Departement of Research Evaluation

RESEARCH UNIT SELF-ASSESSMENT DOCUMENT

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2023-2024 EVALUATION CAMPAIGN
GROUP D

Team Combinatorial Optimization, Algorithms
LAMSADE, PSL Université & CNRS

Contents

1 GENERAL INFORMATION FOR THE CURRENT CONTRACT: COMBINATORIAL OPTIMIZATION, ALGORITHMS TEAM

1.1 Scientific subjects and their implications

The research conducted in the team *Combinatorial Optimization, Algorithms* (a.k.a. Team 2) is mainly about optimization. The team has a long tradition of studying combinatorial (i.e., discrete) problems, but recent developments include continuous aspects such as derivative-free optimization. Optimization problems are ubiquitous: minimizing some costs, or maximizing a profit, are recurring tasks of policy makers, manufacturers, and individuals. That is why algorithms with good performances (in terms of quality of the output and running time) can have a major impact on the society. Indeed, many present challenges can be cast as optimization problems: reducing pollution, saving energy, increasing the welfare of a population, etc. However, most optimization problems are complex and they involve different sources of intractability. Team 2, like many research teams across the world, contributes to the understanding and efficient resolution of optimization problems at different levels of abstraction: from theoretical analysis to concrete applications.
Team 2 participates in several scientific projects of LAMSADE. The ones described in this part are AGAPE (Algorithms with Performance Guarantees), MATHIS (Mathematical Programming and Discrete Structures), and MOCO (Multi-Objective Combinatorial Optimization). These projects deal with the multifaceted field of optimization from different and complementary perspectives: graphs (for modeling and exploiting underlying structures), parameterized complexity (for understanding which intrinsic dimension of a problem makes it computationally hard), approximation (for balancing worst-case quality of a solution and running time), mathematical programming (for exploiting the geometrical properties of combinatorial problems), robustness (for facing uncertainty on the input data), heuristics (for quickly providing operational solutions to hard real-life problems), etc. Moreover, the problems studied in Team 2 cover a wide variety of real life situations: network design, shelter location, community detection, portfolio, web services, etc.

Team 2 also significantly participates in other scientific projects of LAMSADE such as Games and Social Choice, MILES, and Web Services.

The scientific animation of Team 2 relies on: business meetings (every 2 months approximately), regular seminars (seminar of Team 2, transversal seminar, Phd seminar), joint supervision of PhD and Master theses, courses and workshops for master and PhD students (Master MODO, courses at the doctoral school), research conducted within funded projects, regular events (Journée du LAMSADE, journée du Team), one shot events (DHC, celebrations), collaborations with visiting researchers, PhD and HDR defenses. The animation of the team relies on the following resources: an annual budget of 14000 euros, and 2 grants for Master internships per year. We also apply and obtain PhD grants, and months of visiting professors.

Algorithms with Performance garantees (AGAPE)

The research project AGAPE (Algorithms with Performance Guarantees) mainly deals with computational questions arising from combinatorial optimization and decision problems. Given a problem, one ideally wants a fast resolution method, which traditionally means designing an algorithm whose worst-case running time (over the entire set of instances) is at most a polynomial of the input size n. However, the scientific community agrees on the fact that this goal is unachievable for most interesting combinatorial problems. A possible barrier is the uncertainty or incompleteness of the input data, but even when the input is perfectly known, the complexity theory establishes intractability of a wide range of problems. The research conducted within

AGAPE aims at circumventing these obstacles, i.e., tackling hard combinatorial problems with the following two general approaches: approximation and/or parameterization. The AGAPE project also covers computational challenges arising in **dynamical settings** such as algorithmic game theory, and online, probabilistic, and robust optimization.

Approximation. This theory provides an operational response to optimization problems even when the input data is either uncertain or incomplete. It is about designing algorithms whose running time is polynomial in n. For all instance, the cost of the output solution is no more than ρ times the optimum, where the approximation ratio ρ should be as close as possible to 1.
Parameterization. Instead of limiting our perception of the input to its size n, a relevant secondary measurement that encapsulates some of its structural aspects can be sought. Indeed, a parameter of the input, whose size is denoted by k, can substantially influence the hardness of a computational problem. Then, one tries to solve a problem with a fixed parameter (FPT) algorithm whose worst-case running time is $f(k) \cdot n^c$, for a constant c independent of both n and k, or, more generally, with an XP algorithm whose worst-case running time is $n^{f(k)}$. With such an algorithm, the problem is tractable for fixed values of k.
For both approximation and parameterization, an accompanying theory establishes the intractability of the approach, providing lower bounds either on ρ (approximation), or on the running time (parameterization).

During 2017-2022, the main contributions of AGAPE are the following. We participated in the introduction of the new notion called twin-width, which is now a widely studied subject in relation to graph theory, algorithms design, logic, and data structure [1, 2, 3, 4, 5, 6, 7]. We also proposed a new technique called the flow-augmentation, which led to the first FPT-algorithms for a range of cut problems in weighted graphs, the resolution of a major open problem in parameterized complexity, and a full classification of computational complexity of UNSAT of boolean CSPs [8, 9, 10]. The Erdös-Pósa property has been established for holes, thus resolving a major open question [11, 12]. Other contributions were to provide improved results on the complexity of several famous optimization problems on graphs when parameterized by well-studied parameters. For example, we precisely determined the complexity of k-COLORING parameterized by clique-width [13], while the article [14] precisely determined the complexity of DOMINATING SET for the same parameter. In a related line of work, the complexity of Satisfiability problems from AI parameterized by treewidth have been studied [15]. Two open questions in the field of reconfiguration problems have also been resolved [16, 17]. Members of AGAPE focused on studying the complexity of (mainly graph) problems, either purely theoretical [18, 19, 20, 21, 22] or coming from fields like bioinformatics [23, 24, 25], often with a parameterized complexity point of view. Problems affecting the safety of persons were also studied, namely a probabilistic approximation algorithm which guarantees to produce a modification of the topology of a network stopping the spread of an epidemic [26], approximation algorithms for finding (or partition into) defensive alliances or communities in graphs [27, 28, 29, 30, 31, 32, 33], approximation algorithms for modifying a network in an degree-based anonymous one [34, 35, 36], parameterized algorithms for modifying a network and keeping the shortest path bounded [37], and parameterized algorithms for a variant of the VC-dimension [38]. We contributed to the treatment of uncertainty in optimization problems. Given a probability distribution, probabilistic optimization is to find a solution that minimizes the expected value. Robust optimization consists of computing a solution that is acceptable in a majority of scenarios, but never too bad. We studied the approximability of the probabilistic dominating set problem [39], together with the probabilistic and robust p-center problems to locate shelters in wildfire context (introduced in the H2020 GEO-SAFE project) [40]. Regarding the computational complexity of models involving multiple actors, we determined the value of metrics related to the approximation ratio such as the price of anarchy/stability/fairness [41, 42], and the distortion [43]. Contributions in this vein also comprise approximation algorithms for maximizing the social welfare in a common budget apportionment problem [44, 42], optimizing a new fairness criterion for distributing indivisible goods [45], and allocating objects in social

networks [46, 47].

Mathematical Programming and Discrete Structures (MATHIS).

Integer linear programming theory offers general methods to exploit the structural properties of combinatorial problems in order to solve them more efficiently. These structural properties are well translated in terms of integrality of polyhedra, and of duality in linear programming. Although a lot of canonical combinatorial problems are now well understood, many fundamental questions are still open in this area, and it is still challenging to exploit the structure of sophisticated problems, especially those that arise in real-world applications, where constraints are of various type, including robustness.
The Mathis project revolves around this kind of links between structure and efficiency, but its recent evolution is towards more tools, namely the probabilistic method and general optimization.
Probabilistic graph theory and robustness. A recent selected contribution is the disproof of the so-called "Normal Graph Conjecture" due to Janos Kőrner (1999), which had its roots in information theory [48]. Although the disproof is not constructive, through use of probabilistic techniques, we showed that in fact almost all graphs with certain density are counterexamples. Another contribution was extending a classical result of Lovász on existence of small dominating sets to independent dominating sets under mild (and necessary) conditions [49]. Other contributions include decomposition conjectures in graphs due to Barat and Thomassen from 2006: for example, we showed that the edges of any sufficiently connected graph can be partitioned into copies P_ℓ, the path of length ℓ (under the obvious necessary condition that the number of edges is divisible by ℓ) [50]. The more general conjecture claims that the same decomposition holds when P_ℓ is replaced by an arbitrary tree - we settled this affirmatively as well. A complete solution (of about one page) to a problem asked by Paul Seymour at a Princeton University workshop over a decade ago is given in [51]. Robust optimization focuses on the incorporation of uncertainty and indetermination in the modeling of decision and optimization problems. The main research contributions were to propose new robustness models applied to the optimization of financial portfolio [52], and the location of fire-resistant shelters [53].
Polyhedra and network optimization. The studied Polyhedra are convex-hulls of characteristic 0-1-vectors of feasible solutions of a combinatorial problem. Extended formulations add more dimensions to the problem, in order to deal with simplified polyhedra (think that the shadow of a cube may have more facets than the cube the projection of which it is, indeed, the shadow could be an octogone). This idea is exploited for a large class of network design problems with given connectivity requirements [54] and various connectivity constraints such as bounded length paths [55, 56, 57]. Security issues in telecommunication networks are studied in [58]. A full characterization of the minimal subsets of arcs whose vertex-set does not induce a DAG is exploited to make a strong formulation [59].
Strong duality properties, such as min-max theorems, are well-translated in terms of TDI system, that is, a linear system the dual of which has integer solutions. This is strengthened by the notion of box-TDI systems, that is, when TDIness holds with any bounds on the primal variables. A min-max relation for the set of cycles on a given root vertex is studied in [60]. The box-TDIness of the k-edge-connected polyhedron in terms of series-parallel graphs is characterized in [61]. For this polyhedron, we also provided a description by an integer TDI system. It was proved that many classical linear systems defined from a graph G are box-TDI if and only if G is series-parallel [62]. These systems are associated with T-joints, cuts, cycles, and multicuts.
General Optimization. The core of this research is derivative-free optimization. In [63], a popular method for general optimization problems is revisited, and equipped with theoretical guarantees without hindering its practical appeal. In [64], an algorithm dedicated to solving complex problems where only inexact information can be obtained is described, having appli-

cations to data assimilation and machine learning. A PhD thesis aimed at exploring connections between certain concepts in derivative-free optimization and discrete notions from graph theory.

