2021

ACTIVITY REPORT

Project-Team

INOCS

INtegrated Optimization with Complex Structure

DOMAIN

Applied Mathematics, Computation and Simulation

THEME

Optimization, machine learning and statistical methods

Contents

Project-Team INOCS

Creation of the Project-Team: 2019 May 01

Keywords

Computer sciences and digital sciences

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A6.1. – Methods in mathematical modeling

A6.2. – Scientific computing, Numerical Analysis & Optimization

A6.2.3. – Probabilistic methods

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1 Team members, visitors, external collaborators

Research Scientists

- Luce Brotcorne [Team leader, Inria, Senior Researcher, HDR]

- Hélène Le Cadre [Inria, Researcher, from Oct 2021]

Faculty Members

- Diego Cattaruzza [Centrale Lille, Associate Professor]

- Bernard Fortz [Université Libre de Bruxelles, Professor]

- Martine Labbé [Université Libre de Bruxelles, Professor]

- Maxime Ogier [Centrale Lille, Associate Professor]

- Frédéric Semet [Centrale Lille, Professor, HDR]

Post-Doctoral Fellows

- Mathieu Besancon [Univ de Provence, until Jun 2021]

- Gael Guillot [Inria, from Apr 2021]

PhD Students

- Cristian Aguayo [Université libre de Bruxelles, from July 2021]

- Haider Ali [Centrale Lille, from Sep 2021]

- Tifaout Almeftah [Inria, from Dec 2021]

- Jérôme De Boeck [Université libre de Bruxelles]

- Concepcion Dominguez Sanchez [FRIA, until August 2021, Université Libre de Bruxelles]

- Matteo Petris [Inria]

- Fränk Plein [FNRS, until August 2021, Université Libre de Bruxelles]

- Luis Antonio Rojo Gonzalez [Inria, from Oct 2021]

- Luis Salazar Zendeja [National Council of Science and Technology (CONACYT), Mexico, until Oct 2021]

- Juan Pablo Sepulveda Adriazola [Inria, from Nov 2021]

- Wenjiao Sun [Centrale Lille, from Sep 2021]

- Pablo Torrealba Gonzalez [Centrale Lille, from Feb 2021]

Technical Staff

- Tifaout Almeftah [Inria, Engineer, until Nov 2021]

- Gael Guillot [Inria, Engineer, from Feb 2021 until Mar 2021]

- Kaba Keita [Inria, Engineer]

Interns and Apprentices

- Victor Herve [Centrale Lille, from Mar 2021 until Jun 2021]

- Fernanda Paz Urrea Castillo [Inria, from Sep 2021 until Nov 2021]

Administrative Assistant

- Nathalie Bonte [Inria]

Visiting Scientists

- Mehdi El Krari [Centrale Lille, until Aug 2021]

- Arnaud Laurent [Univ de Provence, until Sep 2021]

- Yuan Yuan [Univ de Provence, until Jun 2021]

2   Overall objectives

2.1   Introduction

INOCS is a cross-border "France-Belgium" project team in the Applied Mathematics Computation and Simulation Inria domain. The main goal of this team is the study of optimization problems involving complex structures. The scientific objectives of INOCS are related to modeling and methodological concerns. The INOCS team will focus on:

 (i) integrated models for problems with complex structure (CS) taking into account the whole structure of the problem;

 (ii) on the development of solution methods taking explicitly into account *the nature and the structure of the decisions as well as the properties of the problem.*

Even if CS problems are in general NP-hard due to their complex nature, exact solution methods or matheuristics (heuristics based on exact optimization methods) will be developed by INOCS. The scientific contribution of INOCS will result in a toolbox of models and methods to solve challenging real life problems.

2.2   Schedule of tasks

The research program development of INOCS is to move alternatively:

- *from problems towards new approaches in optimization*: Models and solution algorithms will be developed to fit the structure and properties of the problem. From them, new generic approaches will be used to optimize problems with similar properties.

- *from innovative approaches towards problems*: The relevance of the proposed approaches will be assessed by designing new models and/or solution methods for various classes of problems. These models and methods will be based on the extension and integration of specific, well studied, models and methods.

Even if these two axes are developed sequentially in a first phase, their interactions will lead us to explore them jointly in the mid-term.

3   Research program

3.1   Introduction

An optimization problem consists in finding a best solution from a set of feasible solutions. Such a problem can be typically modeled as a mathematical program in which decision variables must (i) satisfy a set of constraints that translate the feasibility of the solution and (ii) optimize some (or several) objective function(s). Optimization problems are usually classified into *strategic*, *tactical* and *operational* problems, according to types of decision to be taken.

We consider that an optimization problem presents a *complex structure* (CS) when it involves decisions of different types/nature (i.e. strategic, tactical or operational) and/or presents some hierarchical leader-follower structure. The set of constraints may usually be partitioned into *global constraints*, linking variables associated with the different types/nature of decision, and constraints involving each type of variables *separately*. Optimization problems with complex structure lead to extremely challenging problems since a global optimum with respect to the whole sets of decision variables and of constraints must be determined.

Significant progress has been made in optimization to solve academic problems. Nowadays large-scale instances of some NP-hard problems are routinely solved to optimality. *Our vision within INOCS is to make the same advances while addressing CS optimization problems.* To achieve this goal we aim to develop global solution approaches at the opposite of the current trend. INOCS team members have already proposed some successful methods following this research lines to model and solve CS problems (e.g. ANR project RESPET, Brotcorne et al. [48, 49], Gendron et al. [50, 51, 52], and Strack et al. [55]). However, these are preliminary attempts and a number of challenges regarding modeling and methodological issues have still to be met.

3.2   Modeling problems with complex structures

A classical optimization problem can be formulated as follows:

$$
\begin{aligned}
\min \quad & f(x) \\
s.t. \quad & x \in X.
\end{aligned}
\tag{1}
$$

In this problem, X is the set of feasible solutions. Typically, in mathematical programming, X is defined by a set of constraints. x may be also limited to non-negative integer values.

The INOCS team plans to address optimization problem where two types of decision are addressed jointly and are interrelated. More precisely, let us assume that variables x and y are associated with these decisions. A generic model for CS problems is the following:

$$
\begin{aligned}
\min \quad & g(x, y) \\
s.t. \quad & x \in X, \\
& (x, y) \in XY, \\
& y \in Y(x).
\end{aligned}
\tag{2}
$$

In this model, X is the set of feasible values for x. XY is the set of feasible values for x and y jointly. This set is typically modeled through linking constraints. Last, $Y(x)$ is the set of feasible values for y for a given x. In INOCS, we do not assume that $Y(x)$ has any properties.

The INOCS team plans to model optimization CS problems according to three types of optimization paradigms: large scale complex structures optimization, bilevel optimization and robust/stochastic optimization. These paradigms instantiate specific variants of the generic model.

Large scale complex structures optimization problems can be formulated through the simplest variant of the generic model given above. In this case, it is assumed that $Y(x)$ does not depend on x. In such models, X and Y are associated with constraints on x and on y, XY are the linking constraints. x and y can take continuous or integer values. Note that all the problem data are deterministically known.

