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Book of Abstracts

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Presentation of ODS2021

This book contains the abstracts of the contributions presented at the International Conference on Optimization and Decision Science (ODS2021), Rome, Italy, September 14th - 17th, 2021.
ODS2021 is the 50th annual meeting and the first hybrid conference organized by AIRO, the Italian Operations Research Society and the Department of Statistical Sciences Sapienza - University of Rome and supported by Springer. ODS2021 aims at being a unique opportunity for researchers, and practitioners focused on today's problems of knowledge, growth, sustainability and operational excellence from various sectors (quantitative management, engineering, applied mathematics, statistics, computer science, economics and finance, medicine and healthcare), private and public companies, industries and policymakers, to present and share ideas, experiences and knowledge, as well as to enforce or creating a new cooperation network.
The conference theme is open in the wide field of analytics, optimization, problem-solving, and decision-making methods and their application in Production, Service, Knowledge, and IT Systems. However, a special focus is on Optimization in Artificial Intelligence and Data Science.
A number of short papers submitted to ODS2021 were selected for publication. The peer-review process was conducted by experts in Operations Research and related fields. All these contributions will be collected in the Airo Springer Series dedicated to the ODS2021 conference: https://www.springer.com/series/15947?detailsPage=free
We express our gratitude to the plenary speakers for their invaluable contributions, to the authors for their work and dedication, and to all members of the Program Committee and auxiliary reviewers who helped by offering their expertise and time.We deeply thank Springer for strongly supporting us for the online services for presentation and participation.

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Session: OPTSM 1 A1

Bisheng He, An integrated optimization approach for timetabling and infrastructure maintenance scheduling problem during night period at microscopic level

Jiateng Yin, Timetable coordination in a rail transit network with time-dependent passenger demand

Shukai Li, Collaborative train regulation and stop-skipping adjustment strategy of a urban rail transit line by model predictive control

Pengli Mo, An Exact Method for Integrated Optimization of Subway Lines Operations Strategy with Asymmetric Passenger Demand and Operating Costs

An integrated optimization approach for timetabling and infrastructure maintenance scheduling problem during night period at microscopic level

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We present an integration of train timetable and infrastructure maintenance schedule problem during night periods to realize a 24-hours operation and propose an optimization model with sub-route at the microscopic level as the basic unit of train operation to enable an adjustment on the train stop plan. The proposed optimization model is a mixed-integer linear programming (MILP) model, which is built based on the Big-M method to schedule the train movement and infrastructure maintenance simultaneously. Moreover, the objective function of the MILP model is to minimize the deviation of train departure time, the constraints include train movement constraints, train routing constraints, block section occupancy constraints, train routing, and maintenance timing constraints, and speed limitation constraints, and the main decision variables are train routes, enter and exit times of the trains on each cell, and the start and end times of maintenance tasks. We take a real world case in the experiments for the validation of the model. Numerical results show that the model outperformance the models which fix the maintenance tasks or fix the train stop plan, these results prove the effectiveness of the integrated model with sub-routes.

Timetable coordination in a rail transit network with time-dependent passenger demand

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With the expansion of urban rail networks and the increase of passengers demand, the coordination of strongly connected lines becomes more and more important, because passengers transfer several times during their trips and major transfer stations in the rail network often suffer from over-crowdedness, especially during peak-hours. In this paper, we study the optimization of coordinated train timetables for an urban rail network, which is a tactical timetabling problem and includes several operational constraints and time-dependent passengerrelated data. We propose a mathematical formulation with the objective of minimizing the crowdedness of stations during peak hours to synchronously generate the optimal coordinated train timetables. By introducing several sets of passenger flow variables, the timetable coordination problem is formulated as a mixed-integer linear programming problem, that is possible to solve to optimum. To capture the train carrying capacity constraints, we explicitly incorporate the number of invehicle passengers in the modelling framework by considering the number of boarding and alighting passengers as passenger flow variables. To improve the computational efficiency of large-scale instances, we develop an Adaptive Large Neighborhood Search (ALNS) algorithm with a set of destroying and repairing operators and a decomposition-based ALNS algorithm. Real-world case studies based on the operational data of Beijing urban rail network are conducted to verify the effectiveness of timetable coordination. The computational results illustrate that the proposed approaches reduce the level of crowdedness of metro stations by around 8% in comparison with the current practical timetable of the investigated Beijing urban rail network.

