, Associate Professor]
Bilel Derbel [Université de Lille, Associate Professor, HDR]
Arnaud Liefooghe [Université de Lille, Associate Professor]
El-Ghazali Talbi [Université de Lille, Professor, HDR]

Post-Doctoral Fellows

Tiago Carneiro Pessoa [Inria]
Mohammad Rahimi [Université de Lille, until Jan 2019]
Oumayma Bahri [Université de Lille, ATER]

PhD Students

Nicolas Berveglieri [Université de Lille]
Alexandre Borges de Jesus [University of Coimbra, Portugal from Sep 2019]
Guillaume Briffoteaux [University of Mons, Belgium]
Sohrab Faramarzi Oghani [Inria, until Jan 2019]
Maxime Gobert [University of Mons, Belgium]
Ali Hebbal [Université de Lille]
Julien Pelamatti [ONERA]
Geoffrey Pruvost [Université de Lille]
Jeremy Sadet [Université de Valenciennes et du Hainaut Cambrésis]

Technical staff

Nassime Aslimani [Université de Lille, Engineer, from Sep 2019]
Dimitri Delabroye [Inria, Engineer, from Dec 2019]

Jingyu Ji [Inria, Engineer]

Interns and Apprentices

Corwin Fevre [Université de Lille, from Mar 2019 until Aug 2019]
Kazuki Maeda [Shinshu University, Japan, from Nov 2019]
Kyo Migishima [Shinshu University, Japan, from Nov 2019]

Administrative Assistant

Karine Lewandowski [Inria]

Visiting Scientists

Martin Gonzalez [University of Cadiz, Spain, from Jul 2019 until Oct 2019]
Renzo Massobrio [Republica University, Uruguay, PhD student, from Jan 2019 to Mar 2019]
Leonard Whitley [Colorado State University, USA, Professor, Jul 2019]
Matthieu Basseur [Université d'Angers, Associate Professor, from Sep 2019 to Aug 2020, HDR]

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:

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

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/

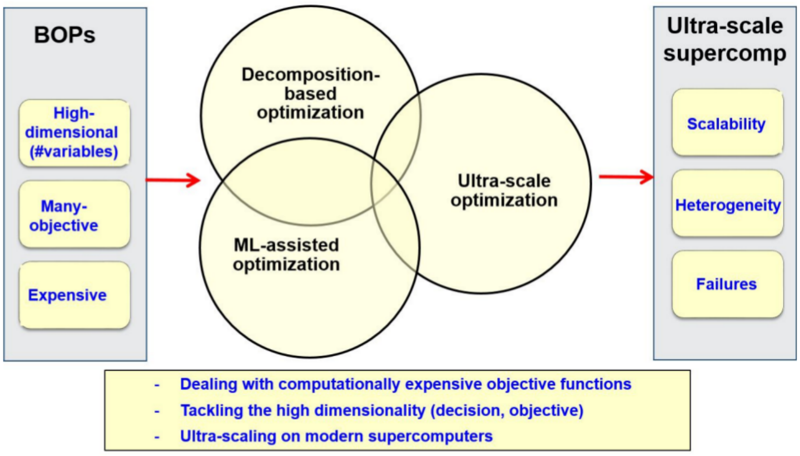

Figure 1. Research challenges/objectives and lines

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 the 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 have to be addressed: (1) how to define the subproblems (decomposition strategy), (2) how to solve them to generate local solutions (local rules), and (3) how to combine these latter with those generated by other subproblems and how to generate global solutions (cooperation mechanism), and (4) how to combine

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

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 lower-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 [48]. *The major issue of this kind of decomposition is the presence of categorial variables in the discrete part [44]. 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 Many-objective problem (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 two main issues: 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 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*

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

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 [50], 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. Artificial Neural Networks) 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 [44], 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 etc.) 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 [46]. 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], [49]. 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 [49], [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 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.

[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.

Another issue the scalability induces is the *increasing probability of failures* in modern supercomputers [47]. Indeed, with the increase of their size to millions of processing cores their Mean-Time Between Failures (MTBF) tends to be shorter and shorter [45]. 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: (1) which critical information defines the state of the work units and allows to resume properly their execution? (2) when, where and how (using which data structures) to store it efficiently? (3) 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 Partitioned Global Address Space (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 these laboratories bigger. 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 four 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 three objectives) requiring different decomposition schemas (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 one 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 three lines of our research program to tackle such BOPs.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

+ The paper [30] was nominated for the *Best Student Workshop Paper Award* at the 28$^{\text{th}}$ ACM (Companion) Genetic and Evolutionary Computation Conference (GECCO 2019).
+ *USA Patent* with Beckman & Coulter on the optimization of large medical laboratories (Prof. E-G. Talbi, S. Faramarzi Oghani, M. Bué), 2019.
+ The paper [29] has received the *Best Student Paper Award* at the 10$^{\text{th}}$ International Conference on Evolutionary Multi-Criterion Optimization (EMO 2019).

BEST PAPER AWARD:

[29]

Y. MARCA, H. AGUIRRE, S. Z. MARTINEZ, A. LIEFOOGHE, B. DERBEL, S. VEREL, K. TANAKA. *Approximating Pareto Set Topology by Cubic Interpolation on Bi-objective Problems*, in "EMO 2019 - International Conference on Evolutionary Multi-Criterion Optimization", East Lansing, Michigan, United States, February 2019, pp. 386-398 [*DOI :* 10.1007/978-3-030-12598-1_31], https://hal.archives-ouvertes.fr/hal-02064548

6. New Software and Platforms

6.1. Platforms

6.1.1. Grid'5000 testbed: extension with storage and 10G network at Lille

Participants: Nouredine Melab [contact person], Dimitri Delabroye, Thierry Peltier [external collaborator], Lucas Nussbaum [external collaborator].

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

Functional description: Grid'5000 is a project intiated in 2003 by the French government to promote scientific research on large scale distributed systems. The project is later supported by 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 equipement. 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 mainly two storage serveurs 200TB and a 10G Internet connexion to the testbed. 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.

URL: https://www.grid5000.fr/mediawiki/index.php/Grid5000:Home

7. New Results

7.1. Decomposition-based optimization

During the year 2019, we have investigated decomposition-based optimization in the decision space as well as in the objective space. In the decision space, we have considered discrete as well as continuous problems. For discrete problems, we have reinvestigated our interval-based decomposition approach proposed in [7] as a baseline to explore ultra-scale Branch-and-Bound algorithms using Chapel [13]. The contribution is presented in Section 7.3. For continuous problems, we have extended the geometric fractal decomposition-based approach [10] to multi-objective optimization [32] and importantly to parallel computing [17] to deal with scalability, one of the major scientific challenges as pointed out in Section 3.1. In the objective space, we have deeply studied in [23] the surrogate-assisted multi-objective optimization based on decomposition. The contributions are summarized in the following.