Bilevel programs allow the modeling of situations in which a decision-maker, hereafter the leader, optimizes his objective by taking explicitly into account the response of another decision maker or set of decision makers (the follower) to his/her decisions. Bilevel programs are closely related to Stackelberg (leader-follower) games as well as to the principal-agent paradigm in economics. In other words, bilevel

programs can be considered as demand-offer equilibrium models where the demand is the result of another mathematical problem. Bilevel problems can be formulated through the generic CS model when $Y(x)$ corresponds to the optimal solutions of a mathematical program defined for a given x, i.e. $Y(x) = \arg\min\{h(x, y)|y \in Y_2, (x, y) \in XY_2\}$ where Y_2 is defined by a set of constraints on y, and XY_2 is associated with the linking constraints.

In robust/stochastic optimization, it is assumed that the data related to a problem are subject to uncertainty. In stochastic optimization, probability distributions governing the data are known, and the objective function involves mathematical expectation(s). In robust optimization, uncertain data take value within specified sets, and the function to optimize is formulated in terms of a min-max objective typically (the solution must be optimal for the worst-case scenario). A standard modeling of uncertainty on data is obtained by defining a set of possible scenarios that can be described explicitly or implicitly. In stochastic optimization, in addition, a probability of occurrence is associated with each scenario and the expected objective value is optimized.

3.3   Solving problems with complex structures

Standard solution methods developed for CS problems solve independent subproblems associated with each type of variables without explicitly integrating their interactions or integrating them iteratively in a heuristic way. However these subproblems are intrinsically linked and should be addressed jointly. In *mathematical optimization* a classical approach is to approximate the convex hull of the integer solutions of the model by its linear relaxation. The main solution methods are (1) polyhedral solution methods which strengthen this linear relaxation by adding valid inequalities, (2) decomposition solution methods (Dantzig Wolfe, Lagrangian Relaxation, Benders decomposition) which aim to obtain a better approximation and solve it by generating extreme points/rays. Main challenges are (1) the analysis of the strength of the cuts and their separations for polyhedral solution methods, (2) the decomposition schemes and (3) the extreme points/rays generations for the decomposition solution methods.

The main difficulty in solving *bilevel problems* is due to their non convexity and non differentiability. Even linear bilevel programs, where all functions involved are affine, are computationally challenging despite their apparent simplicity. Up to now, much research has been devoted to bilevel problems with linear or convex follower problems. In this case, the problem can be reformulated as a single-level program involving complementarity constraints, exemplifying the dual nature, continuous and combinatorial, of bilevel programs.

4   Application domains

4.1   Energy

In energy, the team mainly focuses on pricing models for demand side management, on bids definition in the Energy market and on the design and pricing of electric cars charging stations.

Demand side management methods are traditionally used to control electricity demand which became quite irregular recently and resulted in inefficiency in supply. We have explored the relationship between energy suppliers and customers who are connected to a smart grid. The smart grid technology allows customers to keep track of hourly prices and shift their demand accordingly, and allows the provider to observe the actual demand response to its pricing strategy. We tackle pricing problems in energy according to the bilevel optimization approaches. Some research works in this domain are supported by bilateral grants with EDF.

The increasing number of agents, with different characteristics) interacting on the energy market leads to the definition of new types of bidding process. We have modeled this problem has a bilevel one where the lower lever is the instance allocating the bids (the ISO).

The proliferation of electric cars in cities has lead to the challenging problem of designing and pricing charging stations in order to smooth the demand over time. We are modeling this problem as a bilevel one where the lower lever represents the choice of users in a preference list.

4.2   Transportation and Logistics

In transportation and logistics, the team addresses mainly integrated problems, which require taking into account simultaneously different types of decision. Examples are location and routing, inventory management and routing or staff scheduling and warehouse operations management. Such problems occur from the supply chain design level to the logistic facility level.

4.3   Telecommunications

In telecommunications, the team mainly focuses on network design problems and on routing problems. Such problems are optimization problems with complex structure, since the optimization of capacity installation and traffic flow routing have to be addressed simultaneously.

5   Highlights of the year

5.1   Awards

- In may 2021, the paper [54] was awarded the 2020 Rosenbrock prize. The prize is awarded annually for the best paper published in the journal Optimization and Engineering during the previous year.

6   New software and platforms

6.1   New software

6.1.1   GroupTesting

Keywords: Linear optimization, Group Testing

Functional Description: Group testing is a screening strategy that involves dividing a population into several disjointed groups of subjects. In its simplest implementation, each group is tested with a single test in the first phase, while in the second phase only subjects in positive groups, if any, need to be tested again individually.

To contribute to the effort to tackle the COVID-19 sanitary crisis, we developed this software which allows to create groups of a individuals to test via the group testing technique while minimizing a linear combination of the expected number of false negative and false positive classifications.

The test design problem is modeled as a constrained shortest path problem on a specific graph and we design and implement an ad hoc algorithm to solve this problem. We validate the algorithm on instances based on Santé Publique France data on Covid-19 screening tests.

Contact: Kaba Keita

6.1.2   INOCSBox

Keywords: Linear optimization, Operational research, Toolbox

Functional Description: This software is a toolbox that contains algorithms that are frequently used to solve optimization problems tackled by (but not only) the team.

The objective of the toolbox is to contain a set of code skeletons that allow researchers to integrate adequate data structures and basic algorithms for different structures complexity that appears in the optimization problems we study. The current version of the toolbox contains classical heuristic tools (generic local search) to solve, among others, the vehicle rouring problem and its variants. It also contain a code to exactly and heuristically solve the Shortest Path Problem with Ressource Constraints that is usually encountered in the resolution of problem with Branch-and-Price algorithms.

The future objective is to include automatic reformulation tools for bi-level optimization problems and state-of-the-art codes for the development of decomposition methods.

Contact: Tifaout Almeftah

7 New results

7.1 Large scale complex structure optimization

Last mile delivery and satellite depot management

We reviewed the Operations Research models and methods to plan and manage City Logistics systems, in particular their supply components in [42]. We considered the main planning issues and challenges, and reviewed the proposed methodologies. This article concludes with a discussion on perspectives for City Logistics and decision-support methodological developments.

In [32], we focus on two-tier city logistics systems which are playing a very important role nowadays in the management of urban freight activities. Although several city authorities have promoted different measures to foster the implementation of small urban consolidation centers in a two-tier system, only a few authors have addressed the joint problem of operating these facilities and providing services to customers. We show how the problem can be modeled as a new variant of the bin packing, for which we provide a mixed integer programming formulation and two heuristics that are shown to be quite effective in solving efficiently and to near optimality the problem. The application of our approach on real data from the city of Turin puts into highlight the superiority of the consolidation approach, including the bundle of goods from different providers, stockholding and other value-added logistics services, over the classical single-tier approach. In addition, the paper provides a thorough analysis of some emerging aspects of the on-demand economy, as the consideration of customers' preferences and the integration of multiple delivery options. The managerial insights coming from this work will be part of the new Logistics and Mobility Plan to be activated in 2022 in the Piedmont region, Italy.

Logistics network design problem

Planning transportation operations within a supply chain is a difficult task that is often outsourced to logistics providers, in practice. At the tactical level, the problem of distributing products through a multi-echelon network is defined in the literature as the Logistics Service Network Design Problem (LSNDP). In the LSNDP, a logistics service provider seeks to cost-effectively source and fulfill customer demands of products within a multi-echelon distribution network. However, many industrial settings yield instances of the LSNDP that are too large to be solved in reasonable run-times by off-the-shelf optimization solvers. We introduce an exact Benders decomposition algorithm based on partial decompositions that strengthens the master problem with information derived from aggregated subproblem data. More specifically, the proposed Meta Partial Benders Decomposition intelligently switches from one master problem to another by changing both the amount of subproblem information to include in the master as well as how it is aggregated. Through an extensive computational study, we show that the approach outperforms existing benchmark methods and demonstrate the benefits of dynamically refining the master problem in the course of a partial Benders decomposition-based scheme. [39]. However, realistic instances are still too large to be solved in acceptable run-times, we develop a network reduction heuristic inspired by the recent Dynamic Discretization Discovery algorithm. Through an extensive series of experiments carried out on instances based on the operations of an industrial partner, we demonstrate the efficiency of the proposed approach. We also investigate the impact of the distribution strategy used in practice to determine the transportation plan and how this distribution strategy can be modified to reduce the overall logistics cost [12].