Integer linear programming and Applications. When solving a real instance of a combinatorial optimization problem, a linear relaxation allows to eliminate non-optimal branchings during the enumerating process. Such approach is developed for automatic composition of Web Services [65]. Numerical experiments have been done on the practical efficiency of a reformulation for the coloring problem [66] and for some of its generalizations [67]. Given an exponential-size linear relaxation and a point x, the separation problem is to, either certify feasibility of x, or to give an inequality violated by x. Separation problems are solved in [68, 69], which is known to ensure the polynomiality of solving the linear relaxation. Some challenging graph optimization problems have been addressed using new formulations that exploit novel valid inequalities, and problem structure. This is the case for the partitioned Steiner tree problem [70], which arises in the corridor design problem, i.e., establishing wildlife corridors to connect fragmented habitats of different endangered species. Some variants of the dominating set problem have also been approached by a combination of integer linear programming based algorithms, and heuristic approaches [71, 72]. Also, some classical combinatorial problems like the bin packing problem, have been solved in uncertain context using advanced decomposition methods and tailored algorithms [73]. Project scheduling with quality constraints was studied in [74, 75] and heuristic solution approaches to combinatorial problems such as the disassembly sequencing problem were developed in [76]. The discrete time break scheduling problem under fatigue was addressed in [77].

Multi-Objective Combinatorial Optimization (MOCO)

LAMSADE has long been well known for the development of multicriteria methods when the set of solutions, of relatively small size, is defined explicitly by an exhaustive list (ELECTRE methods). This project addresses multicriteria problems where the set of solutions is defined combinatorially. Indeed, many combinatorial optimization problems require taking into account multiple criteria. This is a transversal project, involving members of teams 1 and 2 of LAMSADE.

This stream of research is quite active with a specialized workshop *Recent Advances in Multi-Objective Optimization* (RAMOO), taking place each year, and the *Multicriteria Decision Making* (MCDM) conference, taking place every two years. Members of our team regularly attend these events where we present our results. Our team is among the leading European teams, being acknowledged by some invitations (two of us were invited keynote speakers in 2017 at RAMOO, and 2018 at ROADEF, respectively). We are also invited in all Dagstuhl seminars devoted to these topics which gather the main researchers in this field (Personalized Multiobjective Optimization 2018, Scalability in Multiobjective Optimization 2020, and the next one in 2023). We maintain a close cooperation with other teams through several bilateral projects (PHC Procope 2016-17 with University of Wuppertal, 2018-2019 with University of Kaiserslautern, PHC Procope Plus including the two previous Universities) and mutual visits with foreign colleagues to work on common topics including PhD students of each country (Kathrin Klamroth (Wuppertal, 2017, 2018, 2019, 2022), Clemens Thielen (Kaiserslautern 2017,2019), Stefan Ruzika (Kaiserslautern 2019), Jose Figueira (Lisbon, 2019), Andreia Guerreiro (Lisbon, 2022), Luis Paquete (Coimbra, 2022).

In multiobjective optimization, an important issue is to determine the set of efficient solutions (also called Pareto-optimal solutions) or more precisely the set of nondominated points, which corresponds to the images of these solutions in the objective space. A main challenge, both from the decision making and computational viewpoints, is the potentially huge size of the nondominated set which can grow exponentially with the size of the instances for multiobjective combinatorial optimization problems. Three main lines of research are developed in our project.

Production of theoretical results on the complexity and approximation of multi-objective optimization problems

Our theoretical works were mainly focused on the approximation of the set of efficient solutions with a priori guarantees. Part of this research was undertaken in close cooperation with several german teams.

We introduced a new multi-factor notion of approximation that is specifically tailored to the multiobjective case and we provide an efficient algorithm that computes an approximation of a multiobjective problem by using an exact or approximate algorithm for its weighted sum scalarization [78]. We characterize in [79] the class of multiobjective optimization problems having a polynomial-time computable approximate ε-Pareto set that is exact in one objective by the efficient solvability of an appropriate auxiliary problem. This class includes important problems such as multiobjective shortest path and spanning tree, and the approximation guarantee we provide is, in general, best possible. In particular, we studied, for biobjective matching problems, the best approximation we can obtain on both objectives when looking for a best compromise solution [80]. In addition, we studied properties of approximations based on dominance cones which generalize the standard Pareto cone [81].

Some problems closely related to the generation of the nondominated set are the parametric and budget constrained versions of standard combinatorial optimization problems. In this respect, we proposed parametric FPTAS for each the parametric versions of the shortest path problem, the assignment problem, and the minimum cost flow problem and a $(3/2 + \varepsilon)$-approximation algorithm for the parametric metric traveling salesman problem [82, 83]. We also introduced and studied a general downgrading variant of the interdiction problem where the goal is to minimize the downgraded capacity of a minimum source-sink cut subject to a node downgrading budget, for which we designed a new LP rounding approximation algorithm that provides a bi-criteria approximation algorithm [84].

Determination of the non dominated set or a preferred subset

We attach a particular importance to the design of practically efficient multi-objective algorithms. For this purpose, we have introduced and studied the essential concept of search region [85] which characterizes the part of the objective space where new non-dominated points may lie. Exploiting this concept as well as strong results enabling discarding large parts of the search region without probing them, we proposed a generic algorithm to enumerate the whole non-dominated set of multiobjective discrete problems [86], which is currently one of the best, if not the best, among the many algorithms proposed in the literature.

While generic algorithms rely on the use of generic MIP solvers, like CPLEX or Gurobi, specialized algorithms rely on extensions of single objective results and algorithms to the multi-objective case. In this respect, we showed that Karger's randomized contraction method can be adapted to multiobjective global minimum cut problems with a constant number of edge or node budget constraints to give efficient algorithms [87]. We also developed strongly polynomial algorithms for some parametric global minimum cut problems that are faster than a direct application of Megiddo's parametric search technique [88]. We also developed a specific algorithm for the multi-objective version of the traveling salesman problem using decomposition techniques [89].

We were interested in producing discrete and tractable representations of the set of non-dominated points for multi-objective optimization problems, both in the continuous and discrete cases. These representations must satisfy some conditions of coverage, i.e. providing a good approximation of the non-dominated set, spacing, i.e. without redundancies, and cardinality, i.e. with the smallest possible number of points. We studied the existence of such representations and provide an algorithm for the biobjective case in [90]. Another original stream of research deals with the generation of the preferred solutions in the sense of a partially defined weighted sum [91].

Implementation in real contexts

Since the creation of this project, we always focused on the effective implementation of multi-objective combinatorial optimization methods in various applied contexts. During the period, in cooperation with ONERA, we developed a biobjective branch and bound procedure in order to plan the mission of a shuttle to remove debris in the space [92]. In cooperation with Cisco, we also developed a multiobjective procedure to define workload migration strategies in data centers [93]. We also worked, in cooperation with Naval Group Research with a CIFRE contract, about the multiobjective optimization of complex systems gathering subsystems whose multiple objectives had to be coordinated.

1.2 Consideration of the recommendations in the previous report

Il est étonnant que malgré l'excellence de la recherche menée au LAMSADE et malgré la présence de plusieurs chercheurs de tout premier plan, le LAMSADE ne soit impliqué dans le montage d'aucun projet ERC (European Research Council) ou projet européen type H2020.

A H2020 project involving members of Team 2 has been funded. GEO-SAFE (Geospatial based Environment for Optimization - Systems Addressing Fire Emergencies) is a Marie Skłodowska-Curie Actions (MSCA) Research and Innovation Staff Exchange (RISE) project with more than 20 partners from 2016 to 2020, Cécile Murat (Dauphine coordinator), Virginie Gabrel, and Marcel Haddad.
Clément Royer was supported to submit an ERC starting grant in the Fall of 2022 (first results expected in May 2023). The topic of this grant aims at further developing the connections between discrete algorithms and continuous optimization.

A part les conventions CIFRE, il y a très peu de contrats collaboratifs impliquant des industriels (2 dans la période). Les prototypes logiciels développés par les membres du LAMSADE sont très peu diffusés et ne sont pas valorisés.

Indeed, we mostly have CIFRE contracts with industrial partners (ex Orange Lab, Huawei). This kind of contracts fits well with our type of research. We can mention that we also supervise master students doing their internship in companies (ex Orange Lab, Huawei). Some of our former PhD students found a job in these companies: Youcef Magnouche, Sébastien Martin, and Yassine Naghmouchi work for Huawei, whereas Amal Benhamiche, Morgan Chopin, Yann Dujardin work for Orange (Yann Dujardin did his PhD in Team 1). Laurent Gourvès worked with EDF through the PGMO project DAMPER.

Il s'agit de mieux identifier l'articulation recherche formation, en particulier entre le LAMSADE et le département d'enseignement MIDO (Mathématiques et Informatique de la Décision et des Organisations).