Collaborative train regulation and stop-skipping adjustment strategy of a urban rail transit line by model predictive control

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Train regulation has received considerable attention with the rapid development of urban rail transit. The purpose of this paper is to explore the possibility of collaborative dynamic train regulation and stop-skipping adjustment strategy to cope with the disturbance management in urban rail transit line. By considering the impact of dynamic passenger flows, an non-linear programming model, with the objective to minimize the total train deviation from the timetable and enhance the passenger service quality simultaneously, is presented and further converted in a mixed integer quadratic programming model for easy to solve. In addition, the constraints related to the train rolling-stock plan are taken into account to provide a feasible scheme. Based on a model predictive control method, the collaborative model can be solved in a real-time manner, laying a theoretical groundwork for implementation of the collaborative strategy. Computational results based on the real-world data of Yizhuang metro line of Beijing illustrate the superiority of the collaborative strategy in comparison with the practical strategy, and the robustness of the method is further examined through various scenarios of random passenger demands.

An Exact Method for Integrated Optimization of Subway Lines Operations Strategy with Asymmetric Passenger Demand and Operating Costs

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Subway lines connecting different urban functional zones in large cities have direction-dependent and time-variant passenger demand, namely, asymmetry in passenger demand. Most existing studies adopt a symmetric strategy to design operations in both directions and sequentially optimize the different problems associated with operations, thereby failing to meet the asymmetry in passenger demand. This study formulates an asymmetric operations strategy as an integrated mixed-integer non-linear model to optimize the entire operational process of rolling stocks from the perspective of service quality and operating costs. Based on the proposed model, an exact algorithm is proposed with speed-up techniques to quickly generate an optimal solution. To this end, the original model is decomposed into several sub-problems that can be exactly solved by using a forward dynamic programming algorithm. Based on actual data from the Beijing subway's Yizhuang line, numerical experiments are conducted to investigate the effectiveness of the asymmetric operations strategy, to identify managerial insights on the integrated optimization, and to evaluate the performance of the proposed methodology.

Invited Session: OPTSM 2 A2

Dian Wang,Integrated rolling stock deadhead routing and timetabling in urban rail transit lines

Lianhua Tang, Scheduling local and express trains in suburban rail transit lines: Mixed-integer nonlinear programming and adaptive genetic algorithm

Yuan Gao, A Branch-and-Price Algorithm for the Weekly Rolling Stock Planning in High-speed Rail Networks

Tommaso Bosi, On-line train calendar generation: linear programming model and algorithmic method

Integrated rolling stock deadhead routing and timetabling in urban rail transit lines

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This paper investigates an integrated rolling stock deadhead routing and timetabling problem from the rolling stock scheduling in an urban rail transit line. Given the train sequences composed of train trips within an operation day, the deadhead routing sub-problem aims at selecting the deadhead routes between the depots and the first/last stations of each train sequence. The task of the deadhead timetabling sub-problem is to determine the arrival and departure times of rolling stocks along these selected routes. By means of a time-space network, we formulate the studied problem as a binary linear model, to minimize the weighted sum of total deadhead distance and total deadhead running time during the depot deadhead operations of rolling stocks. Owing to large numbers of constraints and variables in our model, a row and column generation-based algorithm is developed to solve practical-size problems efficiently, by reducing the numbers of considered constraints and variables. The pricing sub-problem (to identify new variables) in column generation is decomposed into multiple simplified problems, each of which is equivalent to a shortest path problem and can be solved efficiently by using an existing shortest path algorithm. Computational experiments on a set of hypothetical instances and practical-size instances (including a large real-world instance) demonstrate that our approach can compute both tight lower bounds and (near-)optimal solutions (with a maximum relative optimality gap of 1.07%) for all the tested instances within a maximum time of approximately 3 hours for the studied tactical problem. Furthermore, our best-known solution for the real-world instance is better than the empirical solution designed by the rail managers mainly based on experience.