7.1.1. Parallel fractal decomposition for big continuous optimization problems

Participants: El-Ghazali Talbi [contact person], Amir Nakib [Laboratoire Images, Signaux et Systèmes Intelligents (LISSI), Paris], Léo Souquet [Laboratoire Images, Signaux et Systèmes Intelligents (LISSI), Paris].

Fractal Decomposition Algorithm (FDA) is a metaheuristic that was recently proposed to solve high dimensional continuous optimization problems [10]. This approach is based on a geometric fractal decomposition which divides the search space while looking for the optimal solution. While FDA and its fractal decomposition has shown to be an effective optimization algorithm, its running time grows significantly as the problems dimension increases. To deal with this expensive computational time, a parallelized version of FDA, called Parallel Fractal Decomposition Algorithm (PFDA) is proposed in [17]. The focus is on parallelizing the exploration and exploitation phases of the original algorithm in a multi-threaded environment. The performances of PFDA are evaluated on the same Benchmark used to illustrate FDA efficiency, the SOCO 2011. It is composed of 19 functions with *dimensions going from 50 to 5000*. The results show that PFDA allows one to achieve similar performances as the original version with a significantly reduced computational time.

7.1.2. Deterministic multi-objective fractal decomposition

Participants: El-Ghazali Talbi [contact person], Amir Nakib [Laboratoire Images, Signaux et Systèmes Intelligents (LISSI), Paris], Léo Souquet [Laboratoire Images, Signaux et Systèmes Intelligents (LISSI), Paris].

We have proposed in [32] a new deterministic Multi-objective Fractal Decomposition Algorithm (Mo-FDA). The original FDA [10] was designed for single-objective large-scale continuous optimization problems. It is based on a “divide-and-conquer” strategy and a geometric fractal decomposition of the search space using hyperspheres. In this work, a scalarization approach is used to deal with multi-objective problems. The performance of Mo-FDA is compared to state-of-the-art algorithms from the literature on classical benchmarks of multi-objective optimization.

7.1.3. Surrogate-assisted multi-objective optimization based on decomposition

Participants: Nicolas Berveglieri, Bilel Derbel, Arnaud Liefooghe, Hernan Aguirre [Shinshu University, Japan], Kiyoshi Tanaka [Shinshu University, Japan].

A number of surrogate-assisted evolutionary algorithms are being developed for tackling expensive multi-objective optimization problems. On the one hand, a relatively broad range of techniques from both machine learning and multi-objective optimization can be combined for this purpose. Different taxonomies exist in order to better delimit the design choices, advantages and drawbacks of existing approaches. On the other hand, assessing the relative performance of a given approach is a difficult task, since it depends on the characteristics of the problem at hand. In [23], we focus on surrogate-assisted approaches using objective space decomposition as a core component. We propose a refined and fine-grained classification, ranging from EGO-like approaches to filtering or pre-screening. More importantly, we provide a comprehensive comparative study of a representative selection of state-of-the-art methods, together with simple baseline algorithms. We rely on selected benchmark functions taken from the bbob-biobj benchmarking test suite, that provides a variable range of objective function difficulties. Our empirical analysis highlights the effect of the available budget on the relative performance of each approach, and the impact of the training set and of the machine learning model construction on both solution quality and runtime efficiency.

7.2. ML-assisted optimization

As pointed out in our research program 3.2, we investigate the ML-assisted optimization following two directions: building efficiently surrogates to deal with expensive black-box objective functions and automatically building and predicting/improving the performance of metaheuristics through landscape/problem structure analysis. Regarding surrogate-assisted optimization, we put the focus in [31] on mixed discrete-continuous optmization problems, one of the major challenges of this topic. In addition, we focused on the evolution control and batch parallelism to deal with another challenge which consists in efficiently integrating surrogate models (Bayesian neural networks in this case) in evolutionary algorithms [FGCS-Briffoteaux, à compléter]. From the application point of view, we applied our approaches to three different real-world simulation-based problems in the context of three collaborations: multi-stage optimal scheduling of virtual power plants (collaboration with electrical engineering department of UMONS University, Belgium) in [27], aerospace vehicle design (collaboration with ONERA, Paris) in [31], and resource allocation for the Tuberculosis edidemic control (Monash University) in [FGCS-Briffoteax, à compléter]. The two latter ones are summarized in the following sections. Regarding the second direction, we thoroughly study in [16] the impact of landscape characteristics on the performance of search heuristics for black-box multi-objective combinatorial optimization problems. We also introduce in [26] new insightful features for continuous exploratory landscape analysis and algorithm selection. In addition, as pointed out in 3.2, variable selection is highly important to deal with BOPs. In [28], in collaboration with our partners from Shinshu University we come out with an efficient method to classify variables influencing convergence and increase their recombination rate. The contributions are summarized in the following.

7.2.1. Surrogate-assisted optimization of constrained mixed variable problems: application to the design of a launch vehiclethrust frame.

Participants: El-Ghazali Talbi [contact person], Julien Pelamatti, Loïc Brevault [ONERA], Mathieu Balesdent [ONERA], Yannick Guerin [CNES].

Within the framework of complex systems design, such as launch vehicles, numerical optimization is an essential tool as it allows to reduce the design process time and costs. The inclusion of discrete variables in the design process allows to extend the applicability of numerical optimization methods to a broader number of systems and sub-systems. In [31], a recently proposed adaptation of the Efficient Global Optimization method (EGO) for constrained mixed-variable problems is applied to the design optimization of a launch vehicle thrust frame, which depends on both continuous sizing parameters and discrete variables characterizing the number of structural reinforcements. The EGO adaptation that is considered is based on a redefinition of the Gaussian Process kernel as a product between a standard continuous kernel and a second kernel representing the covariance between the discrete variable values. From the results obtained on an analytical test-case as well as on the launch vehicle thrust frame design optimization, it is shown that the use of the mixed-variable EGO algorithm allows to converge towards the neighborhoods of the problems optima with fewer function evaluations when compared to reference optimization algorithms.

7.2.2. Parallel Batched Bayesian Neural Network-assisted GA versus q-EGO

Participants: Guillaume Briffoteaux, Maxime Gobert, Jan Gmys, Nouredine Melab [contact person], Romain Ragonnet [School of Public Health and Preventive Medicine, Monash University, Australia], Mohand Mezmaz [University of Mons, Blegium], Daniel Tuyttens [University of Mons, Blegium].