Network design covering problems

Infrastructure network design constitutes a major step in the planning of a transportation network whose purpose is to improve the mobility of the inhabitants of a city or metropolitan area. Since it is generally too expensive to connect all the existing facilities, one must determine a subnetwork that serves at best the traffic demand. Depending on the application, different optimality measures can be considered. In the area of passengers transportation, the aim is to get the infrastructure close to potential customers. In this framework, the goal may be to minimize the maximum routing cost for an origin destination pair when using the new network. Alternatively, the traffic between an origin and

a destination may be considered as captured if the cost or travel time when using the network is not larger than the cost or travel time of the best alternative solution (not using the new network). In this case, one might select a sub(network) from an underlying network with the aim of capturing or covering as much traffic for a reasonable construction cost. Our contribution in [16] is devoted to this problem, called the Maximum Covering Network Design Problem (MC) as well as to the closely related problem called, Partial Covering Network Design Problem (PC), in which one minimizes the network design cost for building the network under the constraint that a minimum percentage of the total traffic demand is covered. After presenting models for problems (MC) and (PC), we propose exact methods based on Benders decomposition. Our computational experiments show that our Benders implementations are competitive with exact and non-exact methods in the literature.

Multi-commodity two-echelon distribution problem

We address a Multi-commodity two-echelon distribution problem where three sets of stakeholders are involved: suppliers, distribution centers, and customers. Multiple commodities have to be sent from suppliers to customers, using multiple distribution centers for consolidation purposes. Commodities are collected from the suppliers and delivered to the distribution centers with direct trips, while a fleet of homogeneous vehicles distributes commodities to customers. Commodities are compatible, that is any vehicle can transport any set of commodities as long as its capacity is not exceeded. The goal is to minimize the total transportation cost from suppliers to customers. We present two sequential schemes based on the solution, in a different order, of a collection and a delivery subproblem. In both cases, the solution of the first subproblem determines the quantity of each commodity at each distribution center. The second subproblem takes this information as input. We also propose different strategies to guide the solution of the first subproblem in order to take into account the impact of its solution on the second subproblem. The proposed sequential heuristics are evaluated and compared both on randomly generated instances and on a case study related to a short and local fresh food supply chain. The results show the impact of problem characteristics on solution strategies [22].

Generalized routing problems

We study routing problems that arise in the context of last mile delivery when multiple delivery options are proposed to the customers. The most common option to deliver packages is home/workplace delivery. Besides, the delivery can be made to pick-up points such as dedicated lockers or stores. In recent years, a new concept called trunk/in-car delivery has been proposed. Here, customers' packages can be delivered to the trunks of cars. Our goal is to model and develop efficient solution approaches for routing problems in this context, in which each customer can have multiple shipping locations. First, we study the single-vehicle case in the considered context, which is modeled as a Generalized Traveling Salesman Problem with Time Windows (GTSPTW). Four mixed integer linear programming formulations are proposed [33]. Then, we study the multi-vehicle case which is denoted Generalized Vehicle Routing Problem with Time Windows (GVRPTW). We present a set covering formulation for the GVRPTW which is used to provide a column generation based heuristic to solve it. The proposed solving method combines several components including a construction heuristic, a route optimization procedure, local search operators and the generation of negative reduced cost routes. Experimental results on benchmark instances show that the proposed algorithm is efficient and high-quality solutions for instances with up to 120 clusters are obtained within short computation times [34].

Agriculture robot routing problem

To date, the research on agriculture vehicles in general and Agriculture Mobile Robots (AMRs) in particular has focused on a single vehicle (robot) and its agriculture-specific capabilities. Very little work has explored the coordination of fleets of such vehicles in the daily execution of farming tasks. This is especially the case when considering overall fleet performance, its efficiency and scalability in the context of highly automated agriculture vehicles that perform tasks throughout multiple fields potentially owned by different farmers and/or enterprises. The potential impact of automating AMR fleet coordination on commercial agriculture is immense. Major conglomerates with large and heterogeneous fleets of agriculture vehicles could operate on huge land areas without human operators to effect precision farming. In this paper, we propose the Agriculture Fleet Vehicle Routing Problem (AF-VRP) which, to

the best of our knowledge, differs from any other version of the Vehicle Routing Problem studied so far. We focus on the dynamic and decentralized version of this problem applicable in environments involving multiple agriculture machinery and farm owners where concepts of fairness and equity must be considered. Such a problem combines three related problems: the dynamic assignment problem, the dynamic 3-index assignment problem and the capacitated arc routing problem. We review the state-of-the-art and categorise solution approaches as centralized, distributed and decentralized, based on the underlining decision-making context. Finally, we present open challenges in applying distributed and decentralized coordination approaches to this problem [30].

Multi-market portfolio optimization with conditional value at risk

The delegated portfolio management has been at the core of financial debates, leading to a growing research effort to provide modeling and solution approaches. This class of problems focuses on investors relying upon decentralized affiliates for the specialized selection of investment options. In [31] we propose a novel optimization framework for multi-market portfolio management, where a central headquarter delegates the market-wise portfolio selection to specialized affiliates. Being averse to risk, the headquarter endogenously sets the maximum expected loss (in the form of conditional value at risk) for the affiliates, who respond designing portfolios and retaining portions of the expected investment returns as management fees. We show that the problem is NP-Hard and propose a decomposition procedure and strong valid inequalities, capable of boosting the efficiency of the computational solution, when instances become large. In the same line, optimality bounds exploiting overlooked properties of the conditional value at risk are deduced, to provide almost exact solutions with few seconds of computation. Building on this theoretical development, we conduct computational tests using comprehensive firm-level data from 1999 to 2014 on 7256 U.S. listed enterprises. These tests support the effectiveness of the decomposition procedure, as well as the one of the strong valid inequalities.

Discrete Ordered Median Problem

The discrete ordered median problem (DOMP) consists in locating p facilities in order to minimize an ordered weighted sum of distances between clients and closest open facility. We formulate this problem as a set partitioning problem using an exponential number of variables. Each variable corresponds to a set of demand points allocated to the same facility with the information of the sorting position of their corresponding costs. We develop a column generation approach to solve the continuous relaxation of this model. Then, we apply a branch-price-and-cut algorithm to solve small to large sized instances of DOMP in competitive computational time [19].

Segmented isotonic regression

The segmented isotonic regression problem consists in fitting a curve to a cloud of data points under the conditions that the fitted curve must be non-increasing (or non-decreasing) and piecewise constant (or, equivalently, stepwise), with a predefined limited number of pieces (also referred to as steps or blocks in what follows). This problem is inspired by the bidding rules that large consumers or a pool of small consumers must comply with when participating in an electricity market. Their bids for purchasing electricity in these markets must be often submitted in the form of a non-increasing stepwise price-consumption curve, for which the maximum number of bid blocks is also constrained. These curves reflect how consumers value electricity and therefore, their sensitivity to its price (which is referred to as consumers' elasticity). With the advent of Information and Communications Technologies and the roll-out of the so-called smart grids, small consumers of electricity are being provided with the means to actively adjust their consumption in response to the electricity price. However, their consumption patterns are still uncertain, dynamic and affected by other factors different from the electricity price. The result is that estimating a bidding curve that properly reflects consumers' sensitivity to the electricity price is a statistical challenge.