Scheduling local and express trains in suburban rail transit lines: Mixed-integer nonlinear programming and adaptive genetic algorithm

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We investigate the train timetabling problem in suburban rail transit lines by considering (1) the traditional stopping mode (TSM), in which all trains stop at each station, and (2) the express/local stopping mode (ELM), in which express trains can skip certain low-demand stations. We first propose two mixed-integer linear programming models for the train timetabling problem under the TSM with and without capacity constraints. Next, we develop two mixed-integer nonlinear programming models under the ELM with and without "overtaking"; thus, a total of four optimization models are proposed. The objective is to minimize the passenger travel time (PTT). Owing to the NP-hardness of the studied problem, we propose an adaptive genetic algorithm (A-GA) that can efficiently solve the four proposed models. The A-GA is customized to solve the train timetabling problem with train capacity, overtaking, and other operational constraints, reducing the PTT. To evaluate the performance of the proposed algorithm, we conduct numerical experiments on 60 randomly generated realistic instances and a real-world case study based on Shanghai Metro Line 16. The computational results for the realistic instances indicate that our A-GA can obtain near-optimal solutions with significantly less computation time than an established commercial solver. The computational results from the real-world case study quantify the benefits of considering the combination of the ELM and overtaking strategies in train timetabling. Furthermore, we perform a sensitivity analysis on key parameters of our mathematical formulations. The results provide insights to railway managers on how to set key parameters when applying the proposed formulations and solution methodology in practice.

A Branch-and-Price Algorithm for the Weekly Rolling Stock Planning in High-speed Rail Networks

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In high-speed rail networks, train units are scheduled to periodically meet all maintenance requirements while at the same time continuing to serve all scheduled passenger trips. Motivated by the trip demand variances on the days of every week in China, this paper studies a weekly rolling stock planning (W-RSP) problem that aims to optimize the rotation plan for the train units on each day of a week, so as to minimize their operating cost, including any (un)coupling costs and maintenance costs. We model the W-RSP on a newly developed rotation network by adopting particular nodes and arcs to address the (un)coupling operations of train units, and then propose an integer linear programming formulation for the problem. To solve this formulation, we develop a customized branch-and-price algorithm, which relies on a reduced linear programming relaxation for computing the lower bound, embeds a diving algorithm for computing the upper bound, and integrates advanced branching rules for effective explorations of the solution space. Computational results validate the effectiveness and efficiency of the proposed solution algorithm, which is able to solve large instances with up to 5034 trips to near-optimality.

On-line train calendar generation: linear programming model and algorithmic method

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Enhancing the competitiveness of the European railway system, with a view that mainly focuses on the service quality perceived by travellers, is one of the challenges aimed by the Shift2Rail master plan. Consequently, the optimization is moving in the same direction, to reduce travellers inconveniences that may occur while sharing information on the service availability. Due to the nowadays chaotic and frenetic environment, there is a need to focus not only on what we transfer to customers but also on how we transfer it. Train calendars are one of the most basic and important railway transport data for final users and allow them to know whether a train is available or not, on a specific day in the calendar. A main purpose of transport companies is to let users, especially commuters, directly query the ICT system about trains availability, according to an online approach, and give them clear and brief information, expressed through "intelligen" phrases instead of bit maps. This paper provides a linear programming model of this problem and an extremely fast and flexible heuristic algorithm to create descriptive sentences from train calendars. The algorithmic method, based on the "Divide and Conquer" approach, takes the calendar period queried in its whole and divides it into sub-sets, which are successively processed one by one. The dominant limitation of previous methods is their strong dependence on the size and complexity of instances, which is not so good feature for an online tool. The findings show that the algorithm has a constant computation time even when increasing the problem complexity, keeping its processing time between 0 and 16 ms, while producing good quality solutions for railway travellers.

Invited Session: OPTSM 3 A3

Marta Leonina Tessitore,A Simulation-Optimization Framework for Traffic Disturbance Recovery in Metro Systems

Gabor Maroti, Timetable optimisation – on the way from theory to practice

Bianca Pescariu, Algorithmic improvements for the train routing selection in large instances

Marcella Samá, Optimal microscopic train timetabling: a Swiss case study

A Simulation-Optimization Framework for Traffic Disturbance Recovery in Metro Systems