Professors, associate-professors, and researchers of the team are heavily involved in courses of MIDO. We also supervise master internships on research (M1 and M2). We recruit master students of MIDO as PhD candidates or postdocs: Sébastien Kerleau, Axel Faure Beaulieu, Louis Dublois, Pierre Cardi, Charles Nourry, Thomas Pontoizeau, Anaëlle Wilczynski. We also propose two workshops (associated with AGAPE and MATHIS) for students of Master MODO. These workshops are an initiation to research.

L'implication et la prise de responsabilités des chercheurs du LAMSADE dans les formations de master devraient être renforcées. Le LAMSADE est bien impliqué dans la formation par la recherche. Davantage d'implication des chercheurs aux côtés des enseignants-chercheurs serait un plus pour développer ou renforcer des parcours de masters dans les thématiques phares du laboratoire.

Eunjung Kim, Angelo Fanelli and Laurent Gourvès give Master courses (calculability and complexity, algorithmic game theory). L. Gourvès organizes the research workshop of Master MODO on AGAPE since september 2020. He is *Professeur attaché PSL* since september

2022, and head of the computer science program of the doctoral school SDOSE since october 2021.

Pour les pôles 1 et 2, la tendance à rester dans la continuité sur les thématiques historiques du LAMSADE et le manque de prise de risque sur des sujets disruptifs doit être un point de vigilance pour favoriser une dynamique scientifique propice à la créativité.

In 2017, Ararat Harutyunan was recruited as a *maître de conférences*. He brought a brand new expertise to the team: probabilistic graph theory. In 2019, Clément Royer was recruited as a *maître de conférences* to bring a new research area to Team 2, namely continuous optimization. This topic naturally connects to mathematical programming and the Mathis project within Team 2, while bearing strong connections with machine learning research such as that done in Team 3. This recruitment is disruptive since the type of optimization studied within Team 2 was almost exclusively discrete.
For the recent hiring of permanent members (replacement of Fabio Furini and Ridha Mahjoub), the team has explicitly mentioned in the job offer that candidates having a disruptive profile (but still in line with the spirit of the team), are strongly encouraged. Emiliano Lancini, who was recruited as *maître de conférences* in September 2022, has a strong background in Mathematical programming, and a good experience of teaching machine learning.
There many initiatives and collaborations of researchers of Team 2 with members of other teams. These collaborations force us to study different problems and use different tools. In this respect, let us mention the following actions: Clément Royer contributes to MILES and collaborates a lot with members of Team 3. Florian Sikora participated in ANR projects of Team 3 such as DELCO and STAPS and has co-authored several articles with members of Team 3 (articles including postdoctoral researchers recruited on the aforementioned projects: Paul Beaujean, Thomas Pontoizeau). Eunjung Kim has included members of Team 3 in her ANR projects ESIGMA and ASSK. Cristina Bazgan supervises a PhD student (C. Dang, CIFRE Orange) with Tristan Cazenave (Team 1) using Monte Carlo techniques. Laurent Gourvès, together with Julien Lesca from Team 1, have supervised the PhD theses of Anaëlle Wilczynski and Pierre Cardi on AI topics. L. Gourvès also collaborates with R. Laraki (Team 1) and Guillaume Vigeral (CEREMADE) on learning strategies in games (PhD thesis of Lucas Baudin). Michail Lampis has studied the computational complexity of voting rules [94] and the paremetrized complexity of some games [95, 96]. Recently, Ararat Hautyunyan has proposed a PhD thesis with Tristan Cazenave (from Team 1) on a disruptive topic (Deep reinforcement learning for hard graph problems). Emiliano Lancini is currently working on bankrupcy prediction using graph neural nerworks.

Le thème « algorithmes, optimisation combinatoire » n'a pas fait un effort conséquent pour projeter son activité de recherche dans l'horizon du futur contrat. Le projet donne l'image que l'excellence de l'activité actuelle soit un garant suffisant pour les années à venir. Toutefois, Il aurait été intéressant d'avoir une vision prospective sur le prochain contrat des grandes directions scientifiques qui seront prises par le thème.

We hope that the committee will appreciate the current research statement of Team 2 and its trajectory.

La production logicielle du thème reste faible au regard des algorithmes et des méthodes d'optimisation conçus par ses membres. Un effort dans la diffusion de résultats sous forme de logiciels (ou l'inclusion d'algorithmes dans des logiciels open-source d'envergure) serait un plus. Pour améliorer encore leur visibilité internationale, les membres du thème pourraient et devraient davantage participer aux dépôts d'ERC et/ou de projets européens. La qualité de certains membres du thème leur donne de très bonnes raisons de participer à ces compétitions très sélectives.

Florian Sikora has contributed to PACE (Parameterized Algorithms and Computational Experiments Challenge). The goal is to explore the practical implementability of theoretical

results. Florian Sikora was a participant, and a member of the steering committee. More details are given in the portfolio. Four software of Florian Sikora are available at `https://www.lamsade.dauphine.fr/fr/recherche/logiciels.html`.

2 PORTFOLIO INTRODUCTION : COMBINATORIAL OPTIMIZATION, ALGORITHMS TEAM

The portfolio of Team 2 comprises 5 elements. The first two rely on research articles published in highly selective conferences and journals. They reflect the kind of theoretical research conducted within AGAPE and MATHIS. The third element of the portfolio deals with an international conference launched by members of Team 2. The fourth element of the portfolio witnesses the investment of Team 2 in putting algorithms into practice. The fifth element describes how Team 2 paid tribute to one of his beloved and influential member who untimely passed away.

AGAPE publications on Twin-width

Twin-width is a new width measure we introduced in 2020 [1, 6]. In a series of follow-up works [2, 3, 4, 5, 7] we demonstrated that twin-width is a powerful as well as very natural tool which has rich structure and applications. Since the first introduction of twin-width, there is a rapidly expanding literature, including 30+ articles, which reveals its importance in various sub-fields of computer science.

MATHIS publication on graphs

In 2021, a member of Team 2 disproved the following important conjecture in graph theory which has its roots in information theory [48].
[The Normal Graph Conjecture (1999)] A graph with no C_5, C_7 and $\overline{C_7}$ as induced subgraph is normal.
The proof is probabilistic and in fact shows that most “sparse” graphs (with a certain edge-density) are counterexamples. Unfortunately, these graphs are so large that one cannot actually display a counterexample.

International Symposium on Combinatorial Optimization (ISCO)

ISCO is a biennial international symposium whose aim is to bring together researchers from all the communities related to combinatorial optimization. Each edition is preceded or followed by a Spring School. Articles of ISCO are selected by a program committee on the basis of 12-page submissions, and proceedings are published by Springer LNCS. Selected articles are also published in extended versions in special issues of international journals. Two members of Team 2 are in the steering committee of ISCO. They participated in the launch of the conference (2010) and its seven editions.

Parameterized Algorithms and Computational Experiments Challenge (PACE)

PACE was conceived to deepen the relationship between parameterized algorithms and practice. It aims at bridge the divide between the theory of algorithm design and the practice of algorithm engineering, by providing open-source and available implementations (on public repositories with a DOI) and benchmark instances and inspiring new theoretical developments. Each year, one or two (theoretical) problems are selected as well as benchmark instances, and the challenge consists in producing efficient algorithms for these problems. We participated to this challenge two times, co-designed the challenge in 2018 and took part to the Steering Committee.

Tribute to Jérôme Monnot

Jérôme Monnot was member of Team 2 (DR CNRS) until his untimely death on December 11, 2019. A tribute to his scientific contribution has been paid, composed of a special issue of the journal *Theoretical Computer Science*, an international conference held in December 2021 at the university of Paris-Dauphine, and an article published in the journal of the *Société Informatique de France*.

3 SELF-ASSESSMENT DOCUMENT : COMBINATORIAL OPTIMIZATION, ALGORITHMS TEAM

Domaine 2. Attractivité

Référence 1. L'unité est attractive par son rayonnement scientifique et s'insère dans l'espace européen de la recherche.

Invitations

During the period 2017-2022, some members of Team 2 were invited in the following intitutions: University of Bergame (Italy) in 2018, Politecnico di Torino (Italy) from November 2017 to April 2018 (6 month scientific mobility), 1 month at RMIT in Melbourne (Australia) in January 2019, 2 stays of one week at NTUA Athens (Greece), in 2018 and 2019, three-week visit in the United States (Lehigh University, University of Michigan and Johns Hopkins University) in March 2022, University of Parma (2019), four months of research in Dipartimento di Ingegneria e Architettura, University of Southampton (2018), 1 month at the National and Kapodistrian University of Athens in 2019, and visits of the Sultan Qaboos University, Muscat, (Oman), January-May, 2020 and January-May, 2017.
Eunjung Kim was keynote speaker at ALGO 2022 (Germany), and Florian Sikora was invited to the *Shonan 144* meeting (Japan) in 2019.

Scientific Expertise

The members of Team 2 participated in the following instances: CNU (2 members between 2015 and now), HCERES (IBISC December 2018, LRI December 2018, LIRIS March 2020, LERIA October 2021), Expert for FNRS, Belgium in 2020, review of CIFRE funding demands from ANRT, Project evaluation for ECOS Nord - Peru (2019), Post-doctoral evaluation for the LabEx CHARMMMAT (2018), jury for the price in graph theory "Charles Delorme" (from 2018 to 2022). The members of Team 2 participated in the research group *AGAPE* of GDR RO, and the *Polyhedra and Combinatorial Optimization* group of GDR-RO.

Program and Organisation committees

The members of Team 2 participated to the steering committee of IPEC (International Symposium on Parameterized and Exact Computation 2019-2022), ISCO (International symposium on combinatorial optimization 2018-2022), and PACE 2017-2020.