Surrogate-based optimization has been widely used to deal with expensive black-box simulation-based objective functions. The use of a surrogate model allows to reduce the number of calls to the costly simulator. In (SWEVO, Briffoteaux et al., 2020), the Efficient Global Optimization (EGO) reference framework is challenged by a Bayesian Neural Network-assisted Genetic Algorithm, namely BNN-GA. The Bayesian Neural Network (BNN) surrogate provides an uncertainty measure of the prediction that allows to compute the Expected Improvement of a candidate solution in order to improve the exploration of the objective space. BNN is also more reliable than Kriging models for high-dimensional problems and faster to set up thanks to its incremental training. In addition, we propose a batch-based approach for the parallelization of BNN-GA that is challenged by a parallel version of EGO, called q-EGO. Parallel computing is a complementary way to deal with the computational burden of simulation-based optimization. The comparison of the two parallel approaches is experimentally performed through several benchmark functions and two real-world problems within the scope of Tuberculosis Transmission Control (TBTC). The results demonstrate the efficiency and scalability of the parallel batched BNN-GA for small budgets, outperforming it for larger budgets on the benchmark testbed. A significant improvement of the solutions is obtained for two TBTC problems. Finally, our study proves that parallel batched BNN-GA is a viable alternative to q-EGO approaches being more suitable for high-dimensional problems and parallelization impact.

7.2.3. Landscape-aware performance prediction and algorithm selection for single- and multi-objective evolutionary optimization

Participants: Arnaud Liefooghe, Bilel Derbel, Fabio Daolio [ASOS.com, UK], Sébastien Verel [LISIC, Université du Littoral Côte d'Opale], Hernan Aguirre [Shinshu University, Japan], Kiyoshi Tanaka [Shinshu University, Japan].

Extracting a priori knowledge informing about the landscape underlying an unknown optimization problem has been proved extremely useful for different purposes, such as designing finely-tuned algorithms, predicting algorithm performance and designing automated portfolio-based solving approaches. Considering black-box continuous single-objective optimization problems, in [26], we adopt an exploratory landscape analysis approach providing a unified methodology for integrating landscape features into sophisticated machine learning techniques. More precisely, we consider the design of novel informative and cheap landscape features on the basis of the search tree constructed by the so-called SOO (Simultaneous Optimistic Optimization) algorithm, which is arguably a global optimizer coming from the machine learning community and having its foundations in the multi-armed bandit theory. We thereby provide empirical evidence on the accuracy of the proposed features for both predicting high-level problem properties, and tackling the algorithm selection problem with respect to a given portfolio of available solvers and a broad range of optimisation problems taking from the specialized literature and exposing different degrees of difficulty.

Considering black-box combinatorial multi-objective optimization problems, in [16], we expose and contrast the impact of landscape characteristics on the performance of search heuristics for black-box multi-objective combinatorial optimization problems. A sound and concise summary of features characterizing the structure of an arbitrary problem instance is identified and related to the expected performance of global and local dominance-based multi-objective optimization algorithms. We provide a critical review of existing features tailored to multi-objective combinatorial optimization problems, and we propose additional ones that do not require any global knowledge from the landscape, making them suitable for large-size problem instances. Their intercorrelation and their association with algorithm performance are also analyzed. This allows us to assess the individual and the joint effect of problem features on algorithm performance, and to highlight the main difficulties encountered by such search heuristics. By providing effective tools for multi-objective landscape analysis, we highlight that multiple features are required to capture problem difficulty, and we provide further insights into the importance of ruggedness and multimodality to characterize multi-objective combinatorial landscapes.

7.2.4. Estimating Relevance of Variables for Effective Recombination

Participants: Arnaud Liefooghe, Bilel Derbel, Sébastien Verel [LISIC, Université du Littoral Côte d'Opale], Taishi Ito [Shinshu University, Japan], Hernan Aguirre [Shinshu University, Japan], Kiyoshi Tanaka [Shinshu University, Japan].

Dominance and its extensions, decomposition, and indicator functions are well-known approaches used to design MOEAs. Algorithms based on these approaches have mostly sought to enhance parent selection and survival selection. In addition, several variation operators have been developed for MOEAs. In [28], we focus on the classification and selection of variables to improve the effectiveness of solution search. We propose a method to classify variables that influence convergence and increase their recombination rate, aiming to improve convergence of the approximation found by the algorithm. We incorporate the proposed method into NSGA-II and study its effectiveness using three-objective DTLZ and WFG benchmark functions, including unimodal, multimodal, separable, non-separable, unbiased, and biased functions. We also test the effectiveness of the proposed method on a real-world bi-objective problem. Simulation results verify that the proposed method can contribute to achieving faster and better convergence in several kinds of problems, including the real-world problem.

7.3. Towards ultra-scale Big Optimization

During the year 2019, we have addressed the ultra-scale optimization research line following two main directions: designing efficient optimization algorithms dealing with scalability in terms of number of processing cores and/or in terms of the size of tackled problem instances. For the first direction, the challenge is to take into account in addition to the traditional performance objective the productivity awareness which is highly important to deal with the increasing complexity of medern supercomputers. With the short-term perspective of establishing a collaboration with one of the major HPC builders (Cray Inc.), we have investigated in [13], [24], [25] the exascale-aware Chapel language. Regarding the second direction, we contributed to solve difficult unsolved flow-shop [15] and Quadratic Assignement Problem (QAP) [22] permutation problem instances using moderate-scale parallelism. The contributions are summarized in the following.

7.3.1. Towards ultra-scale Branch-and-Bound using a high-productivity language

Participants: Tiago Carneiro Pessoa, Jan Gmys, Nouredine Melab, Daniel Tuyttens [University of Mons, Blegium].

Productivity is crucial for designing ultra-scale algorithms able to harness modern supercomputers which are increasingly complex, including millions of processing cores and heterogeneous building-block devices. In [13], we investigate the partitioned global address space (PGAS)-based approach using Chapel for the productivity-aware design and implementation of distributed Branc-and-Bound (B&B) for solving large optmization problems. The proposed algorithms are intensively experimented using the Flow-shop scheduling problem as a test-case. The Chapel-based implementation is compared to its MPI+X-based traditionally used counterpart in terms of performance, scalability, and productivity. The results show that Chapel is much more expressive and up to $7.8\times$ more productive than MPI+Pthreads. In addition, the Chapel-based search presents performance equivalent to MPI+Pthreads for its best results on 1024 cores and reaches up to 84% of the linear speedup. However, there are cases where the built-in load balancing provided by Chapel cannot produce regular load among computer nodes. In such cases, the MPI-based search can be up to $4.2\times$ faster and reaches speedups up to $3\times$ higher than its Chapel-based counterpart. Thorough feedback on the experience is given, pointing out the strengths and limitations of the two opposite approaches (Chapel vs. MPI+X). To the best of our knowledge, the present study is pioneering within the context of exact parallel optimization.