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A safe, fast and energy efficient metro system is one of the key elements for a sustainable urban transport system. However, due to high frequency of services, metro networks are heavily affected by disturbances and disruptions which makes them particularly sensitive to train delay propagation. This work analyses how delays due to disturbances and disruptions propagate in a metro network when different recovery strategies are implemented. Metro regulators use traffic management policies to recover from delays as fast as possible, return to a predefined schedule, or achieve an expected regularity of train arrivals and departures. We use as a metro traffic simulator SIMSTORS, which is based on a Stochastic Petri Net variant and simulates a physical system controlled by traffic management algorithms. To model existing metro lines, SIMSTORS has been mainly used with rule-based traffic management algorithms. We consider an enhancement of such management strategies by integrating in a closed-loop framework SIMSTORS with decision procedures relying on solutions provided by AGLIBRARY, a deterministic optimization solver for managing complex scheduling and routing problems. We formulate the real-time train rescheduling problem by means of alternative graphs and use the decision procedures of AGLIBRARY to obtain rescheduling solutions. Several operational issues have been investigated throughout the use of the proposed simulation-optimization framework, among which how to design suitable periodic or event-based rescheduling strategies and how to decide the frequency and the length of the optimization process. The Santiago Metro Line 1, in Chile, is used as a practical case study. Computational results on various settings of the framework show that integrating the optimization algorithms provided by AGLIBRARY to the rule-based traffic management embedded in SIMSTORS optimizes the performance of the network, both in terms of train delay minimization and of service regularity.

Timetable optimisation – on the way from theory to practice

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The timetable is the best recognisable, and most frequently discussed, product of a passenger train operator. The combination of high societal relevance and immense computational difficulty has attracted a vast body of academic research.

This talk summarises our work to turn two recent optimisation approaches to prototype implementations at Netherlands Railways. The first project concerns strategic timetabling (Polinder et al. 2020), the second project is for short-term timetabling rescheduling (Van Aken et al. 2016, 2019).

The talk focuses on the conceptual and methodological challenges, as well as on the preliminary results that showcase the practical applicability of the studied methods.

Algorithmic improvements for the train routing selection in large instances

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The real-time Railway Traffic Management Problem (rtRTMP) is the problem of detecting and solving time-overlapping conflicting request done by multiple trains on the same track resources. This problem consists in retiming, reordering and rerouting trains in such a way that the propagation of disturbances in the railway network is minimized. The rtRTMP is an NP-Hard problem and finding good strategies to simplify its solution process is paramount to obtain good quality solutions in a short computation time. Solving the Train Routing Selection Problem (TRSP) aims to reduce the size of rtRTMP instances by limiting the number of routing variables: during a pre-processing the most promising routing alternatives among the available ones are selected for each train. This work proposes a parallel Ant Colony Optimization (ACO) to improve the convergence in large instances. The parallel framework is used to speed up the algorithm, and to diversify a local search in order to escape from local minima. Additionally, rolling stock re-utilization timing constraints and estimation of train delay propagation are taken into account in the TRSP model. We analyze the TRSP improvements on the rtRTMP through an extended computational campaign performed on a French case study with timetable disturbances and infrastructure disruptions. The model presented leads to better correlation between TRSP and rtRTMP solutions, while the proposed ACO algorithm results the best with respect to the state-of-the-art in this topic.

Optimal microscopic train timetabling: a Swiss case study

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This work deals with the computation of optimized train timetabling solutions at a tactical level. The problem is modeled as a Job Shop Scheduling problem using the Alternative Graph with variables related to train timing, sequencing, and routing decisions. Constraints deal with service intention satisfaction, in terms adherence to the required time windows for the services, plus additional operational constraints dealing with passengers satisfaction and limited infrastructure, rolling stock, and crew resources. The objective function is focused on minimizing the maximum deviation from the intended list of service intentions. Two solvers are compared: AGLibrary, a state-of-the-art deterministic solver for job shop scheduling problem modelled via the alternative graph, developed by Roma Tre University, and CPLEX, a commercial solver developed by IBM ILOG. The former solver is based on state-of-the-art exact and (meta)heuristic algorithms, while the latter is here utilized to solve a classical big-M mixed-integer linear-programming formulation of the alternative graph model. This work springs from a collaboration between Roma Tre University and SBB AG, thus the two solvers have been tested on instances derived from local networks of the Swiss railways. For the given computational settings, the state-of-the-art solver outperforms the latter solver, and it can be applied to compute feasible microscopic timetables with acceptable maximum deviations and a compatible computation time.