In [17], we provide an algorithm to efficiently computes that curve from a set of price-consumption observations. To ease the computational burden of the proposed algorithm, we develop various strategies to efficiently calculate upper and lower bounds that substantially reduce the number of paths to be explored. Numerical results reveal that our algorithm is able to provide the globally optimal monotone stepwise curve for samples with thousands of data points in less than a few hours.

Shortest paths and location problems with different l_p -norms on different regions

The weighted region problem (WRP) is a generalization of the shortest path problem considered in a geometric domain where the travel distance is region-dependent. More precisely, given a subdivision of the plane in polyhedra with different associated weights, the WRP asks for the Euclidean shortest path between two points but taking into account that the distance traversed along a polyhedron has to be multiplied by its associated weight. Besides its mathematical interest, the WRP is motivated by its application to design the route of robots through zones with different terrains that are traversed at different speeds. Other practical applications of the WRP have been proposed for instance in geographical information systems (GIS) and in Seismology. In [28] we consider the Weighted Region Problem with different l_p-norms (l_p-WRP), a variant of the WRP where each polyhedron of the subdivision is endowed with a different l_p- norm, $1 \le p \le +\infty$. We study this problem not only in the plane, but also in R^d. As an intuitive qualitative criterion, we restrict feasible paths to be simple, i.e., a path can visit each polyhedron at most once. In general, simple paths fit the criteria of smoothness and sharp turns avoidance better than the paths that enter to and leave the same polyhedron several times. Since the WRP is not solvable in any algebraic computation model over the rational numbers, the l_p-WRP is not either. We propose a solution scheme based on the representation of the problem as a mixed-integer second order cone problem (MISOCP). We derive two different MISOCPs formulations, theoretically compare the lower bounds provided by their continuous relaxations, and propose a preprocessing scheme to improve their performance. The usefulness of this approach is validated through computational experiments. The second problem that we consider is the Weber problem that results in this subdivision of l_p-normed polyhedra. To solve it, we adapt the solution scheme that we developed for the shortest path problem and validate our methodology with extensive computational experiments.

Finding the root graph through minimum edge deletion

Given a graph, its line graph is another graph whose vertices are the edges of the original one. Further an edge links two nodes of the line graph if and only if the corresponding edges of the original graph share a node. A graph is said to be line-invertible if it is isomorphic to the line graph of some other graph, called the root. Although obtaining the line graph of a given graph is straightforward, doing the reverse is not a trivial task.

In genetics, haplotypes codify certain regions of the genome that show a statistically significant variability within a population. It has been observed that such variability plays an important role in human variation and genetic diseases. Haplotype phasing consists of estimating the haplotypes that produced a current population of genotypes, and is a primary problem in the analysis of genetic data. In this context, consistency relations between genotypes that could have been originated from a common ancestor are codified by a graph. Root graph reconstruction is useful here to estimate the original population size, that is, the number of generating haplotypes. However, if all the consistency relations are considered, sometimes reconstruction from the graph is not possible. In other words, the graph encoding consistency relations is not line-invertible. In these cases, one needs to disregard some of these relations, that is, to delete some of the edges of the consistency graph. A combinatorial problem then arises, namely which edges to remove so that the graph is disrupted as little as possible. In [26], we study the problem of identifying a set of edges of minimum cardinality that have to be deleted from a graph so that it becomes line-invertible. We propose different integer linear programming models as well as valid inequalities to strengthen them. Our computational experiments allow empirical comparison between the different models and ultimately demonstrate their utility.

Transmission-Distribution Stable Cost Allocation for the Joint Procurement of Flexibility: A Cooperative Game Approach

In [46], a transmission-distribution systems flexibility market is introduced, in which system operators (SOs) jointly procure flexibility from different systems to meet their needs (balancing and congestion management) using a common market. This common market is, then, formulated as a cooperative game aiming at identifying a stable and efficient split of costs of the jointly procured flexibility among the participating SOs to incentivize their cooperation. The non-emptiness of the core of this game is then mathematically proven, implying the stability of the game and the naturally-arising incentive for cooperation among the SOs. Several cost allocation mechanisms are then introduced, while characterizing their

mathematical properties. Numerical results focusing on an interconnected system (composed of the IEEE 14-bus transmission system and the Matpower 18-bus, 69-bus, and 141-bus distributions systems) showcase the cooperation-induced reduction in systemwide flexibility procurement costs, and identifies the varying costs borne by different SOs under various cost allocations methods.

7.2   Bilevel Programming

Pricing for Energy Management

Power systems face higher flexibility requirements from generation to consumption due to the increasing penetration of non-controllable distributed renewable energy. In this context, demand side management aims at reducing excessive load fluctuation and match the price of energy to their real cost for the grid. Pricing models for demand side management methods are traditionally used to control electricity demand. First, we proposed bilevel pricing models to explore the relationship between energy suppliers and customers who are connected to a smart grid. The smart grid technology allows customers to keep track of hourly prices and shift their demand accordingly, and allows the provider to observe the actual demand response to its pricing strategy. Moreover, we assumed that the smart grid optimizes the usage of a renewable energy generation source and a storage capacity. Results over a rolling horizon were obtained (Léonard Von Niederhausern PhD thesis [56]). Time and Level-of-Use is a recently proposed energy pricing scheme, designed for the residential sector and providing suppliers with robust guarantee on the consumption. We formulate the supplier decision as a bilevel problem optimizing for financial loss. Numerical results on experimental residential power consumption data show the method effectively finds the optimal candidate [11].

A Generalized Nash Equilibrium analysis of the interaction between a peer-to-peer market and the distribution grid

In [35], we consider the interaction between the distribution grid (physical level) managed by the distribution system operator (DSO), and a financial market in which prosumers optimize their demand, generation, and bilateral trades in order to minimize their costs subject to local constraints and bilateral trading reciprocity coupling constraints. We model the interaction problem between the physical and financial levels as a noncooperative generalized Nash equilibrium problem. We compare two designs of the financial level prosumer market: a centralized design and a peer-to-peer fully distributed design. We prove the Pareto efficiency of the equilibria under homogeneity of the trading cost preferences. In addition, we prove that the pricing structure of our noncooperative game does not permit free-lunch behavior. Finally, in the numerical section we provide additional insights on the efficiency loss with respect to the different levels of agents' flexibility and amount of renewables in the network. We also quantify the impact of the prosumers' pricing on the noncooperative game social cost.

Broader results are obtained in [36], relying on duality theory extension.