7.3.2. A computationally efficient Branch-and-Bound algorithm for the permutation flow-shop scheduling problem

Participants: Jan Gmys, Nouredine Melab, Mohand Mezmaz [University of Mons, Blegium], Daniel Tuyttens [University of Mons, Blegium].

In [15], we propose an efficient Branch-and-Bound (B&B) algorithm for the permutation flow-shop problem (PFSP) with makespan objective. We present a new node decomposition scheme that combines dynamic branching and lower bound refinement strategies in a computationally efficient way. To alleviate the computational burden of the two-machine bound used in the refinement stage, we propose an online learning-inspired mechanism to predict promising couples of bottleneck machines. The algorithm offers multiple choices for branching and bounding operators and can explore the search tree either sequentially or in parallel on multicore CPUs. In order to empirically determine the most efficient combination of these components, a series of computational experiments with 600 benchmark instances is performed. A main insight is that the problem size, as well as interactions between branching and bounding operators substantially modify the trade-off between the computational requirements of a lower bound and the achieved tree size reduction. Moreover, we demonstrate that parallel tree search is a key ingredient for the resolution of large problem instances, a strong super-linear speedups can be observed. An overall evaluation using two well-known benchmarks indicates that the proposed approach is superior to previously published B&B algorithms. For the first benchmark we report the exact resolution – within less than 20 minutes – of two instances defined by 500 jobs and 20 machines that remained open for more than 25 years, and for the second a total of 89 improved best-known upper bounds, including proofs of optimality for 74 of them.

7.3.3. A Parallel Tabu Search for the Large-scale Quadratic Assignment Problem

Participants: Omar Abdelkafi, Bilel Derbel, Arnaud Liefooghe.

Parallelization is an important paradigm for solving massive optimization problems. Understanding how to fully benefit form the aggregated computing power and what makes a parallel strategy successful is a difficult issue. In [22], we propose a simple parallel iterative tabu search (PITS) and study its effectiveness with respect to different experimental settings. Using the quadratic assignment problem (QAP) as a case study, we first consider different small-and medium-size instances from the literature and then tackle a large-size instance that was rarely considered due the its inherent solving difficulty. In particular, we show that a balance between the number of function evaluations each parallel process is allowed to perform before resuming the search is a critical issue to obtain an improved quality.

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.

- *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 Decathlon (2019, Lille)*: This project deals with scalable multi-objective optimization for the eco-design of material, clothing and sports shoes.
- *In contact with Vinci Autoroutes (2019, Paris)*: This project deals with the optimization of deep neural networks for computer vision.

9. Partnerships and Cooperations

9.1. Regional Initiatives

- *CPER Data (2015-2020)*: 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 (2015-2020)*: 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) and a one-year (2019-2020) engineer position (N. Aslimani).

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 - 03 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

University of Mons, Belgium, Parallel surrogate-assisted optimization, large-scale exact optimization, two joint PhDs (M. Gobert and G. Briffoteaux).

University of Luxembourg, Q-Learning-based Hyper-Heuristic for Generating UAV Swarming Behaviours.

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.

University of Mohamed V, Morocco, Large scale (multi-objective) optimization.

9.4. International Initiatives

9.4.1. Inria International Labs

9.4.1.1. Other IIL projects

Title: Frontiers in Massive Optimization and Computational Intelligence (MODO)

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

- School of Public Health and Preventive Medicine, Monash University, Australia (ranked 73^{th} over 1000 in the Shangai international ranking).
- Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Maracanaú, Brazil.

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. It is focused on evolutionary many-objective optimization and its application to smart cities and engineering design.

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

- Luís Paquete, University of Coimbra, Portugal, April 2019
- Darrell Whitley, Colorado State University, USA, Invited Professor, July 2019
- Minami Miyakawa, Shinshu University, Japan, October 2019
- Renzo Massobrio, Republica University, Uruguay, January to March 2019
- Bernabe Dorronsoro, University of Cadiz, Spain, March 2019
- Rachid Ellaia, University of Mohamed V, Morocco, April 2019

9.5.1.1. Internships

- Kazuki Maeda, Shinshu University, Japan, November-December 2019
- Kyo Migishima, Shinshu University, Japan, November-December 2019

9.5.2. Visits to International Teams

9.5.2.1. Explorer programme

- T. Carneiro, Cray Inc., Seattle, WA, USA, December 2019
- E-G. Talbi, University of Elche, Spain, November 2019
- E-G. Talbi, University of Luxembourg, Luxembourg, June 2019
- E-G. Talbi, University of Bangkok, Thailand, January 2019
- E-G. Talbi, University of Colorado, USA, November 2019
- E-G. Talbi, University of Mohamed V, Morocco, April 2019
- A. Liefooghe, Shinshu University, Japan, May 2019
- B. Derbel, University of Coimbra, Portugal, October 2019
- A. Liefooghe, University of Coimbra, Portugal, October 2019
- N. Melab, University of Mons, Belgium, working meetings throughout the year

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 chair): Intl. Conf. on Multiple Objective Programming and Goal Programming (MOPGP'2019), Marrakech, Morocco, Oct 28-31, 2019.
- N. Melab (Workshop co-chair): Intl. Workshop on the Synergy of Parallel Computing, Optimization and Simulation (HPCS/PaCOS'2019), Dublin, Ireland, Jul 15-19, 2019.
- E-G. Talbi (Steering committee Chair): Intl. Conf. on Optimization and Learning (OLA'2019), Bangkok, Thailand, Jan 29-31, 2019.
- E-G. Talbi (Steering committee): 9^{th} IEEE Workshop Parallel Distributed Computing and Optimization (IPDPS/PDCO'2019), Rio de Janeiro, Brazil, May 20-24, 2019.
- O. Abdelkafi, B. Derbel and A. Liefooghe (workshop co-chairs): 2^{nd} Intl. Workshop on Computational Intelligence for Massive Optimization (CIMO 2019), Lille, France, July 2019 (with H. Aguirre, K. Tanaka and S. Verel).