Session: Machine Scheduling B1

Matteo Avolio, Heuristic approaches for balancing the average completion times of two sets of jobs in a single-machine scheduling problem

Giulia Caselli, Mixed Integer Linear Programming for a Real-World Parallel Machine Scheduling Problem with Workforce and Precedence Constraints

Elena Rener, Single machine rescheduling for new orders with maximum lateness minimization

Vincent T'kindt, Adversarial bilevel scheduling on a single machine

Heuristic approaches for balancing the average completion times of two sets of jobs in a single-machine scheduling problem

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We introduce a new single-machine scheduling problem, whose objective is to balance the average completion times of two sets of jobs. Differently from the standard multiagent problems, which are of the competitive type since each job only contributes to the objective function of its agent, this problem can be interpreted as a two-agent cooperative type problem, because both the job classes are involved in the optimization of the same objective function. This kind of scheduling problem finds application in various contexts such as in logistics, services and manufacturing. For solving this problem, which we show to be NP-hard, we propose some heuristic approaches, based on Lagrangian relaxation, genetic algorithms and local search strategies. Numerical results on a large number of randomly generated test problems are presented.

Mixed Integer Linear Programming for a Real-World Parallel Machine Scheduling Problem with Workforce and Precedence Constraints

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In this work, we consider a real-world scheduling problem occurring in the engineering test laboratory of a multinational company producing hydraulic components for motion systems. Similar problems have been solved in the literature under the framework of resource constrained parallel machine scheduling problems. In our work, the tests on the hydraulic components are the jobs to be scheduled. Each job must be processed on a machine and requires an additional human resource to prepare the machine and supervise the job. Machine and workforce eligibility constraints are also included. Release and due dates are given for jobs. The aim is to minimize the total weighted tardiness. Each job has a processing time expressed in working days that depends on the machine and requires a fixed number of hours per day for its assigned worker. Moreover, precedence and contiguity relations between jobs must be respected. We propose a Mixed Integer Linear Programming formulation to model the problem and demonstrate its effectiveness on both real-world and randomly generated instances.

Single machine rescheduling for new orders with maximum lateness minimization

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Rescheduling problems typically arise from production facilities that have to deal with incoming new orders for which is not optimal to be simply schedule them at the end of an existing schedule of old jobs. Then, a compromise must be given between scheduling old and new jobs to minimize a scheduling criterion, and minimizing the disruption induced by perturbing the initial schedule of old jobs. This kind of approach enables flexibility in the system while not disturbing too much the commitments with the customers. Hall and Potts (2004) proposed a seminal paper by studying several single machine scheduling problems. They proposed either polynomial time algorithms or showed NP-hardness results. The problems tackled by Hall and Potts are considered again by Teghem and Tuyttens (2014) but on multiobjective side. A generalization of these problems has been introduced by Zhao et al. (2016) who impose on each old job a maximum amount of allowed disruption. The problem tackled in this work involves the minimization of the maximum lateness criterion of all jobs on a single machine with the additional requirement of no-idle schedules. Moreover, the assumption is that the total disruption, measured by means of jobs completion of old jobs with respect to their initial schedule, does not exceed a given threshold. We provide structural properties and heuristic algorithms. Heuristics are a local search and two matheuristics. Computational experiments on hard instances show that the local search outperforms the matheuristic approaches.

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[2] Teghem, J., Tuyttens, D., 2014. A bi-objective approach to reschedule new jobs in a one machine model. International Transactions in Operational Research 21, 871-898.

[3] Zhao, Q., Lu, L., Yuan, J., 2016. Rescheduling with new orders and general maximum allowable time disruptions. 4OR 14, 261-280.