Linear bilevel optimization

One of the most frequently used approaches to solve linear bilevel optimization problems consists in replacing the lower-level problem with its Karush–Kuhn–Tucker (KKT) conditions and by reformulating the KKT complementarity conditions using techniques from mixed-integer linear optimization. The latter step requires to determine some big-M constant in order to bound the lower level's dual feasible set such that no bilevel-optimal solution is cut off. In practice, heuristics are often used to find a big-M although it is known that these approaches may fail. In [53], we consider the hardness of two proxies for the above mentioned concept of a bilevel-correct big-M. First, we prove that verifying that a given big-M does not cut off any feasible vertex of the lower level's dual polyhedron cannot be done in polynomial time unless $P = NP$. Second, we show that verifying that a given big-M does not cut off any optimal point of the lower level's dual problem (for any point in the projection of the high-point relaxation onto the leader's decision space) is as hard as solving the original bilevel problem. Similarly to mixed-integer programming, valid inequalities could be used to provide tighter relaxations of bilevel problems by cutting off bilevel-infeasible points, i.e. points that violate optimality of the lower-level problem. However, for linear bilevel problems not many tailored valid inequalities are known. In [25], we derive such a valid inequality for linear bilevel problems by exploiting the strong-duality condition of the lower-level problem. This primal-dual inequality turns out to be very effective for some instances.

Product pricing

One of the main concerns in management and economic planning is to sell the right product to the right customer for the right price. Companies in retail and manufacturing employ pricing strategies to maximize their revenues.

In the Rank Pricing Problem (RPP), a firm intends to maximize its profit through the pricing of a set of products to sell. Customers are interested in purchasing at most one product among a subset of products. To do so, they are endowed with a ranked list of preferences and a budget. Their choice rule consists in purchasing the highest-ranked product in their list and whose price is below their budget. In [20], we consider an extension of RPP, the Rank Pricing Problem with Ties (RPPT), in which we allow for indifference between products in the list of preferences of the customers. We propose different mixed integer programming formulations for the problem and valid inequalities to strengthen them. Computational experiments assess the performance of the proposed approaches. In [43], we generalize the RPP assuming that each product has a limited amount of copies for sale, and we call this extension the Capacitated Rank Pricing Problem (CRPP). We compare the envy-free allocation of the products (a fairness criterion requiring that customers receive their highest-ranked product given the pricing) with the envy version of the problem. Next, we focus on the CRPP with envy. We introduce two integer linear formulations for the CRPP and derive valid inequalities leveraging the structure of the problem. Afterwards, we develop separation procedures for the families of valid inequalities of greater size. The performance of the formulations and the resolution algorithms developed is tested by means of extensive computational experiments.

Bilevel Minimum Spanning Tree Problem

Consider a graph G whose edge set is partitioned into a set of red edges and a set of blue edges, and assume that red edges are weighted and contain a spanning tree of G. Then, the Bilevel Minimum Spanning Tree Problem (BMSTP) consists in pricing (i.e. weighting) the blue edges in such a way that the total weight of the blue edges selected in a minimum spanning tree of the resulting graph is maximized. We propose different mathematical formulations for the BMSTP based on the properties of the Minimum Spanning Tree Problem and the bilevel optimization. We establish a theoretical and empirical comparison between these new formulations and we also provide reinforcements that together with a proper formulation are able to solve medium to big size instances [28].

Stackelberg games

We formulate a Stackelberg Security game that coordinates resources in a border patrol problem. In this security domain, resources from different precincts have to be paired to conduct patrols in the border due to logistic constraints. Given this structure the set of pure defender strategies is of exponential size. We describe the set of mixed strategies using a polynomial number of variables but exponentially many constraints that come from the matching polytope. We then include this description in a mixed integer formulation to compute the Strong Stackelberg Equilibrium efficiently with a branch and cut scheme. Since the optimal patrol solution is a probability distribution over the set of exponential size, we also introduce an efficient sampling method that can be used to deploy the security resources every shift. Our computational results evaluate the efficiency of the branch and cut scheme developed and the accuracy of the sampling method. We show the applicability of the methodology by solving a real world border patrol problem [15].

Fare inspection patrols scheduling in transit systems using a Stackelberg game approach

We analyze the scheduling of unpredictable fare inspections in proof-of-payment transit systems, where the transit operator chooses a collection of patrol paths (one for each patrol) every day with some probability in order to avoid any regularity that could be exploited by opportunistic passengers. We use a Stackelberg game approach to represent the hierarchical decision-making process between the transit operator and opportunistic passengers, whose decision on whether to evade the fare depends on the inspection probabilities set by the transit operator. Unlike previous work, we use an exact formulation of the inspection probabilities that allows us to develop new heuristics for the fare inspection scheduling problem, and to assess their solution quality in terms of their optimality gap [14].

Strategic bidding in price coupled regions

With the emerging deregulated electricity markets, a part of the electricity trading takes place in day-ahead markets where producers and retailers place bids in order to maximize their profit. We present a price-maker model for strategic bidding from the perspective of a producer in Price Coupled Regions (PCR) considering a capacitated transmission network between local day-ahead markets. The aim for the bidder is to establish a production plan and set its bids taking into consideration the reaction of the market. We consider the problem as deterministic, that is, the bids of the competitors are known in advance. We are facing a bilevel optimization problem where the first level is a Unit Commitment problem, modeled as a Mixed Integer Linear Program (MILP), and the second level models a market equilibrium problem through a Linear Program. The problem is first reformulated as a single level problem. Properties of the optimal spot prices are studied to obtain an extended formulation that is linearized and tightened using new valid inequalities. Several properties of the spot prices allow to reduce significantly the number of binary variables. Two novel heuristics are proposed [18].

Mixed integer programming techniques for bilevel optimization

The scientific interest in computational bilevel optimization increased a lot over the last decade and is still growing. Independent of whether the bilevel problem itself contains integer variables or not, many state-of-the-art solution approaches for bilevel optimization make use of techniques that originate from mixed-integer programming. These techniques include branch-and-bound methods, cutting planes and, thus, branch-and-cut approaches, or problem specific decomposition methods. In [24], we review bilevel-tailored approaches that exploit these mixed-integer programming techniques to solve bilevel optimization problems.

Bilevel network design

In the context of network design, the bilevel paradigm is especially relevant when the designer of a network does not have a direct control of user flows, who are assigned according to their own logic. In the chapter [38], we illustrate, through four distinct applications, the modelling and algorithmic issues that characterize bilevel network design problems. Throughout, we assign a broad sense to the term 'network design', meaning any program that involves the determination of variables that impact the structure of a graph or a network.

Design of Poisoning Attacks on Linear Regression Using Bilevel Optimization

Poisoning attack is one of the attack types commonly studied in the field of adversarial machine learning. The adversary generating poison attacks is assumed to have access to the training process of a machine learning algorithm and aims to prevent the algorithm from functioning properly by injecting manipulative data while the algorithm is being trained. In [47], our focus is on poisoning attacks against linear regression models which target to weaken the prediction power of the attacked regression model. We propose a bilevel optimization problem to model this adversarial process between the attacker generating poisoning attacks and the learner which tries to learn the best predictive regression model. We give an alternative single level optimization problem by benefiting from the optimality conditions of the learner's problem. A commercial solver is used to solve the resulting single level optimization problem where we generate the whole set of poisoning attack samples at once. Besides, an iterative approach that allows to determine only a portion of poisoning attack samples at every iteration is introduced. The proposed attack strategies are shown to be superior than a benchmark algorithm from the literature by carrying out extensive experiments on two realistic datasets.

7.3   Robust/Stochastic programming

Complexity study of robust bilevel optimization problems

Near-optimality robustness extends multilevel optimization with a limited deviation of a lower level from its optimal solution, anticipated by higher levels. We analyze the complexity of near-optimal robust multilevel problems, where near-optimal robustness is modeled through additional adversarial decision makers. Near-optimal robust versions of multilevel problems are shown to remain in the same complexity class as the problem without near-optimality robustness under general conditions [13].