- B. Derbel (workshop co-chair): Decomposition Techniques in Evolutionary Optimization (DTEO), workshop at GECCO 2019, Prague, Czech Republic, July 2019 (with K. Li, X. Li, S. Zapotecas, and Q. Zhang).
- A. Liefooghe (workshop co-chair): Landscape-aware heuristic search (LAHS), workshop at GECCO 2019, Prague, Czech Republic, July 2019 (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 CEC 2019, Wellington, New Zealand, June 2019 (with S. Zapotecas, K. Li and Q. Zhang).
- A. Liefooghe (track chair): GECCO 2019: Genetic and Evolutionary Computation Conference, Evolutionary multi-objective Optimization (EMO) track (Prague, Czech Republic, 2019).
- N. Melab: Chair of 4 simulation and HPC-related seminars at Université de Lille: The Arctic University of Norway (HPC Group, UiT), IBM, DSI (Supercomputing division) Ulille, Inria Lille), Oct-Dec 2019.

10.1.2. Scientific Events: Selection

10.1.2.1. Chair of Conference Program Committees

- A. Liefooghe (program co-chair): EvoCOP 2019: 19$^{\text{th}}$ European Conference on Evolutionary Computation in Combinatorial Optimisation (Leipzig, Germany, 2019).

10.1.2.2. Member of the Conference Program Committees

- IEEE Congress on Evolutionary Computation (CEC), Wellington, New Zealand, Jun 10-13, 2019.
- IEEE Workshop on Understanding of Evolutionary Optimization Behavior, Wellington, New Zealand, Jun 10-13, 2019.
- The ACM Genetic and Evolutionary Computation Conference (GECCO), Prague, Czech Republic, July 13-17, 2019.
- 13$^{\text{th}}$ Metaheuristics International Conference (MIC), Cartagena, Colombia, July 28-31, 2019.
- The 2018 International Conference on High Performance Computing & Simulation (HPCS), Dublin, Ireland, July 15–19, 2019.
- IEEE Intl. Workshop on Parallel/Distributed Computing and Optimization (IPDPS/PDCO), Rio de Janeiro, Brazil, May 20-24, 2019.
- EvoCOP'2019, 19$^{\text{th}}$ European Conference on Evolutionary Computation in Combinatorial Optimization, Leipzig, Germany, Apr 24-26, 2019.
- Int. Conf. on Multiple objective Programming and Goal Programming (MOPGP'2019), Marrakech, Morocco, Oct 28-31, 2019.
- Intl. Conf. on Optimization and Learning (OLA'2019), Bangkok, Thailand, Jan 29-31, 2019.
- Int. Conf. on Computing (ICC 2019), Springer's CCIS Book Series, Riyadh, Saudi Arabia, Oct 22-24, 2019.
- 15$^{\text{th}}$ Workshop on Foundations of Genetic Algorithms (FOGA), Potsdam, Germany, 2019.
- 10$^{\text{th}}$ Intl. Conference on Evolutionary Multi-criterion Optimization (EMO), Michigan, USA, 2019.
- ICANN'2019 28$^{\text{th}}$ Intl. Conf. on Artificial Neural Networks, Munich, Germany, Sept 2019.
- Metaheuristics Intl. Conference (MIC'2019), Cartagena, Colombia, July 2019.
- Intl. Conference on Industrial Engineering and Systems Management (IESM 2019), Shanghai, China, Sept 2019.
- 8$^{\text{th}}$ Intl. Conf. on Modeling, Simulation and Applied Optimizaiton (ICMSAO'2019), Bahrin, April 2019.
- Colloque sur l'Optimisation et les Systèmes d'information (COSI), Tizi-Ouzou, Algérie, Jun 24-26, 2019.

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- N. Melab: Associate Editor of ACM Computing Surveys (IF: 6.131) since 2019.
- N. Melab: Guest and Managing Editor (in collaboration with P. Korosec, J. Gmys and I. Chakroun) of a special on *Synergy between Parallel Computing, Optimization and Simulation* in *Journal of Computational Science (JoCS)*, 2019.
- E-G. Talbi: Guest Editor (with L. Amodeo and F. Yalaoui) of a special issue on *Metaheuristics in Industry 4.0* in *Swarm and evolutionary computation*, 2019.
- E-G. Talbi. Guest Editor (with H. Masri) on *Multiple criteria decision making models for economic developement* in *JMCDA Journal of Multi-Criteria Decision Analysis*, 2019.
- B. Derbel: Associate Editor, IEEE Transactions on Systems, Man and Cybernetics: Systems (IEEE).

10.1.3.2. Reviewer - Reviewing Activities

- Transactions on Evolutionary Computation (IEEE TEC, IF: 8.508), IEEE.
- ACM Computing Surveys (IF: 6.131), ACM.
- Swarm and Evolutionary Computation (SWEVO, IF: 6.330), Elsevier.
- Future Generation Computer Systems (FGCS, IF: 5.7), Elsevier.
- European Journal of Operational Research [15], Elsevier.
- IEEE Transactions on Parallel and Distributed Systems (IEEE TPDS, IF: 3.4), IEEE.
- Journal of Computational Science (JoCS, IF: 2.5), Elsevier.
- Annals of Operations Research (IF: 2.284), Springer.
- Journal of Heuristics (JoH, IF: 1.392), Springer.
- Intl. Journal on Artificial Intelligence Tools (IJAIT, IF: 0.8), World Scientific.

10.1.4. Invited Talks

- E-G. Talbi. Learning-based metaheuristics, Distinguished seminar, University of Michigan, USA, Jan 2019.
- E-G. Talbi. Machine learning and optimization: inseparable disciplines, Keynote speaker, KST'2019 11^{th} Intl. Conf. on Knowledge and Smart Technology, Phuket, Thailand, Jan 2019.
- E-G. Talbi. How machine learning can help metaheuristics?, Invited seminar, American University of Sharjah, Emirates Arabs United, Feb 2019.
- E-G. Talbi. Machine learning into optimization, Invited seminar, University of Elche, Spain, Nov 2019.

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: 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 Scientific Board (Bureau Scientfique du Centre) for the Inria Lille - Nord Europe research center.
- N. Melab: Member of the steering committee of “Maison de la Simulation” at Université de Lille.

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 High-perforpmance Computing and Simulation, 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.

- Master leading: O. Abdelkafi, superviser of the Master MIAGE alternance, Université de Lille, FRANCE.