The members of Team 2 were program committee members (or program chair of a track) of the following international events: STACS 2023, AAMAS 2023, SODA 2023, IPEC 2023, AAAI 2023, CPM 2023, WG 2023, IPEC 2022, JCDCG 2022, AAMAS 2022, IJCAI 2022, SAGT 2022, MFCS 2022, ICGT 2022, WG 2022, IWOCA 2022, APPROX 2021, AAAI 2021, AAMAS 2021, ADT 2021, FCT 2021, IJCAI 2021, CIAC 2021, STACS 2021, WG 2021, SOFSEM 2021, ISCO 2020, SOFSEM 2020, AAAI 2020, IJCAI 2020, IPEC 2020, WG 2020, SOFSEM 2020, AAAI 2019, AAMAS 2019, IJCAI 2019, SAGT 2019, WG 2019, MFCS 2019, CIAC 2019, IPEC 2018, ISCO 2018, IJCAI 2018, LOPAL 2018, AFROS 2018, ICGT 2018, IWOCA 2018, PACE 2018, CAM 2018, International Conference on Challenges in Industrial Engineering and Operations Management 2018, CoDIT 2017, FAW 2017, CIAC 2017, AAAI 2017, FCT 2017, COCOON 2017, IWOCA 2017, IJCAI 2017, CIAC 2017, WG 2017, and IWOCA 2017.

The members of Team 2 participated to the organisation of PAAW (Parameterized Algorithms Workshop 2022, 50 participants), ROSA Colloquium (Operations research and Health 2018, 15 participants), IBS Summer Research Program on Algorithms and Complexity in Discrete Structures (2019, apprx 30 participants), the *International Symposium on Combinatorial Optimization* (ISCO 2018) and its Spring School, ISCO 2022 and its Spring School, the IEEE - 6th 2019

International Conference on Control, Decision and Information Technologies (IEEE-CoDIT 2019), the joint Tunisian Decision Aid Society and the Tunisian Operational Research Society (TDAS/TORS) Conference (2019 Djerba, Tunisia), the International conference in memory of Jérôme Monnot, (2021, 50 participants), the Workshop celebrating Mike Fellows' DHC in june 2022, 30 participants, CIAC 2017 (International Conference on Algorithms & Complexity), CTW 2018 in Paris (2018, CNAM), and SPOC18 in Paris (2018, Paris-Dauphine). They also organized sessions in the Joint EURO/ALIO International Conference 2018 on Applied Combinatorial Optimization, Bologna, June 25-27, 2018, ISMP International Conference, Bordeaux, June 1-6, 2018, the 31st European Conference on Operational Research (2021), the 2021 SIAM Conference on Linear Algebra, and the 2022 PGMO Days.

Editorial Board

Ridha Mahjoub is Co-editor in Chief of RAIRO - Operations Research, Area Editor of Computers and Industrial Engineering (since Nov 2015), Advisory Editor of EURO Journal on Computational Optimization, (from July 2011 to September 2020), Co-editor of the proceedings of ISCO 2022 (Springer LNCS 13526), ISCO 2020 (Springer LNCS 12176), and ISCO 2018 (Springer LNCS 10856), Guest editor of a special issue of *Discrete Applied Mathematics* dedicated to ISCO 2018 (volume 308, 2022), Guest editor of a special issue of *Annals of Operations Research* dedicated to CoDIT 2017 (volume 298, 2021), Guest editor of a special issue of *Journal of combinatorial Optimization* dedicated to ISO 2016 (volume 37, 2019). Vangelis Paschos is Editor of the track Algorithms, Automata, Complexity and Games (TCS-A) of Theoretical Computer Science, member of the editorial board of Computers & Industrial Engineering (Operations Research), Asociate Editor of RAIRO Operations Research, International Journal of Multicriteria Decision Making (Board Member), Board Member of Foundations of Computing and Decision Sciences, Board Member of The Yugoslav Journal of Operations Research, Guest editor of a special issue of *Theoretical Computer Science* on Algorithms and Complexity (CIAC 2017), volume 754, 2019, and Co-editor of the Proceedings of CIAC 2017 (Springer LNCS 10236). Laurent Gourvès and Vangelis Paschos were guest editors (with Bruno Escoffier) of a special issue of *Theoretical Computer Science*, in memory of J. Monnot, 18 articles between 2021 and 2022. Jully Jeunet is member of the editorial committee of Journal of Project Management (Growing Science) (since 2017), and member of the editorial committee of Journal of Industrial Engineering (Hindawi) (2012–2019). Ararat Harutyunyan is Associate Editor of *Annals of Combinatorics*. Clément Royer is Associate Editor of Journal of Optimization Theory and Applications since June 2022. Cristina Bazgan was co-editor of the Proceedings of the 33rd International Workshop on Combinatorial Algorithms, IWOCA 2022, Trier, Germany, June 7-9, 2022, Lecture Notes in Computer Science 13270, Springer 2022. Fabio Furini was Associate Editor of Omega journal of management science, Guest Editor of the special issue of *Discrete Applied Mathematics* entitled *Graphs and Combinatorial Optimization*, and Guest Editor of the special issue of *Annals of Operations Research* entitled *Recent Advances in Decomposition Methods for hard Optimization Problems*. Florian Sikora was co-editor of the proceedings of SOFSEM 2020 and 2021.

Prizes and Distinctions

- Eunjung Kim received in 2017 a Bronze medal, awarded by CNRS (already mentioned in the previous report)
- Clément Royer was awarded a junior chair endowment from PRAIRIE (Paris Artificial Intelligence Research Institute) in May 2021. This endowment funded a two-year postdoctoral position as well as a reduced teaching load for 3 years.
- Clément Royer received the Meritorious Service Award for outstanding activity as a reviewer for the international journal *Mathematical Programming* in 2022.
- The PhD thesis of Anaëlle Wilczynski supervised by Laurent Gourvès and Julien Lesca,

defended in 2019, received the following distinctions: Thesis prize AI 2019 (ex aequo) from the French Association for Artificial Intelligence (AFIA), Young researcher award 2019 from Fondation Dauphine and Accuracy, Honorable mention of the dissertation prize "Artificial Intelligence, Data Sciences and Interfaces" from PSL and ADELI

- Paul Beaujean got the prize of the best student paper at the conference COCOA 2018 for the paper : Cristina Bazgan, Paul Beaujean, Éric Gourdin, Relaxation and Matrix Randomized Rounding for the Maximum Spectral Subgraph Problem, COCOA 2018, pp. 108-122 [97].

Référence 2. L'unité est attractive par la qualité de sa politique d'accompagnement des personnels.

Today, Team 2 consists of the following permanent members: 2 Full Professors, 2 Emeritus Professors, 8 Maîtres de conférences, 1 *Directeur de recherche* CNRS, 3 *Chargés de recherche* CNRS, and 1 Associate researcher. Ali Ridha Mahjoub was Full Professor and became Professor Emeritus after his retirement in 2022. Fabio Furini was Maître de conférences, and moved to IASI-CNR (Italy) in 2019. Jérôme Monnot was DR CNRS, and he passed away in December 2019. Laurent Gourvès was CR and he was promoted DR in October 2019. Ararat Harutyunyan, Clément Royer and Emiliano Lancini were recruited as Maître de conférences in 2017, 2019, and 2022, respectively. Angelo Fanelli (CR CNRS) joined the group in May 2022. Ivana Ljubic (PR) was associate researcher during the period. Nicolas Gastineau was ATER in 2017 (but not PhD within LAMSADE). Michail Lampis obtained his Habilitation thesis in March 2022. The head of the team was Denis Cornaz until December 2019, followed by Laurent Gourvès in January 2020 until now.

During the period 2017-2022, the invited Professors were: [2021-2022] O-joung KWON (Hanyang University, Korea), Aris PAGOURTZIS (NTUA, Greece), Warren HARE (University of British Columbia, Canada, visited October-December 2022), Romeo RIZZI (University of Verona, Italy). [2020-2021] Eduardo UCHOA (Universidade Federal Fluminense, Brazil), Gianpiero MONACO (University of L'Aquila, Italy). [2019-2020] Pavol HELL (université Simon Fraser, Canada), Thomas MC CORMICK (UBC Sauder, Canada), Aris PAGOURTZIS (NTUA, Greece), Pablo SAN SEGUNDO (Universidad Politécnica de Madrid, Spain), Euiwoong LEE (University of Michigan, USA). [2018-2019] Eduardo UCHOA (Universidade Federal Fluminense, Brazil), Janka CHLEBIKOVA (University of Portsmouth, UK), Vittorio BILO (Università del Salento, Italy), Pablo SAN SEGUNDO (Universidad Politécnica de Madrid, Spain), Isolde ADLER (University of Leeds, UK), Stefano CONIGLIO (University of Southampton, UK), Henning FERNAU (Universität Trier, Germany). [2017-2018] Eduardo UCHOA (Universidade Federal Fluminense, Brazil), Vadim LOZIN (University of Warwick, UK), Vittorio BILO (Università del Salento, Italy), Stefan KRATSCH (Humboldt-Universität zu Berlin, Germany), Stefano CONIGLIO (University of Southampton, UK), Aurélie THIELE (SMU Lyle School of Engineering, USA), Bernard RIES (Université de Fribourg, Swiss), Martin MILANIC (University of Primorska in Koper, Slovenia), Magnus WAHLSTROM (Royal holloway, University of London, UK).