Deciding feasibility of a booking in the European Gas Market

During the last decades, the European gas market has undergone ongoing liberalization, resulting in the so-called entry-exit market system. The main goal of this market reorganization is the decoupling of trading and actual gas transport. To achieve this goal within the European entry-exit market, gas traders interact with transport system operators (TSOs) via bookings and nominations. A booking is a capacity-right contract in which a trader reserves a maximum injection or withdrawal capacity at an entry or exit node of the TSO's network. On a day-ahead basis, these traders are then allowed to nominate an actual load flow up to the booked capacity. To this end, the traders specify the actual amount of gas to be injected to or withdrawn from the network such that the total injection and withdrawal quantities are balanced. On the other hand, the TSO is responsible for the transport of the nominated amounts of gas. By having signed the booking contract, the TSO guarantees that the nominated amounts can actually be transported through the network. More precisely, the TSO needs to be able to transport every set of nominations that complies with the signed booking contracts. Thus, an infinite number of possible nominations must be anticipated and checked for feasibility when the TSO accepts bookings. As a consequence, the entry-exit market decouples trading and transport. However, it also introduces many new challenges, e.g. the checking of feasibility of bookings or the computation of bookable capacities on the network.

Deciding the feasibility of a booking can be seen as an adjustable robust feasibility problem, where the set of booking-compliant nominations is the uncertainty set. The feasibility of a booking, if the underlying network is a tree, can be decided in polynomial time. In [27], we extend the knowledge on the frontier of hardness by showing that deciding the feasibility of a booking on single-cycle networks is in P. We analyze the structure of potential difference maximizing nominations by exploiting the cyclic structure of the network as well as techniques specific to potential-based flow models. Interestingly, this allows to reduce the task of checking the feasibility of a booking to checking the solvability of a system of polynomial equalities and inequalities in fixed dimension, where the latter does not depend on the size of the cycle.

In [45], we consider networks with linearly modeled active elements such as compressors and control valves that do not lie on cycles of the network. Since these active elements allow the TSO to control the gas flow, the single-level approaches from the literature are no longer applicable. We thus present a bilevel approach to decide the feasibility of bookings in networks with active elements. Besides the classical Karush–Kuhn–Tucker reformulation, we obtain three problem-specific optimal-value-function reformulations, which also lead to novel characterizations of feasible bookings in active networks. We compare the performance of our methods by a case study based on data from the GasLib.

8 Bilateral contracts and grants with industry

8.1 Bilateral contracts with industry

- Urban hub. Development of an integrated tool for warehouse management and delivery to the end customer (2019 – 2021).

8.2 Bilateral grants with industry

- Program PGMO funded by the Fondation Mathématiques Jacques Hadamard. A generic framework for routing and scheduling problems (2019 – 2022).

- Program PGMO funded by the Fondation Mathématiques Jacques Hadamard. Integrated models for the dimensioning and location of charging electric vehicles stations in the presence of renewable energy sources: Models and Algorithms (2019 – 2022).

- Inria/OVH Cloud joint challenge. Towards energy-oriented pricing strategies in the cloud (2021 – 2025).

9 Partnerships and cooperations

9.1 International initiatives

9.1.1 Associate Teams in the framework of an Inria International Lab or in the framework of an Inria International Program

BIO-SEL

Title: BIlevel Optimization in Security, Energy and Logistics.

Duration: 2020 – 2024 (with restart in 2022).

Coordinator: Vladimir Marianov (marianov@ing.puc.cl).

Partners:

- Pontificia Universidad Católica de Chile.

Inria contact: Martine Labbé.

Summary: This projet is devoted to bilevel optimization problems with application in the security, energy, and logistics domains. Stackelberg games, including one defender and several followers, bidding problems in energy supply markets and product selection problems will be considered. Mixed integer optimization models and efficient algorithms to solve them will be developed.

9.1.2 Inria associate team not involved in an IIL or an international program

LOBI

Title: Learning within Bilevel Optimization.

Duration: 2018 – 2021.

Coordinator: Gilles Savard (gilles.savard@polymtl.ca).

Partners:

- Polytechnique Montréal, Canada.

Inria contact: Diego Cattaruzza.

Summary: The interplay between optimization and machine learning (ML) is one of the most important developments in modern computational science. The project LOBI is concerned with the interconnection between ML approaches and a particular branch of optimization, that is bilevel optimization (BO). LOBI research focuses on the development of new approaches integrating ML within BO.

9.1.3 Participation in other International Programs

CityFreight

CityFreight — Freight logistics in sustainable cities

Partner Institutions:

- University of Bergen – Centre for Climate and Energy Transformation
- The Norwegian Public Roads Administration
- Sparebanken Vest
- City of Bergen
- Vestland County, Bergen Chamber of Commerce and Industry, Nordic Edge AS (Norway)

- Centrale Lille
- The Polytechnic University of Turin (Italy)
- Sichuan University, Chengdu (China)

Duration: 2020 – 2024

Additionnal info: The primary objective of this project is to provide public authorities, particularly in smaller, topologically complicated, cities and initially the City of Bergen, with a toolbox for realistically evaluating major decisions that would make a city more energy efficient and sustainable in terms of freight transportation

9.2   European initiatives

9.2.1   Other european programs/initiatives

CHIST-ERA project SEC-OREA — Supporting Energy Communities- Operational Research and Energy Analytics.
The SEC-OREA project enables local energy communities (LECs) to participate in the decarbonisation of the energy sector by developing advanced efficient algorithms and analytics technologies.

LECs are an efficient way to manage energy by increasing the use of renewable energy sources (RES) at a local level. We aim to co-create an overarching LEC enabling framework with our stakeholders. Our goal is to create technical tools to empower citizens and place them at the core of the Energy Union. It is important to ensure that the participation of LECs in the energy systems transformation has the desired effect of decarbonising the system, and that this is done in a fair manner without destabilising the power system. We propose to use business analytics to define our stakeholders' research and innovation question, and to use energy analytics and operational research techniques to gather appropriate data, build statistical and machine learning models, and mathematical optimization models to find solutions and support decision making by our stakeholders.

The consortium brings together expertise from Business, Climatology, Computational Methods, Secure ICT, and Power Systems. We reach across the EU with researchers, innovators and stakeholders in Belgium, France, Ireland, Latvia and Portugal. Stakeholders include a national meteorological service, an LEC, and a distribution system operator (DSO).

We use climate services to gather energy-relevant pan-European indicators of climate trends and variability. We model energy consumption data to understand and create dynamic scenarios of electricity consumption. This allows us to capture the uncertainty in the availability of RES, and the electricity demand of the LEC. We create ensemble models of climate dependent RES and consumer electricity demand. We create and solve a set of mathematical optimization models to solve the multilateral economic dispatch (MED) of the LEC RES in a fair manner. We evaluate the implications of the LEC activity and net demand on sample grid topologies, and support the DSO to understand the impacts of, and requirements for LECs on the low voltage (LV) distribution network. This understanding supports the LEC and DSO decisions on asset reinforcement, network power flow and congestion management.

We provide recommendations for an overarching LEC enabling framework to ensure safe reliable efficient sustainable operation of the LEC and LV network. Our framework will allow LEC members to take ownership of the energy transition, benefit from the new technologies we develop and so reduce their bills and their carbon footprint. We provide business model analyses, efficient scalable multilateral economic dispatch and energy analytics algorithms, and integrated climate/LEC/LV models to support all stakeholder decision makers.