10.2.2. Supervision

- PhD: Z. Garroussi, Multi-objective matheuristics for demand-side management in smart grids, To be defended on December 21th, 2019. PhD supervised by 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, Deep Gaussian processes and Bayesian optimization for non-stationary, multi-objective and multi-fidelity problems, Oct 2017, El-Ghazali Talbi and Nouredine Melab.
- PhD in progress (cotutelle): Maxime Gobert, Parallel multi-objective global optimization with applications to several simulation-based exlporation parameter, Oct 2018, Nouredine Melab (Université de Lille) and Daniel Tuyttens (Université de Mons, BELGIUM).
- PhD in progress (cotutelle): Guillaume Briffoteaux, Bayesian Neural Networks-assisted multi-objective evolutionary algorithms: Application to the Tuberculosis Transmission Control, Oct 2017, Nouredine Melab (Université de Lille) and Daniel Tuyttens (Université de Mons, BELGIUM).
- PhD in progress: Jeremy Sadet, Surrogate-based optimization in automotive brake design, El-Ghazali Talbi (Université de Lille), Thierry Tison (Université Polytechnique Hauts-de-France, FRANCE).
- 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 (cotutelle): Alexandre Jesus, Algorithm selection in multi-objective optimization, Bilel Derbel and Arnaud Liefooghe (Université de Lille), Luís Paquete (University of Coimbra, PORTUGAL).

10.3. Popularization

10.3.1. Internal or external Inria responsibilities

- N. Melab: Chargé de Mission of High Performance Computing and Simulation at Université de Lille, since 2010.

10.3.2. Internal action

- A. Liefooghe: 30 minutes de sciences, Inria Lille-Nord Europe, Lille, France, June 2019.
- O. Abdelkafi: Intervention auprès des inspecteurs d'académie, Inria Lille-Nord Europe, Lille, France, Mars 2019.

11. Bibliography

Major publications by the team in recent years

[1] O. ABDELKAFI, L. IDOUMGHAR, J. LEPAGNOT. *A Survey on the Metaheuristics Applied to QAP for the Graphics Processing Units*, in "Parallel Processing Letters", 2016, vol. 26, n^{o} 3, pp. 1–20

[2] A. BENDJOUDI, N. MELAB, E. TALBI. *FTH-B&B: A Fault-Tolerant HierarchicalBranch and Bound for Large ScaleUnreliable Environments*, in "IEEE Trans. Computers", 2014, vol. 63, n^{o} 9, pp. 2302–2315

[3] S. CAHON, N. MELAB, E. TALBI. *ParadisEO: A Framework for the Reusable Design of Parallel and Distributed Metaheuristics*, in "J. Heuristics", 2004, vol. 10, n^{o} 3, pp. 357–380

[4] F. DAOLIO, A. LIEFOOGHE, S. VEREL, H. AGUIRRE, K. TANAKA. *Problem Features versus Algorithm Performance on Rugged Multiobjective Combinatorial Fitness Landscapes*, in "Evolutionary Computation", 2017, vol. 25, n^{o} 4

[5] B. DERBEL. *Contributions to single- and multi- objective optimization: towards distributed and autonomous massive optimization*, Université de Lille, 2017, HDR dissertation

[6] B. DERBEL, A. LIEFOOGHE, Q. ZHANG, H. AGUIRRE, K. TANAKA. *Multi-objective Local Search Based on Decomposition*, in "Parallel Problem Solving from Nature - PPSN XIV - 14th International Conference, Edinburgh, UK, September 17-21, 2016, Proceedings", 2016, pp. 431–441

[7] J. GMYS, M. MEZMAZ, N. MELAB, D. TUYTTENS. *IVM-based parallel branch-and-bound using hierarchical work stealing on multi-GPU systems*, in "Concurrency and Computation: Practice and Experience", 2017, vol. 29, n^{o} 9

[8] A. LIEFOOGHE, B. DERBEL, S. VEREL, H. AGUIRRE, K. TANAKA. *Towards Landscape-Aware Automatic Algorithm Configuration: Preliminary Experiments on Neutral and Rugged Landscapes*, in "Evolutionary Computation in Combinatorial Optimization - 17th European Conference, EvoCOP 2017, Amsterdam, The Netherlands, April 19-21, 2017, Proceedings", 2017, pp. 215–232

[9] T. V. LUONG, N. MELAB, E. TALBI. *GPU Computing for Parallel Local Search Metaheuristic Algorithms*, in "IEEE Trans. Computers", 2013, vol. 62, n^{o} 1, pp. 173–185

[10] A. NAKIB, S. OUCHRAA, N. SHVAI, L. SOUQUET, E. TALBI. *Deterministic metaheuristic based on fractal decomposition for large-scale optimization*, in "Appl. Soft Comput.", 2017, vol. 61, pp. 468–485

Publications of the year

Articles in International Peer-Reviewed Journals

[11] J. S. ALMEIDA, P. P. REBOUÇAS FILHO, T. CARNEIRO, W. WEI, R. DAMAŠEVIČIUS, R. MASKELIŪNAS, V. H. C. DE ALBUQUERQUE. *Detecting Parkinson's Disease with Sustained Phonation and Speech Signals using Machine Learning Techniques*, in "Pattern Recognition Letters", July 2019, vol. 125, pp. 55-62 [*DOI :* 10.1016/J.PATREC.2019.04.005], https://hal.archives-ouvertes.fr/hal-02380596

[12] L. ASLI, M. AÏDER, E.-G. TALBI. *Solving a dynamic combinatorial auctions problem by a hybrid metaheuristic based on a fuzzy dominance relation*, in "RAIRO - Operations Research", January 2019, vol. 53, n^{o} 1, pp. 207-221 [*DOI :* 10.1051/RO/2018051], https://hal.archives-ouvertes.fr/hal-02304722

[13] T. CARNEIRO, J. GMYS, N. MELAB, D. TUYTTENS. *Towards ultra-scale Branch-and-Bound using a high-productivity language*, in "Future Generation Computer Systems", November 2019 [*DOI :* 10.1016/J.FUTURE.2019.11.011], https://hal.archives-ouvertes.fr/hal-02371238

[14] N. DUPIN, E.-G. TALBI. *Parallel matheuristics for the discrete unit commitment problem with min-stop ramping constraints*, in "International Transactions in Operational Research", January 2020, vol. 27, n^{o} 1, pp. 219-244 [*DOI :* 10.1111/ITOR.12557], https://hal.archives-ouvertes.fr/hal-02304758

[15] J. GMYS, M. MEZMAZ, N. MELAB, D. TUYTTENS. *A computationally efficient Branch-and-Bound algorithm for the permutation flow-shop scheduling problem*, in "European Journal of Operational Research", 2020, forthcoming, https://hal.inria.fr/hal-02421229