The 31 PhD students whose thesis intersects with the period 2017-2022 are: Paul Beaujean (CIFRE Orange), Dublois Louis (MESRI), Ben Fekih Hajer (CIFRE), Pierre Cazals (MESRI), Faure Beaulieu Axel (MESRI), Baudin Lucas (ENS), Cardi Pierre (MESRI), Bentoumi Isma (CIFRE HUAWEI), Dang Chen (CIFRE Orange), Ardevol Martinez Virginia (MESRI), Haddad Marcel Adonis (MESRI), Katsikarelis Ioannis (MESRI), Kerleau Sébastien (MESRI), Khosravian Ghadikolaei Mehdi (MESRI), Labidi Mohamed Khalil (Co-tutelle Tunisie), Legheraba Iskander (ENS), Magnouche Youcef (MESRI), Mahjoub Meriem (Co-tutelle Tunisie), Melissinos Nikolaos (MESRI), Mouaci Ahlam (CIFRE), Naghmouchi Mohamed Yassine (CIFRE), Nourry

Charles (MESRI), Pereira Vargas Liguori Pedro Henrique (Grant from Brazil), Pontoizeau Thomas (MESRI), Puig I Surroca Gil (ANR), Shen Xueying (CIFRE), Ternier Ian (MESRI), Vasilakis Emmanouil (MESRI), Vazquez Alferez Sofia (MESRI), Wilczynski Anaelle (PSL), Bou Orm Mayassa (self-financing). These students are (or were) supervised by at least one member of Team 2 (sometimes co-supervised with someone from another team).

The Postdoctoral researchers whose thesis intersects with the period 2017-2022 are: Noleen Köhler (ANR ASSK, 09/2021- 06/2023), Raul Wayne Teixeira Lopes (ANR ASSK, 10/2021 – 10/2022), Florentin Goyens (PRAIRIE, 01/2022 - 12/2023), Abhinav Srivastav (PSL project MultiFAC, 2018)

Référence 3. L'unité est attractive par la reconnaissance de ses succès à des appels à projets compétitifs.

The members of Team 2 are PI of the following funded projects during the period 2017-2022:

- GEO-SAFE (Geospatial based Environment for Optimization - Systems Addressing Fire Emergencies) is a Marie Skłodowska-Curie Actions (MSCA) Research and Innovation Staff Exchange (RISE) project with more than 20 partners from 2016 to 2020, Cécile Murat (Dauphine coordinator).
- ANR S-EX-AP-PE-AL (Sub-EXponential APproximation and ParametErized ALgorithms), Michael Lampis (PI), Feb 2022-Feb 2026.
- ANR ASSK (Algorithms with Small Separations acKnowledged: graphs and linear matroids) Eunjung Kim (PI), 2019-2024.
- ANR DAGDigDec (DAGs and Digraph Decompositions) Ararat Harutyunyan (PI), 2021-2024.
- Project PAR.A.G.A. (Parameterized Approximation Graph Algorithms) funded by CNRS (between France and Japan), Michael Lampis (PI), 2019-2022.
- Project GR.A.P.A. (GRaph Algorithms for Parameterized Approximation) funded by CNRS (between France and Japan), Michael Lampis (PI), 2017-2019.
- PSL Multiple Facility Location and Generalizations: Approximation Algorithms, Robustness, Mechanisms, Incentives (MULTIFAC) between Dauphine and ENS (Vangelis Paschos and Claire Mathieu, PI), 2017-18.
- PEPS JCJC of the CNRS entitled *Efficient Quadratic Programming Exact Algorithm mixing Relaxations*, (Fabio Furini, PI), 2016-2017.
- Fondation Mathématique Jacques Hadamard PGMO on Most Vital Elements for multiobjective combinatorial optimization problems (Cristina Bazgan, PI) 2017-2019
- Fondation Mathématique Jacques Hadamard PGMO Multi-Objective Combinatorial Optimization: Mathematical Programming and Algorithmic Approaches (Ali Ridha Mahjoub, PI) 2018-2021
- Fondation Mathématique Jacques Hadamard PGMO (Fabio Furini, PI), *Rich Graph Coloring Problems with applications to resource allocation*, 2017-2018
- Fondation Mathématique Jacques Hadamard PGMO (Clément Royer, PI), *PDE-Constrained Optimization: Complexity Analysis and Numerical Relevance*, 2022-2023

- Collaborative project *Improving Optimization Algorithms through Advanced Eigenvalue Approximation* with the University of British Columbia (Canada), funded by the French Canada Research Fund (Clément Royer, co-PI) 2022-2024
- Collaborative project *Adaptive, Local and Innovative Algorithms for Stochastic Optimization* with the University of Michigan (United States), funded by the French-Americal Cultural Exchange (FACE) Foundation (Clément Royer, co-PI) 2022-2024

The members of Team 2 also actively participated in the following funded projects (without being PI): ANR ESIGMA (Efficiency and Structure in Graph Mining Applications) 2018-22. ANR THEMIS (Theory and evidence to measure Influence in Social structure) (Stefano Moretti,PI), 2021-24. ANR Computation, Communication, Rationality and Incentives in Collective and Cooperative Decision Making (COCORICO), (Jérôme Lang, PI), 2014-19. ANR Deep Learning for Constraint Optimization (DELCO) (Benjamin Négrevergne, PI) 2019-2023. ANR Analyse spatio-temporelle d'images IRM d'enfants et de nouveaux nés (STAP), 2017-2022. Network on Exploitation, Smuggling and Trafficking (NEST) between PSL and UCL (Hervé Borrion and Sonia Toubaline, PIs), 2021-23. Fondation Mathématique Jacques Hadamard PGMO Designing ContrACTS and Matching Platforms for green EnerRy (DAMPER), (Rida Laraki and Clemence Alasseur, PIs), 2018-21. JCJC INS2I ADDICTED (Florian Yger, PI), 2017-2018. PHC (Partenariat Hubert Curien) : 2016-2017 PROCOPE between Paris Dauphine University (french PI Daniel Vanderpooten) and University of Wuppertal (german PI Katrin Klamroth) on the multiobjective combinatorial optimization. PHC (Partenariat Hubert Curien) : 2017-2018 CEDRE between Paris Dauphine University (french PI Joyce El Haddad) and Lebanese American University (libanese PI Faisal Abu-Khzam) on efficient algorithms for quality repair in dynamic networks. PHC (Partenariat Hubert Curien) : 2018-2019 PROCOPE between Paris Dauphine University (french PI Daniel Vanderpooten) and University of Kaiserslautern (german PI Clemens Thielen) on the approximation multiobjective problems. PHC (Partenariat Hubert Curien) : 2020-2021 PROCOPE Plus between Paris Dauphine University (french PI Daniel Vanderpooten) and University of Kaiserslautern and University of Wuppertal (german PI Stefan Ruzika) on the representation of efficient solutions of multiobjective problems. PHC (Partenariat Hubert Curien) 2018-2019 STEFANIK between Paris Dauphine University and Pavol Jozef Safarik University in Kosice (Slovakia) (PI, Katarina Cechlarova & Jérôme Lang) on Fairness criteria and sequential mechanisms for matchings.

There are also CIFRE contracts whose details are given in a different section.

Référence 4. L'unité est attractive par la qualité de ses équipements et de ses compétences techniques.

Cf DAE of LAMSADE.

Domaine 3. Production scientifique

Référence 1. La production scientifique de l'unité satisfait à des critères de qualité.

The publications of Team 2 are in highly selective conferences and journals which attest the solid theoretical and methodological foundations.

Let us mention the following 43 publications of Team 2 in international conferences ranked A* or A on CORE: STOC [8], FOCS [1], SODA [9, 2, 98, 11], IJCAI [99, 47], AAAI [100], ISAAC [101, 102, 103, 104, 105, 106], ESA [107, 95, 87], ICALP [4, 108, 109, 96], STACS [16, 18, 94, 110, 111, 112], SoCG [113], AAMAS [46, 42, 44, 114], WG [115, 116, 117, 118, 119], SAT [15], APPROX RANDOM [120], SPAA [121], ECAI [122], MFCS [123].

One can also mention the following 43 publications of Team 2 in journals ranked Q1: SIAM Journal on Optimization [54, 63], Transportation Science [124], Computers & Industrial Engineering [125, 55, 74], Annals of Operations Research [126, 127], European Journal of Operational Research [128, 129, 130, 131, 132, 133, 90, 75], Future Generation Computer Systems [65], Networks [134, 37], Computers & Operations Research [135, 136, 76, 137], Mathematical Programming Computation [138], Journal of Combinatorial Theory, Series B [48, 51, 12], Combinatorica [139, 140], Journal of Graph Theory [141], International Journal of Production Research [142, 143, 144], SIAM Journal on Discrete Mathematics [145, 13], Journal of the ACM [22, 146], IEEE Transactions on Information Theory [147], SIAM/ASA Journal on Uncertainty Quantification [64], SIAM Journal on Scientific Computing [148], Mathematical Programming [149, 150], and Computational Optimization and Applications [151].

On top of the aforementioned venues, the members of Team 2 have many publications in the following conferences and journals: CIAC, IPEC, FCT, SWAT/WADS, COCOON, IWOCA, COCOA, SOFSEM, WAOA, SAGT, WALCOM, AAIM, Theoretical Computer Science, Algorithmica, Discrete Applied Mathematics, Theory of Computing Systems, Journal of Combinatorial Optimization, Electronic Notes on Discrete Mathematics, Journal of Computer and System Science, and Discrete Optimization.