9.3   National initiatives

9.3.1   ANR

ANR project AGIRE – Decision system for smart management of resources in warehouses.
In collaboration with Ecole des Mines de Saint-Etienne (Gardanne), IFSTTAR (Champs-sur-Marne), HappyChic (Tourcoing).

This project addresses human resources management in warehouses which supply either sale points (B2B) or final consumers (B2C). Nowadays, such warehouses are under pressure. This is mainly due to the no inventory policy at the sale points and to the constant growth of e-commerce sales in France and Europe. In terms of logistics, this translates into an increasing number of parcels to prepare and to ship to satisfy an order, which is known typically a few hours before. Moreover, the total number of products to be packed varies very significantly from day-to-day by a factor of at least 3.

The novelty of the project is twofold: (1) The human factor is explicitly be taken into account. It is integrated in the mathematical models and algorithms that are developed for the project. The aim is to improve the quality of employees' work ensuring the efficiency of the logistic system; (2) Problems at different decision levels are integrated and tackled jointly. At the tactical level, the main problematics are workload smoothing and the management of the storage zone. At operational level, the major issues concern the rearrangement of the picking zone, the picking tours, and the dynamic reorganization of activities to manage uncertainties.

10   Dissemination

10.1   Promoting scientific activities

10.1.1   Scientific events: organisation

General chair, scientific chair

- Chair of the invited session Incentive design and strategic information: Theory and applications, INFORMS annual meeting, Anaheim, California, USA (online), October 24-27, 2021: Hélène Le Cadre.

10.1.2   Scientific events: selection

Chair of conference program committees

- Chair of the program committee, the 22nd Conference of the International Federation of Operational Research Societies (IFORS 2021), Seoul, Korea (online), August 23-27, 2021: Bernard Fortz.

Member of the conference program committees

- 31st European Conference on Operational Research (EURO 2021), Athens, Greece, July 11-14, 2021: Bernard Fortz.

- 10th International Conference on Game Theory for Networks, Larnaca, Cyprus (online), December 2021: Hélène Le Cadre.

10.1.3   Journal

Member of the editorial boards

- Computers & Operations Research Optimization: Luce Brotcorne – Member of the Editorial Advisory Board.

- EURO Journal on Computational Optimization: Martine Labbé , Bernard Fortz – Associate Editors.

- International Transactions in Operations Research: Bernard Fortz, Martine Labbé– Associate Editors.

- Journal of Optimization Theory and Applications: Martine Labbé – Area Editor.

- Open Journal of Mathematical Optimization: Martine Labbé –Member of the steering committee.

- Transportation Science: Martine Labbé – Member of the Advisory Board.

Special issue guest editor

- Integration of Human Factors and Ergonomics (HF/E) in Transportation and Logistics, EURO Journal on Transportation and Logistics: Diego Cattaruzza (with Nabil Absi and Valeria Borodin, Ecole des Mines de Saint Etienne).

Reviewer - reviewing activities

Annals of Operations Research, Applied Computing and Informatics, Central European Journal of Operations Research, Computers & Operations Research, Computational Optimization and Applications, Discrete Applied Mathematics, EURO Journal on Transportation and Logistics, European Journal of Operational Research, IISE Transactions, INFORMS Journal on Computing, International Journal of Management Science and Engineering Management, Mathematical Programming Computation, Networks, Omega, Operations Research, Optimization and Engineering, RAIRO - Operations Research, Transportation Science, IEEE Transactions on Power Systems, IEEE Transactions on Smart Grids, IEEE Power Engineering Letters, IEEE Transactions on Control of Network Systems: Luce Brotcorne, Diego Cattaruzza, Bernard Fortz, Martine Labbé, Hélène Le Cadre, Maxime Ogier, Frédéric Semet.

10.1.4   Invited talks

- Plenary talk at the EUROPT conference, Toulouse (online), July 2021: Martine Labbé.

- Plenary talk at the EURO Pricing and Revenue Management workshop, Warwick,UK (online), August 2021: Martine Labbé.

- Tutorial at the ROADEF conference, Mulhouse (online), April 2021: Martine Labbé.

- Talk at Network of the Future 2021, Orange Atalante, Rennes, September 2021: Bernard Fortz.

- Talk at Huawei Global Connect 2021 (online), November 2021: Bernard Fortz.

- Talk at the MINOA / TRR154 conference, Nurenberg, Germany (online), March 2021: Martine Labbé.

- Talk at the workshop Agents behaviour in combinatorial game theory, Montreal, Canada (online), November 2021: Martine Labbé.

- Talk at the enOPTIMA seminar (joint MIT LIDS and energy initiative), December 2021: Hélène Le Cadre.

10.1.5   Leadership within the scientific community

- Coordinator of the European Network Optimization Group: Bernard Fortz.

- co-Coordinator of the European working group on Pricing and Revenue Management: Luce Brotcorne.

- Mercator fellow for the ALOP research group of Trier University, Germany: Martine Labbé.

- Honoray Professor, School of Mathematics, University of Edinburgh, UK: Martine Labbé.

- Member of the board of the EURO Working Group on Vehicle routing and logistics optimization (VEROLOG): Frédéric Semet.

- Member of the board of the CNRS GdR 3002: Operations Research: Frédéric Semet.

10.1.6 Scientific expertise

- Selection committe for the SEIO-BBVA Awards: Martine Labbé.

- Selection committee for the prize Jean-Jacques Moreau from the Société Mathématique de France: Martine Labbé.

- Selection committee for the ORBEL award for the best OR thesis: Martine Labbé.

- ANID, Chile Evaluation Group: Luce Brotcorne.

- NSERC Evaluation Group 1509: Bernard Fortz.

- CIRRELT Scientific Orientation Committee: Bernard Fortz, Frédéric Semet.

- IVADO International consultative committee, Montreal, Canada: Martine Labbé.

- Informs, Enre, Early Career Best Paper award, president of the commission: Luce Brotcorne.

10.1.7 Research administration

- Deputy-director of CRIStAL: Frédéric Semet.

- Elected member of the Scientific Council of Centrale Lille: Diego Cattaruzza.

- Member of the OPTIMA Scientific Council: Diego Cattaruzza.

10.2 Teaching - Supervision - Juries

10.2.1 Teaching

- Master: Bernard Fortz, Recherche Opérationnelle et Applications, 30hrs, M1, University of Mons (Charleroi campus), Belgium.

- Master: Bernard Fortz, Continuous Optimization, 24hrs, M1 & M2, Université libre de Bruxelles, Belgium.

- Master: Frédéric Semet, Non-linear Optimization, 30hrs, M2, Centrale Lille.

- Master: Frédéric Semet, Operations Research, 28hrs, M2, Centrale Lille.

- Master: Luce Brotcorne, Optimisation, 14hrs, M1, Polytech Lille.

- Master: Luce Brotcorne, Recherche opérationnelle, 16hrs, M1 apprentissage, Polytech Lille.

- Master: Diego Cattaruzza, Frédéric Semet, Prescriptive analytics and optimization, 64hrs, M1, Centrale Lille.

- Master: Diego Cattaruzza, Object-Oriented Programming, 48hrs, M1, Centrale Lille.

- Master: Diego Cattaruzza, Operations Research, 16hrs, M1, Centrale Lille.

- Licence: Diego Cattaruzza, Maxime Ogier, Object-Oriented Programming, 40hrs, L3, Centrale Lille.

- Licence: Frédéric Semet, Advanced programming and Complexity, 24hrs, L3, Centrale Lille.

- Licence: Diego Cattaruzza, Maxime Ogier, Object-Oriented Programming, 44hrs, L2, Centrale Lille.