[16] A. LIEFOOGHE, F. DAOLIO, S. VEREL, B. DERBEL, H. AGUIRRE, K. TANAKA. *Landscape-aware performance prediction for evolutionary multi-objective optimization*, in "IEEE Transactions on Evolutionary Computation", 2019, forthcoming [*DOI :* 10.1109/TEVC.2019.2940828], https://hal.archives-ouvertes.fr/hal-02294201

[17] A. NAKIB, L. SOUQUET, E.-G. TALBI. *Parallel fractal decomposition based algorithm for big continuous optimization problems*, in "Journal of Parallel and Distributed Computing", November 2019, vol. 133, pp. 297-306 [*DOI :* 10.1016/J.JPDC.2018.06.002], https://hal.archives-ouvertes.fr/hal-02304882

[18] J. PELAMATTI, L. BRÉVAULT, M. BALESDENT, E.-G. TALBI, Y. GUERIN. *Efficient global optimization of constrained mixed variable problems*, in "Journal of Global Optimization", March 2019, vol. 73, n^{o} 3, pp. 583-613 [*DOI :* 10.1007/S10898-018-0715-1], https://hal.archives-ouvertes.fr/hal-02304730

[19] O. SCHUTZE, C. HERNANDEZ, E.-G. TALBI, J.-Q. SUN, Y. NARANJANI, F.-R. XIONG. *Archivers for the representation of the set of approximate solutions for MOPs*, in "Journal of Heuristics", February 2019, vol. 25, n^{o} 1, pp. 71-105 [*DOI :* 10.1007/S10732-018-9383-Z], https://hal.archives-ouvertes.fr/hal-02304717

[20] E.-G. TALBI. *A unified view of parallel multi-objective evolutionary algorithms*, in "Journal of Parallel and Distributed Computing", November 2019, vol. 133, pp. 349-358 [*DOI :* 10.1016/J.JPDC.2018.04.012], https://hal.archives-ouvertes.fr/hal-02304734

[21] A. TCHERNYKH, U. SCHWIEGELSOHN, E.-G. TALBI, M. BABENKO. *Towards understanding uncertainty in cloud computing with risks of confidentiality, integrity, and availability*, in "Journal of computational science", September 2019, vol. 36, 100581 p. [*DOI :* 10.1016/J.JOCS.2016.11.011], https://hal.archives-ouvertes.fr/hal-02304771

International Conferences with Proceedings

[22] O. ABDELKAFI, B. DERBEL, A. LIEFOOGHE. *A Parallel Tabu Search for the Large-scale Quadratic Assignment Problem*, in "IEEE CEC 2019 - IEEE Congress on Evolutionary Computation", Wellington, New Zealand, June 2019, https://hal.archives-ouvertes.fr/hal-02179193

[23] N. BERVEGLIERI, B. DERBEL, A. LIEFOOGHE, H. AGUIRRE, K. TANAKA. *Surrogate-assisted multiobjective optimization based on decomposition*, in "GECCO '19 - Proceedings of the Genetic and Evolutionary Computation Conference", Prague, Czech Republic, ACM Press, July 2019, pp. 507-515 [*DOI :* 10.1145/3321707.3321836], https://hal.archives-ouvertes.fr/hal-02292851

[24] T. CARNEIRO, N. MELAB. *An Incremental Parallel PGAS-based Tree Search Algorithm*, in "HPCS 2019 - International Conference on High Performance Computing & Simulation", Dublin, Ireland, July 2019, https://hal.archives-ouvertes.fr/hal-02170842

[25] T. CARNEIRO, N. MELAB. *Productivity-aware Design and Implementation of Distributed Tree-based Search Algorithms*, in "ICCS 2019 - International Conference on Computational Science", Faro, Portugal, June 2019, https://hal.archives-ouvertes.fr/hal-02139177

[26] B. DERBEL, A. LIEFOOGHE, S. VEREL, H. AGUIRRE, K. TANAKA. *New Features for Continuous Exploratory Landscape Analysis based on the SOO Tree*, in "FOGA 2019 - 15th ACM/SIGEVO Workshop on Foundations of Genetic Algorithms", Potsdam, Germany, ACM Press, August 2019, pp. 72-86, https://hal.inria.fr/hal-02282986

[27] M. GOBERT, J. GMYS, J.-F. TOUBEAU, F. VALLEE, N. MELAB, D. TUYTTENS. *Surrogate-Assisted Optimization for Multi-stage Optimal Scheduling of Virtual Power Plants*, in "PaCOS 2019 - International Workshop on the Synergy of Parallel Computing, Optimization and Simulation (part of HPCS 2019)", Dublin, Ireland, July 2019, https://hal.inria.fr/hal-02178314

[28] T. ITO, H. AGUIRRE, K. TANAKA, A. LIEFOOGHE, B. DERBEL, S. VEREL. *Estimating Relevance of Variables for Effective Recombination*, in "EMO 2019 - International Conference on Evolutionary Multi-Criterion Optimization", East Lansing, Michigan, United States, February 2019, pp. 411-423 [*DOI :* 10.1007/978-3-030-12598-1_33], https://hal.archives-ouvertes.fr/hal-02064547

[29] *Best Paper*
Y. MARCA, H. AGUIRRE, S. Z. MARTINEZ, A. LIEFOOGHE, B. DERBEL, S. VEREL, K. TANAKA. *Approximating Pareto Set Topology by Cubic Interpolation on Bi-objective Problems*, in "EMO 2019 - International Conference on Evolutionary Multi-Criterion Optimization", East Lansing, Michigan, United States, February 2019, pp. 386-398 [*DOI :* 10.1007/978-3-030-12598-1_31], https://hal.archives-ouvertes.fr/hal-02064548.