Many publications of Team 2 are co-authored with international partners. Let us illustrate this with the following examples: KAIST, South Korea [147, 108, 102], University of Electro-Communications, Chofu, Tokyo, Japan [145], Mohammed VI Polytechnic University, Ben Guerir, Morocco [142, 143, 144, 64, 133], Department of Applied Mathematics and Computer Science Technical University of Denmark [141, 139], Instituto de Computacao and Universidade Federal Fluminense Brazil [54], Bilkent University, Ankara, Turkey [124], Athens University of Economics and Business, Greece [128], University of Vienna, Austria [129], University of Southampton, United Kingdom [130], Universidad Politécnica de Madrid, Spain [131], HEC Montréal, Canada [132, 124], TU Berlin, Germany [37], Universidad Pompeu Fabra, and Barcelona GSE, Spain [135], University of Bologna, Italy [136], Politecnico di Torino, Italy [76], School of Industrial Engineering, Eindhoven, The Netherlands [137], Department of Mathematical Optimization Berlin Germany, University of Pisa Italy, Imperial College London UK, Institut fur Mathematik Klangenfurt am Worthersee Austria, CMU Pittsburg USA, Ecole Polytechnique de Montreal Canada [138], Fudan University Shanghai, China [51], Hanyang University South Korea [12], Czech Technical University in Prague Czech republic [148], University of Coimbra, Portugal [149] and The Hong Kong Polytechnic University, China [151], Lehigh University, USA [63], University of Wisconsin, USA [150], Humboldt-Universität zu Berlin, Germany [9, 8], University of Warsaw, Poland [9, 8], Royal Holloway, University of London, UK [9, 8], Pavol Jozef Safarik University in Kosice, Slovakia [99], New York University, USA [102], Universitat Politecnica de Catalunya, Barcelona, Spain [103, 115], National and Kapodistrian University of Athens, Greece [103], NTUA Athens Greece [101, 122, 152, 153], Nagoya University Japan [95, 105], CMU Pittsburg USA [87, 138], Kumamoto University, Japan [16, 107], Middlesex University London UK and Warsaw University of Technology, Poland [113], Southern Methodist University, Dallas USA [52], School of Science RMIT University, Melbourne, Australia [53], University of Primorska, Koper, Slovenia [115], University of Warwick, UK [154], University of Trier, Germany [155, 156], University of Auckland, New Zealand [114], Union college, USA [114], University of Portsmouth, UK [30], Hungarian Academy of Sciences, Hungary [28], Lebanese American University, Beirut, Lebanon [157].

The members of Team 2 have long term collaborations with the following institutions: National and Kapodistrian University of Athens (Greece), University of Rome La Sapienza (Italy), Sauder School of Business, University of British Columbia (Canada), Universidade Federal Fluminense, Niteroi, (Brazil), IBM, T.J. Watson Research Center (USA), University of Nagoya (Japan), Ecole polytechnique de Turin (Italy), Université technologique de Eindhoven (The Netherlands), RMIT University (Australia), NTUA Athens (Greece), SMU, Dallas (USA), KAIST

(South Korea), Institute for Basic Science in Daejeon (South Korea), Institut für Informatik Humboldt-Universität zu Berlin (Germany), University of Warsaw (Poland), Royal Holloway University of London (UK), University of Michigan (USA), University of Chieti-Pescara (Italy), Hungarian Academy of Sciences (Hungary), Lebanese American University (Lebanon), Technical University of Berlin (Germany), and the universities of Bologna, Modena, Padova, Pisa, and CNR IASI (Italy).

Référence 2. La production scientifique de l'unité est proportionnée à son potentiel de recherche et correctement répartie entre ses personnels.

The total number of documents available for Team 2 in the LAMSADE's HAL collection contains 338 elements signed by at least one member of Team 2.
The overall repartition among document categories is presented in the pie chart of Figure 1. Figure 2 shows the production for each year of the evaluation period for the main categories (journal articles, communication in conferences, book chapters). For these main categories, the total number of contributions is 295. In Team 2, the average number of documents per year is 49.2, the average number of authors per publication is 3.7, the number of papers involving PHD students is 73[1], the number of papers involving at least two Teams is 30.
See Figures 3 and 4 for the most targeted publication venues.

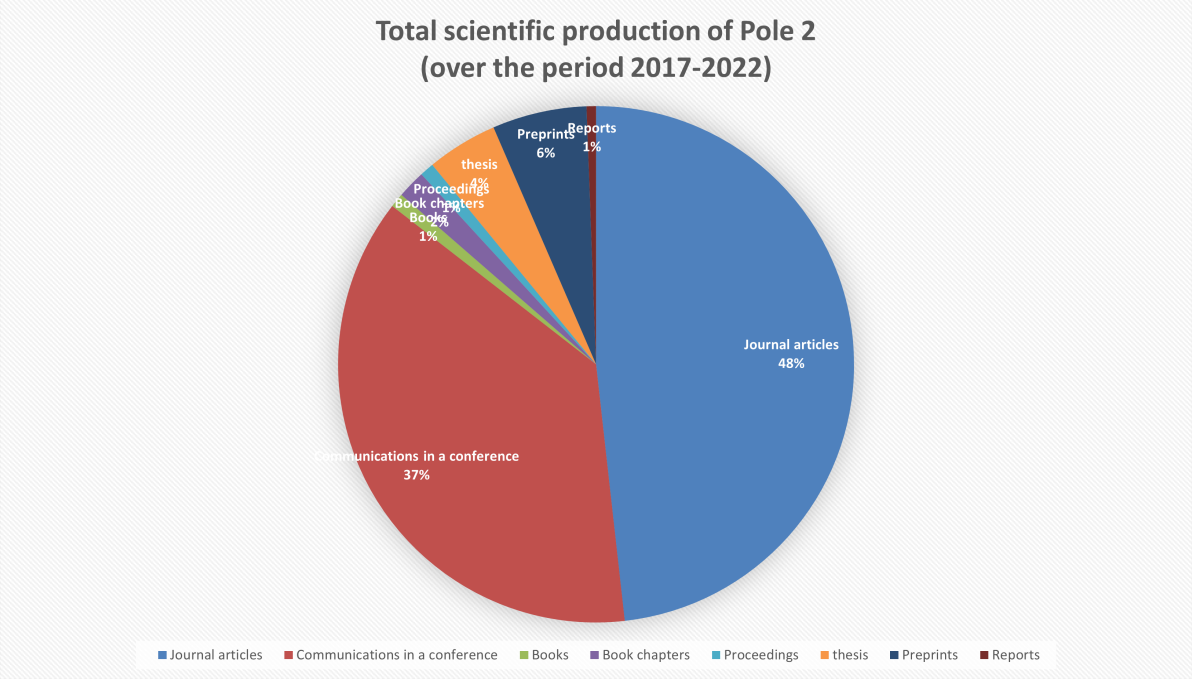

Figure 1: Overall scientific production of LAMSADE during the evaluation period (HAL collection LAMSADE-DAUPHINE).

Team 2 has a budget of approximatively 14000 euros per year, plus the money for funding two master internships. These resources are available to everybody within Team 2. We can use rules if not all the requests can be accepted (favor young researchers, favor publications, etc). We collectively discuss the use of scarce resources.

[1] 30 journals, 41 articles in proceedings, and 2 book chapters.

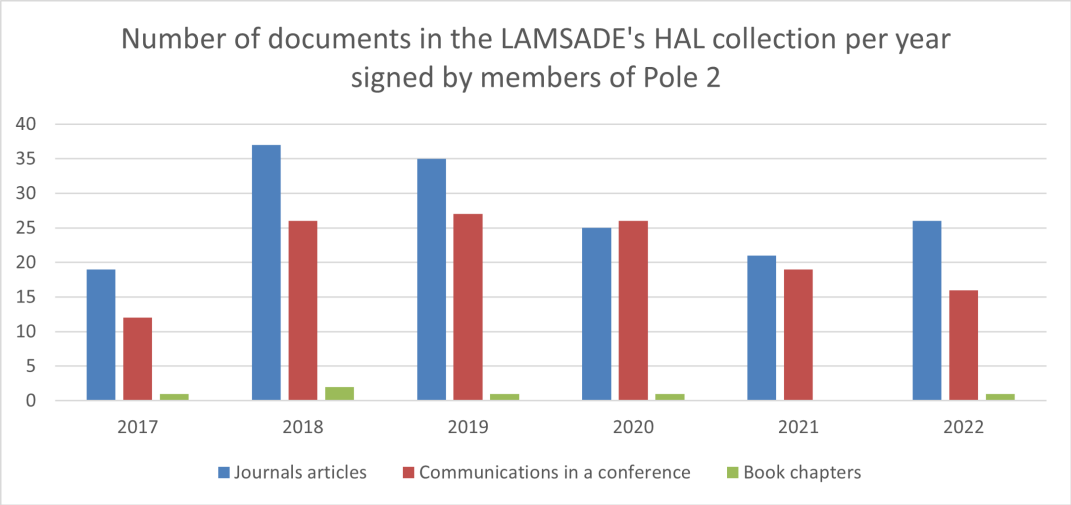

Figure 2: Scientific production of Team 2 (Combinatorial Optimization, Algorithms) during the evaluation period.

Three maîtres de conferences joined Team 2 during the period 2017-2022 (Ararat Harutyunyan in September 2017, Clément Royer in September 2019, and Emiliano Lancini in September 2022). They all benefited (or still benefit) from a 3 year teaching discharge. LAMSADE has a fund (*budget jeunes chercheurs*) which can cover the traveling expenses of young researchers (PhD students and newly recruited permanent members). The university and the CNRS also offer grants for young permanent researchers (Emiliano Lancini obtained them). The LAMSADE strongly encourages young researchers to supervise PhD students (e.g., Ararat Harutyunyan supervised Nikos Melissinos with Jerôme Monnot, Clément Royer is supervising Sébastien Kerleau with Denis Cornaz; two PhD students with a MESRI grant). This is also the case for master students. Team 2 can fund two master theses per year. In 2022, Clément Royer got a grant for supervising a master student. This year, Ararat Harutyunyan has such a grant. Ararat Harutyunyan and Clément Royer are very active in research in terms of publications, and they also managed to get their own financial supports (ANR DAGDIgDec, PRAIRIE, collaborative project with British Columbia). Angelo Fanelli (CR CNRS) also joined Team 2 recently (May 2022) but he is not a junior. Angelo has taught during the first semester of 2022/23, applied for a CNRS project (appel unique) and proposed a PhD topic (possibly starting in September 2023). Ararat, Clément and Angelo benefited from Dauphine's program of invited professors since they could invite Pavol Hell, Warren Hare, and Luca Moscardelli.
Team 2 also funds research visits for postdocs: in 2022 Noleen Kölher and Raul Lopes visited colleagues from a lab of Clermont-Ferrand.
All researchers within Team 2 have exactly the same rights. The resources of Team 2 can be used for attending a conference even if the colleague has no accepted paper to present. The resources of LAMSADE such as PhD grants are allocated in a fair manner (involving young researchers is strongly encouraged): besides the quality of the Phd applicant which is predominant, any permanent member can obtain this resource, and it is sometimes an opportunity to support a restart.