- Licence: Bernard Fortz, Algorithmique 1, 12hrs, L1, Université libre de Bruxelles, Belgium.

- Licence: Bernard Fortz, Algorithmique et Recherche Opérationnelle, 24hrs, L3, Université libre de Bruxelles, Belgium.

10.2.2　Supervision

- PhD completed: Jérôme de Boeck, From vertical to horizontal structures: New optimization challenges in electricity markets, January 2021, Bernard Fortz.

- PhD completed: Fränk Plein, When Bilevel Optimization Meets Gas Networks: Feasibility of Bookings in the European Entry-Exit Gas Market: Computational Complexity Results and Bilevel Optimization Approaches, June 2021, Bernard Fortz, Martine Labbé, Martin Schmidt (Trier University, Germany).

- PhD completed: Concepción Domínguez Sánchez, The Rank Pricing Problem: A mixed-integer linear optimization approach, October 2021, Bernard Fortz, Martine Labbé, Alfredo Marin (University of Murcia, Spain).

- PhD in progress: Luis Alberto Salazar Zendeja, Models and algorithms for network interdiction problems, from October 2018, Diego Cattaruzza, Martine Labbé, Frédéric Semet.

- PhD in progress: Matteo Petris, Column generation approaches for integrated operationnal problems, from October 2019, Diego Cattaruzza, Maxime Ogier, Frédéric Semet.

- PhD in progress: Ilia Shilov, Algorithmic game and distributed learning for peer-to-peer energy market, from December 2019, Hélène Le Cadre, Ana Busic (Inria/ENS Paris), Goncalo Terca (VITO).

- PhD in progress: Thibault Prunet, Models and algorithm for tactical problems in warehouses with human factor considerations, from February 2020, Nabil Absi (Ecole des Mines de Saint Etienne), Valeria Borodin (Ecole des Mines de Saint Etienne), Diego Cattaruzza.

- PhD in progress: Natividad Gonzales Blanco, Exact and heuristic approaches for network design problems, from 2020, Bernard Fortz, Martine Labbé, Juan Antonio Mesa Lopez-Colmenar (University of Sevilla, Spain).

- PhD in progress: Moises Rodriguez Madrena, Design problems in continous spaces with different norms, from 2020, Bernard Fortz, Martine Labbé, Justo Puerto (University of Sevilla, Spain).

- PhD in progress: Pablo Torrealba Gonzalez, Batching and picker routing problems in warehouses taking into account human factors, from February 2021, Dominique Feillet (Ecole des Mines de Saint Etienne), Maxime Ogier, Frédéric Semet.

- PhD in progress: Cristian Aguayo, Supporting Energy Communities - Operational Research and Energy Analytics, from July 2021, Bernard Fortz.

- PhD in progress: Wenjiao Sun, Integrated optimization algorithms for routing and scheduling problems, from October 2021, Maxime Ogier, Frédéric Semet.

- PhD in progress: Luis Pablo Rojo, Incentive mechanisms for electric vehicle charging, from October 2021, Luce Brotcorne, Michel Gendreau (Polytehcnique Montréal, Canada), Miguel Anjos (University of Edinburgh, UK).

- PhD in progress: Haider Ali,Optimal techniques for charging autonomous electric vehicles with renewable energy sources, from October 2021, Luce Brotcorne, Bruno François (Centrale Lille).

- PhD in progress: Clement Legrand, Integration of machine learning into multi objective optimization problems, from October 2021, Marie-Eleonore Kessaci (Ecole Polytechnique de Lille), Laetitia Jourdan (Université de Lille), Diego Cattaruzza.

- PhD in progress: Juan Sepulveda, New optimization models and algorithms for local energy communities, from December 2021, Luce Brotcorne, Hélène Le Cadre.

- PhD in progress: Tifaout Almeftah, Models and algorithms for group testing, from December 2021, Diego Cattaruzza, Martine Labbé, Frédéric Semet.

10.2.3 Juries

- Boris Detiene, HDR, Université de Bordeaux, Decomposition algorithms for deterministic and uncertain integer programs: Luce Brotcorne – member, president of the jury.

- Fayçal Touzout, PhD, Université de Lyon, Inventory routing problem: Managing demand and travelling time uncertainties: Maxime Ogier – member.

- Niels Goaverts, PhD, KU Leuven, Distribution grid tariff design: Hélène Le Cadre – external assessor.

- Wesley Da Silva Coelho, PhD, Conservatoire National des Arts et Métiers, Paris, Modélisation et optimisation de la conception des réseaux 5G: Bernard Fortz – member.

- Sebastian Davila, PhD, University of Chile, Santiago, Chile, Algorithms for bi-level optimization in retail: pricing, assortment and demand coordination: Martine Labbé, Frédéric Semet – members.

- Martina Cerulli, PhD, Institut Polytechnique de Paris, Bilevel Optimization and Applications: Luce Brotcorne – member, Martine Labbé – external referee.

- Thanh Cong Lai Nguyen,PhD, Université de Perpignan, University of Brescia, Italy, An analysis of Equilibria for Nash Problems, Radner problems and multi-leader follower games: Luce Brotcorne – member, president of the jury.

- Yannis Flet Berliac,PhD, Université de Lille, Apprentissage par renforcement profond effcace pour le contrôle, l'exploration et la sûreté: Luce Brotcorne – member, president of the jury.

- Benoit Sohet, PhD, Université d'Avignon, Optimization of Coupled driving-and-charging strategies for electric vehicles in an urban environment: Luce Brotcorne – member, president of the jury.

- Mathieu Stephant, PhD, Arts et métiers, Optimisation de l'autoconsommation dans une communauté énergétique locale via une blockchain: Luce Brotcorne – member, president of the jury.

- Emilie Allart, PhD, Université de Lille, Abstractions de différences exactes de réseaux de réaction: améliorer la précision de prédiction de changements de systèmes biologiques: Luce Brotcorne – member, president of the jury.

- Christian Clavejo-Lopez, PhD, Universty of Liège, Belgium, Distribution Network Models with Contracts in Transportation: Frédéric Semet – member.

- Greta Laage, PhD, Polytechnique Montréal, Canada, 2021, Models for Integrated Demand Forecasting and Planning : Application to Large-scale Transportation Networks and Impact Assessment: Frédéric Semet – external referee.

- Dorian Dumez, PhD, IMT-Atlantique, Approches matheuristiques pour la résolution de problèmes d'optimisation des transports en logistique urbaine: Frédéric Semet – reviewer.

10.3   Popularization

10.3.1   Internal or external Inria responsibilities

- Présidente de la commission CDT, Inria Lille: Luce Brotcorne.

- Membre élue de la commission d'évaluation Inria: Luce Brotcorne.

- Journée Filles et Maths : une équation lumineuse, October 2021, Arras, France: Hélène Le Cadre, Tifaout Almeftah.

11   Scientific production

11.1   Major publications

[1]   N. Absi, D. Cattaruzza, D. Feillet, M. Ogier and F. Semet. 'A heuristic branch-cut-and-price algorithm for the ROADEF/EURO challenge on Inventory Routing'. In: *Transportation Science* (2019). URL: https://hal-emse.ccsd.cnrs.fr/emse-02163171.

[2]   S. Afsar, L. Brotcorne, P. Marcotte and G. Savard. 'Achieving an optimal trade-off between revenue and energy peak within a smart grid environment'. In: *Renewable Energy* (Mar. 2016). URL: https://hal.inria.fr/hal-01230915.

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