[30] H. MONZÓN, H. AGUIRRE, S. VEREL, A. LIEFOOGHE, B. DERBEL, K. TANAKA. *Dynamic compartmental models for algorithm analysis and population size estimation*, in "Genetic and Evolutionary Computation Conference Companion", Prague, Czech Republic, Proceedings of the Genetic and Evolutionary Computation Conference Companion (GECCO '19), ACM Press, July 2019, pp. 2044-2047 [*DOI :* 10.1145/3319619.3326912], https://hal.archives-ouvertes.fr/hal-02436226

[31] J. PELAMATTI, L. BRÉVAULT, M. BALESDENT, E.-G. TALBI, Y. GUERIN. *Surrogate model based optimization of constrained mixed variable problems: application to the design of a launch vehicle thrust frame*, in "SciTech 2019 - AIAA Science and Technology Forum and Exposition", San Diego, United States, American Institute of Aeronautics and Astronautics, January 2019 [*DOI :* 10.2514/6.2019-1971], https://hal.archives-ouvertes.fr/hal-02304816

[32] L. SOUQUET, A. NAKIB, E.-G. TALBI. *Deterministic multi-objective fractal decomposition algorithm*, in "MIC 2019 - 13th Metaheuristics International Conference", Cartagena, Colombia, July 2019, https://hal.archives-ouvertes.fr/hal-02304975

National Conferences with Proceedings

[33] D. DELABROYE, S. DELAMARE, D. LOUP, L. NUSSBAUM. *Remplacer un routeur par un serveur Linux : retour d'expérience des passerelles d'accès à Grid'5000*, in "JRES - Journées Réseaux de l'Enseignement et de la Recherche", Dijon, France, December 2019, https://hal.inria.fr/hal-02401684

Scientific Books (or Scientific Book chapters)

[34] T. BARTZ-BEIELSTEIN, B. FILIPIČ, P. KOROŠEC, E.-G. TALBI. *High-Performance Simulation-Based Optimization*, Springer, 2020 [*DOI :* 10.1007/978-3-030-18764-4], https://hal.archives-ouvertes.fr/hal-02304686

[35] N. DUPIN, F. NIELSEN, E.-G. TALBI. *K-Medoids Clustering Is Solvable in Polynomial Time for a 2d Pareto Front*, in "Optimization of Complex Systems: Theory, Models, Algorithms and Applications", Springer, June 2020, pp. 790-799 [*DOI :* 10.1007/978-3-030-21803-4_79], https://hal.archives-ouvertes.fr/hal-02304806

[36] A. LIEFOOGHE, L. PAQUETE. *Proceedings of the 19th European conference on evolutionary computation in combinatorial optimization (EvoCOP 2019)*, Lecture Notes in Computer Science, Springer, 2019, vol. 11452 [*DOI :* 10.1007/978-3-030-16711-0], https://hal.archives-ouvertes.fr/hal-02292912

[37] N. MELAB, J. GMYS, M. MEZMAZ, D. TUYTTENS. *Many-core Branch-and-Bound for GPU accelerators and MIC coprocessors*, in "High-Performance Simulation-Based Optimization", T. BARTZ-BEIELSTEIN, B. FILIPIČ, P. KOROŠEC, E.-G. TALBI (editors), Studies in Computational Intelligence, Springer, June 2019, vol. 833, 16 p. , https://hal.inria.fr/hal-01924766

[38] J. PELAMATTI, L. BRÉVAULT, M. BALESDENT, E.-G. TALBI, Y. GUERIN. *Overview and Comparison of Gaussian Process-Based Surrogate Models for Mixed Continuous and Discrete Variables: Application on Aerospace Design Problems*, in "High-Performance Simulation-Based Optimization", Springer, June 2020, pp. 189-224 [*DOI :* 10.1007/978-3-030-18764-4_9], https://hal.archives-ouvertes.fr/hal-02304707

References in notes

[39] M. BALESDENT, L. BRÉVAULT, N. B. PRICE, S. DEFOORT, R. LE RICHE, N.-H. KIM, R. T. HAFTKA, N. BÉREND. *Advanced Space Vehicle Design Taking into Account Multidisciplinary Couplings and Mixed Epistemic/Aleatory Uncertainties*, in "Space Engineering: Modeling and Optimization with Case Studies", G. FASANO, J. D. PINTÉR (editors), Springer International Publishing, 2016, pp. 1–48, http://dx.doi.org/10.1007/978-3-319-41508-6_1

[40] B. DERBEL, D. BROCKHOFF, A. LIEFOOGHE, S. VEREL. *On the Impact of Multiobjective Scalarizing Functions*, in "Parallel Problem Solving from Nature - PPSN XIII - 13th International Conference, Ljubljana, Slovenia, September 13-17, 2014. Proceedings", 2014, pp. 548–558

[41] B. DERBEL, A. LIEFOOGHE, G. MARQUET, E. TALBI. *A fine-grained message passing MOEA/D*, in "IEEE Congress on Evolutionary Computation, CEC 2015, Sendai, Japan, May 25-28, 2015", 2015, pp. 1837–1844

[42] R. HAFTKA, D. VILLANUEVA, A. CHAUDHURI. *Parallel surrogate-assisted global optimization with expensive functions – a survey*, in "Structural and Multidisciplinary Optimization", 2016, vol. 54(1), pp. 3–13

[43] D. JONES, M. SCHONLAU, W. WELCH. *Efficient Global Optimization of Expensive Black-Box Functions*, in "Journal of Global Optimization", 1998, vol. 13(4), pp. 455–492

[44] J. PELAMATTI, L. BREVAULT, M. BALESDENT, E.-G. TALBI, Y. GUERIN. *How to deal with mixed-variable optimization problems: An overview of algorithms and formulations*, in "Advances in Structural and Multidisciplinary Optimization, Proc. of the 12th World Congress of Structural and Multidisciplinary Optimization (WCSMO12)", Springer, 2018, pp. 64–82, http://dx.doi.org/10.1007/978-3-319-67988-4_5

[45] F. SHAHZAD, J. THIES, M. KREUTZER, T. ZEISER, G. HAGER, G. WELLEIN. *CRAFT: A library for easier application-level Checkpoint/Restart and Automatic Fault Tolerance*, in "CoRR", 2017, vol. abs/1708.02030, http://arxiv.org/abs/1708.02030

[46] N. SHAVIT. *Data Structures in the Multicore Age*, in "Communications of the ACM", 2011, vol. 54, n^{o} 3, pp. 76–84

[47] M. SNIR, AL.. *Addressing Failures in Exascale Computing*, in "Int. J. High Perform. Comput. Appl.", May 2014, vol. 28, n^{o} 2, pp. 129–173

[48] E.-G. TALBI. *Combining metaheuristics with mathematical programming, constraint programming and machine learning*, in "Annals OR", 2016, vol. 240, n^{o} 1, pp. 171–215

[49] T. VU, B. DERBEL. *Parallel Branch-and-Bound in multi-core multi-CPU multi-GPU heterogeneous environments*, in "Future Generation Comp. Syst.", 2016, vol. 56, pp. 95–109

[50] X. ZHANG, Y. TIAN, R. CHENG, Y. JIN. *A Decision Variable Clustering-Based Evolutionary Algorithm for Large-Scale Many-Objective Optimization*, in "IEEE Trans. Evol. Computation", 2018, vol. 22, n^{o} 1, pp. 97–112