Référence 3. La production scientifique de l'unité respecte les principes de l'intégrité scientifique, de l'éthique et de la science ouverte. Elle est conforme aux directives applicables dans ce domaine.

Cf DAE of LAMSADE.

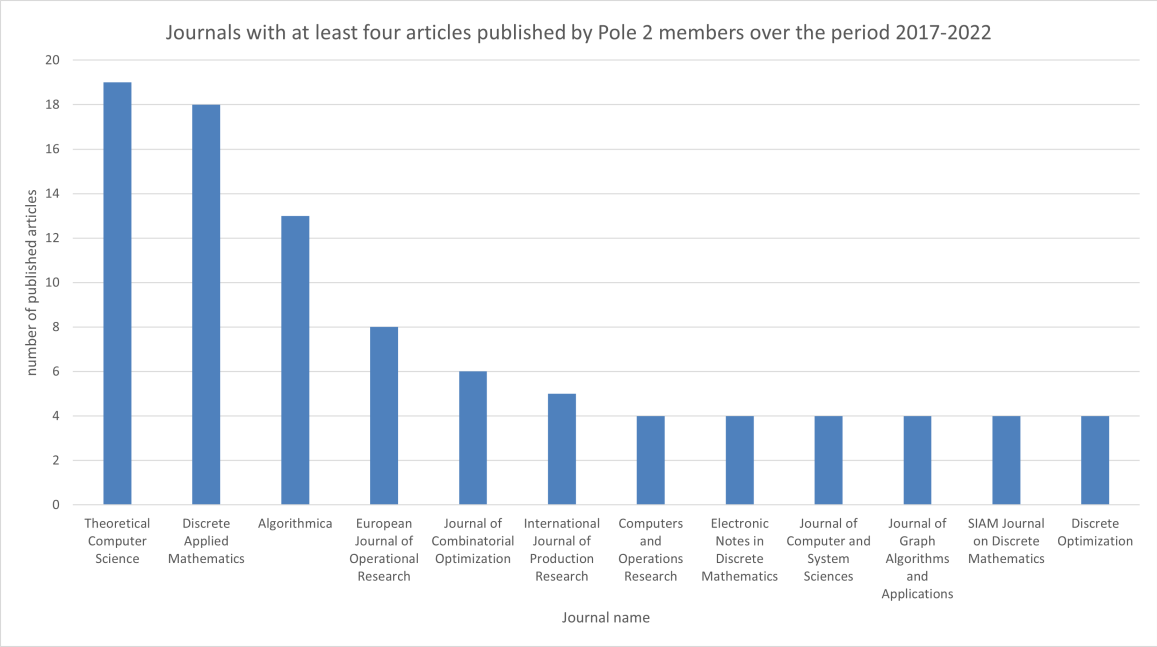

Figure 3: Journals with at least 4 articles published by members of Pole 2.

Domaine 4. Inscription des activités de recherche dans la société

Référence 1. L'unité se distingue par la qualité et la quantité de ses interactions avec le monde non-académique.

The activity of Team 2 is mainly theoretical, but the problems under study often come from the industry. The relations of Team 2 with the non-academic world mostly rely on CIFRE contracts. The following CIFRES theses were prepared within Team 2: Xueying Shen (Decision Brain), Paul Beaujean (Orange Lab), Yassine Nagmouchi (Orange Lab), Ahlam Mouaci (Orange Lab), Hajer Ben Fekih (ADIAS), Isma Bentoumi (Huawei), Chen Dang (Orange Lab). Most of them deal with optimization in communication networks. CIFRE theses are good opportunities for our students to enter the job market after the PhD. Members of Team 2 also supervise master thesis in collaboration with companies (e.g., Master MODO students). We also worked with EDF on the management of green energy (PGMO DAMPER project): two master theses were supervised. One master thesis also supervised with Artelys. In 2018, we participated in the organisation a conference on Operations Research & health (ROSA).

Référence 2. L'unité développe des produits à destination du monde culturel, économique et social.

Cf DAE of LAMSADE.

Référence 3. L'unité partage ses connaissances avec le grand public et intervient dans des débats de société.

Some members of Team 2 participated to the following dissemination actions: "Samedi des lycéens" (in order to ask questions to students that want to joint our university), one Saturday every year, from 2021; presentation of the scientific job to 10 years old children (2017) ; presentation about Theoretical Computer Science during the Forum "La recherche, & Sciences et Avenir" in La cité des Sciences, Paris (2017) ; Speed-Meeting (DECLICS) with highschool students to popularize the scientific job (2017, 2018, 2019).

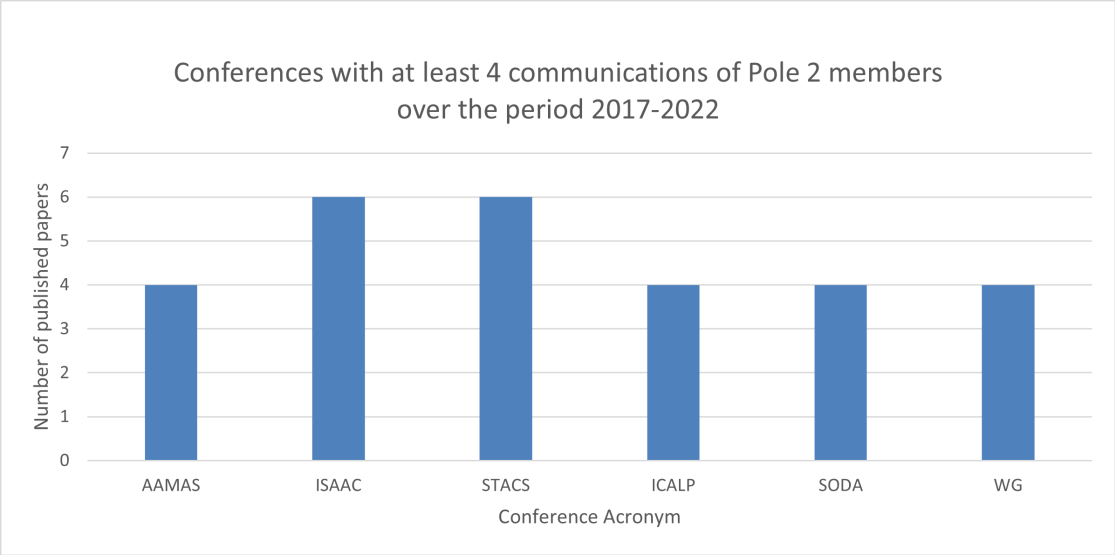

Figure 4: Conferences proceedings with at least 4 papers published by members of Pole 2.

Two articles in *50 years of Research in Dauphine: Yesterday, Today and tomorrow*, published in 2020: "Couvrir l'espace entre recherche opérationnelle et Informatique fondamentale: l'optimisation combinatoire", and "La quête du Graal en informatique théorique et le chemin tortueux de la complexité paramétrée y menant". A member of Team 2 has written "The shortest way to visit all metro lines in Paris", seen in the magazines *Sciences et Avenir* and *Ça m'intéresse!*, mentionned on the radio (France Inter) and in an article of *Interstices.info*. We also authored a tribute to Jérôme Monnot published in the journal *1024* of the *Société Informatique de France*, N°19, April 2022, pages 51-53 [158].

4 TRAJECTORY : COMBINATORIAL OPTIMIZATION, ALGORITHMS TEAM

4.1 SWOT

Strengths.
The subjects dealt with by Team 2 are at the same time well identified, sufficiently broad and robust not to be a passing fad. These research topics are shared by a national and international community that is both extensive and dynamic. Team 2 members collaborate and compete with these international teams for obtaining the most advanced results, publishing their findings in selective conference, and recruiting the best students and faculty members. The team develops many international relationships: collaboration with foreign researchers, participation in international conferences, etc. It is also heavily involved in the program committees of international conferences on its domain.
Given its size, we believe that Team 2 has a volume and quality of publications of a good level, balanced between articles in conference proceedings and international journals. In addition, the results of Team 2 are published in a large variety of high-quality journals and conferences.
The team is attractive for CNRS researchers (5 people intersecting the period). The kind of research of Team 2 does not require any expensive equipment. The team has numerous funded projects (H2020, ANR, PSL, PGMO, PHC). An ERC application is currently under evaluation.

Weaknesses.
The team develops relationships with companies mainly through CIFRE contracts supervised by a small number of colleagues (one of them has recently retired). The team needs successors to maintain the link with the companies.
The team has a low production of software or concrete platform-type tool. The scientific effort is mainly on a theoretical analysis valued by high quality publications. This perhaps explains the lack of attractiveness of the team for the non-academic world, which can be a source of funding and thematic renewal.
The team has a moderate number of PhD students and post-docs. The main source of funding for PhD theses comes from ministerial scholarships and CIFRE. There is little alternative funding of non-permanent researchers.
Though they are numerous, the financed projects within the team are of small size (i.e., a few people involved). The team might undertake a big project on which it would massively invest time, and where one of its members would be a leader with high visibility.
Risk-taking on disruptive subjects is moderate. Communication about our significant work and skills is quite weak.

Opportunities
Team 2 deals with optimization and this theme is omnipresent in our society. Indeed, a wide variety of concrete situations can be turned into an optimization problem. We can therefore have links with a large number of companies if our know-how is valued, and direct our type of optimization towards current topics: reduce the carbon impact, minimize energy consumption, maximize equity in the sharing of resources, etc.
Team 2 is already changing with the recent recruitments. A new position of Professor is going to be filled and this is an opportunity to continue the change.
The team may invest in fields of research at the intersection with other trendy disciplines (thus, offering opportunities) as with some members' recent work in Data Science.
We have the possibility of using the recruitments of faculty members to modify the landscape of the team. Although a part of the members is ideologically against, it is possible to try to recruit on alternative, non-traditional, job supports.
From a scientific point of view, it is necessary to find fields where the guarantee of performance is crucial (safety, security), or combine performance guarantees with other more operational or

even empirical aspects.
Being located in Paris is a chance. This allows a lot of passage and connections. This also makes Team 2 attractive for recruitment. The environment (Dauphine, PSL, PG) is favorable to attractiveness of good students and researchers (juniors and seniors): teaching releases, visiting professors, etc.
Communicate more and meet other actors (ROADEF congress, PGMO days) would increase the visibility of the team and improve the number of opportunities. LAMSADE is mainly a computer laboratory but it is also a place of interdisciplinarity. We need to make better use of this opportunity, as well as within PSL.

Threats.
Although numerous funded projects exist within the team, a threat could be their future scarcity due to an unfavorable political orientation (more applied topics, or theoretical aspects of other, more trendy fields, could be favoured). Another threat would be the scarcity of funds for small and medium-sized projects.
The team benefits from the resources (sometimes not earmarked) of its environment (LAMSADE), e.g., PhD thesis scholarships of the minister. If these resources were to be earmarked (PhD track of the PG), in order to satisfy requirements of establishment or laboratory policy, the number of theses prepared within Team 2 could be rarer due to the small number of alternative financing options.
The research conducted within Team 2 is largely based on theoretical analysis of the worst case type. It can be supplanted (i.e., attract less funding) by a kind of optimization that can combine theoretical and empirical aspects.
Although the environment of Team 2 is financially favorable, certain material aspects are clearly unfavorable such as the little work space (offices, meeting rooms) and renovation works inside and outside the building. There are also few traditional career development opportunities in academia. The scarcity of human support forces researchers either to give up certain opportunities (PhD and master theses, internships), or to devote more time to administration (missions, contracts, fundraising, reports) at the expense of research.
The list of members of Team 2 has significantly changed during the period. Three active members can potentially leave in a near future for retirement or promotion. One Professor is about to join in September 2023. All these movements can destabilize the team, especially if their scientific activity represents a significant part of the team. Refusing new kinds of positions (because it is not permanent or not renewed after the retirement), can prevent the development of the team.

4.2 Trajectory

In the report of the previous mandate, Team 2 had two “proper” research projects (AGAPE & MATHIS), two main interactions with Team 1 via the projects MOCO and Games and Social Choice, an interaction with Team 3 via the research project on Web Services, and an intersection with Policy Analytics. The criticisms made by HCERES for the previous mandate and the actions undertaken to fix them were addressed in Section 1.2. Concerning the research perspectives of the projects AGAPE, MATHIS and MOCO written in the previous report, most of them were studied and leaded to publications (see, for example, [159, 160, 26, 125, 84, 161, 90]). The factual elements of this report, together with the SWOT analysis, show the quality of the activity conducted within Team 2 in terms of publications (selectivity and quantity), diversity of topics, obtained financial supports, international visibility and attractiveness. At the same time, some elements of vigilance were raised for maintaining these results, and directions for improvements were listed. The perspectives of Team 2 for the next 5 years are to continue its transformation towards the study of new and ambitious subjects, to deepen research avenues that marked the past mandate and were described in Section 1, and to broaden its way of doing research, particularly in terms of software production and relationship to the socio-economic world.

The name of Team 2 (currently *Combinatorial Optimization, Algorithms*) changes in order to better fit with its new objectives and central themes: *Optimization, Structure & Algorithms*. Indeed, the main topics of the group are Optimization (mainly combinatorial optimization, but also continuous optimization), Structure (determine and study the parameters that are the source of computational intractability, structural graph theory) and Algorithms (exact resolution, approximation with performance guarantee, and heuristics).

The **AGAPE** project (Algorithms with Performance Guarantee) keeps the same acronym and general agenda. However, parameterized complexity and algorithms have become central topics, at the expense of polynomial approximation. Exploring the interplay between them (to what extent one needs to sacrifice optimality to obtain efficient parameterized algorithms for hard graph problems?) is a current line of future research which can be, for example, applied on paradigmatic problems such as graph coloring. The future of AGAPE is to define and study the relevant parameters which constitute the source of computational intractability. A possible plan is to work more on the logical characterizations of graph and matroid classes which are algorithmically well behaved. Another high level challenge is to deepen the interplay between discrete (combinatorial) optimization and machine learning, in collaboration with members of Team 3. This, for example, can be be applied to graph partitioning problems, new definitions of network communities and graph anonymization techniques. An effort must be made for increasing the number of implemented algorithms, and make them available online. A possible future direction is the generation of hard instances for combinatorial problems, and the composition of a public library. Another perspective of AGAPE is to explore the theoretical aspects of optimization problems coming from today's societal concerns (e.g., climate change, social networks).

The **MATHIS** project (Mathematical programming and discrete Structures) keeps the same acronym but for a different denomination: Mathematics of Discrete Structures, because its content evolves. Its research axes now include two new themes, namely probabilistic method and non-linear optimization, in addition with the historic themes, namely integer linear programming, combinatorial optimization and graph theory. The main challenge is to deeply exploit the links between these new research areas and the historic ones. Two PhD students are working on transversal subjects, and each of them is directed by one researcher specialist of one historic theme, and another researcher specialist in a new theme. One subject concerns structure of minimal vector sets whose non-negative linear combinations generate the whole linear space, which has application in derivative-free optimization. Another subject is a question from extremal graph theory associated with coloring problems, where monochromatic sets are nodes inducing an acyclic subgraph.
Interplay with Team 3 (MILES) on continuous optimization will be developed. In the upcoming years, connections between discrete mathematics and continuous optimization techniques with applications to data science (e.g., submodular optimization) have to be developed. Another area of investigation lies in derivative-free optimization, in which certain problems involve discrete variables by design. The use of discrete structures is quite unexplored, and members of MATHIS can provide the expertise needed to make a significant leap on this topic. The future of MATHIS is also to work on graph decomposition, extremal graph theory and general coloring problems. Recent techniques and concepts such as box TDIness and anchor-reoptimization can be explored.
A research direction is to consider difficult combinatorial objects and to try to adapt approaches that have been successful with graphs or matroids. Substantial preliminary results have been obtained concerning three related conjectures: signed graphs, structure of profile matrices, a sequential matroid game.

MOCO continues to be an active project between Teams 1 and 2, with some new perspectives. Even if the determination of the non-dominated set is now relatively well-studied, with rather efficient exact or approximate algorithms (including the one developed in our team), the

computational challenge remains for addressing larger and larger instances. With colleagues from Lisbon University we aim at developing a new algorithm based on a formulation as a constrained satisfaction problem, taking advantage of powerful sat solvers. Another stream of research deals with optimization over the efficient set, where we aim at optimizing a function in order to discriminate among all the many efficient solutions. The main difficulty of this problem lies in the fact that the efficient set, unlike the feasible set, is not explicitly characterized by constraints. A particular case of interest is the determination of the nadir point, whose components are the worst possible values of each criterion over the efficient set. These challenging problems could benefit from the concepts and algorithmic tools we developed for the problem of generating the non-dominated set. They require, however, additional insight, in particular taking advantage of specific properties of the nadir point, in order to produce really efficient algorithms for these problems.
A very important aspect refers to the *representation* of the non-dominated set which usually consists of hundreds or thousands of points. We are currently working with a PhD student on this issue so as to present the decision maker with a tractable set of a few points representing the main tradeoffs between criteria. The objective is to extend our previous work where an efficient algorithm was proposed for the biobjective case to general multiobjective problems. Besides generating a general representation of the whole non-dominated, a new perspective is to provide *personalized* representations, integrating the decision maker's preferences so as to focus on his/her zones of interest.

Team 2's interplay with Team 1 is also maintained with respect to the research project **Games and Social Choice**. This is even strengthened by the recent transfer of Angelo Fanelli. The goal is to bring new results for the construction of approximate equilibria (performance guarantees on the convergence and the degree of stability) and study combinatorial optimization problems arising from social choice settings.

For the next term, we decided to open a new research project named **Decision Aiding and Optimization under Uncertainty** shared by Teams 1 and 2. Its aim is to provide solutions to decision aiding and optimization challenges resulting from real world applications, based on operational research tools for problem modeling and efficient resolution (e.g. Mathematical programming, graph theory, (Meta)-heuristics, approximation, etc.). The targeted applications are numerous (network, transportation, safety, ecological transition), and are characterized by an uncertain context (unforeseen events, failures, attacks, climate change, imperfect information, etc). Depending on the source of uncertainty, the proposed solutions should be robust, adaptative, or resilient.
The relevance of the creation of this project originates from the impact of being able to propose appropriate methods for handling uncertainty, and the efforts that researchers from Teams 1 and 2 have already devoted, and will continue to dedicate to this important topic.

The work conducted within Team 2 during the period 2017-2022 exhibits a new link between Teams 2 and 3, through the research project **Miles**, and the perspectives are in favor of a strengthening of this collaboration. Of course, any kind of intermittent collaboration with another project is possible, like the one with automated Web Services. As opposed to the previous report, the present research statement and perspectives lead to the observation that no striking link exists between Team 2 and the research project **Policy Analytics**.

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