Adversarial bilevel scheduling on a single machine

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In this contribution we focus on a particular setting in which two agents are concerned by the scheduling of a set of n jobs. The first agent, called the leader, can take some decisions before providing the jobset to the second agent, called the follower, who then takes the remaining decisions to solve the problem. As an example, the leader could select a proper subset of the n jobs that the follower has to schedule. Notice that the decisions the agents can take are exclusive: in this example, the follower cannot decide the jobs to schedule and the leader cannot schedule the jobs. This setting falls into the category of bilevel optimization (Dempe et al. 2015). In such problems it is assumed that the leader and the follower follow their own objectives which can be contradictory, so leading to very hard optimization problems. Recently, many papers on bilevel combinatorial optimization appeared, here we refer to (Caprara et al. 2016, Della Croce et al. 2019, Fischetti et al. 2019) just to mention a few. On the other hand, to the authors knowledge, the literature on bilevel scheduling is much more limited. We focus here on single machine scheduling under the adversarial framework where the goal of the leader is to make the follower solution as bad as possible and provide several exact polynomial time algorithms for different objective functions when the leader can only modify data of the problem.

Session: Combinatorial Optimization and Integer Programming I B2

Ciriaco D'Ambrosio, The Knapsack Problem with Forfeit Sets

Paolo Detti, Sequential upper bounds for the multiple knapsack problem

Sara Mattia, The clique interdiction problem by graph mapping

Lorenzo Moreschini, The Set Covering Problem with Conflicts

The Knapsack Problem with Forfeit Sets

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The Knapsack Problem with forfeit sets (KPFS) is an extension of the recently introduced Knapsack Problem with forfeit pairs (KPF)[1]. KPFS considers a collection of possibly overlapping sets of items (forfeit sets), each with an associated allowance threshold and an associated penalty cost. The allowance threshold defines how many items can be chosen from each set before paying, in the objective function, the associated penalty cost. We also consider a global limit on the number of allowed violations. We propose three heuristic approaches: a greedy, a Carousel Greedy algorithm and a Memetic metaheuristic. We tested and compared the proposed approaches on a wide set of benchmark instances.

[1] Raffaele Cerulli, Ciriaco D'Ambrosio, Andrea Raiconi, and Gaetano Vitale. The knapsack problem with forfeits. In Combinatorial Optimization. 5th International Symposium ISCO 2020. Lecture notes in computer science, volume 12176, pages 263-272, 2020.

Sequential upper bounds for the multiple knapsack problem

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In this work, new upper bounds for the Multiple Knapsack Problem (MKP) are presented. The upper bounds are computed by relaxing the problem to a Bounded Sequential Multiple Knapsack Problem (BSMKP) [1,2], i.e., a multiple knapsack problem in which item sizes are divisible. Such a relaxation, called "sequential relaxation", is obtained by suitably replacing the items of an MKP instance with items with divisible sizes. In BSMKP, multiple copies may exist of each item, and items can be partitioned into classes, each class containing items with the same profit and weight. BSMKP can be polynomially solved in $O(q^2 + qm)$ time [2], where q is the number of item classes and m the number of knapsacks (the complexity reduces to $O(qlogq+qm)$ when a single copy of each item exists). We prove that the upper bound provided by the sequential relaxation is always not worse than that get from the linear relaxation of the classic Integer Linear Programming model. Computational results on benchmark instances from the literature show that, in comparison with a classical upper bound for MKP [3, 4], the sequential upper bounds are very fast to compute and effective in terms of quality when the ratio n/m is smaller than 3. Improvements of the sequential bounds requiring the introduction and solution of new variants of MKP are also discussed.

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The clique interdiction problem by graph mapping

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We show how to solve a maximum clique problem on a given graph by an equivalent problem on an auxiliary graph. The transformation has interesting consequences in the bilevel setting. In fact, it allows to map a clique interdiction problem with edge interdiction into a clique interdiction problem with node interdiction. As a byproduct of the mapping, we can generalize to the edge interdiction problem some complexity and algorithmic results for the node interdiction problem. We describe how to perform the mapping and derive some new results for the clique interdiction problem.

The Set Covering Problem with Conflicts

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Given a finite set U, a family F of subsets S_j of U and a cost c_j for each S_j in F, the "set covering problem" (SCP) seeks to find a subfamily of F that covers U with the minimum cost. The SCP is well-known to be an NP-complete problem. In this paper, we introduce a new variant of the problem where a "conflict" occurs between any two subsets S_j and S_r if they share more than k elements. If two subsets S_j and S_r are in conflict, they can be selected in an optimal solution provided that a penalty p_{jr} is paid. The penalty depends on how much the cardinality of the intersection of the two sets is greater than k. The problem, called "Set Covering Problem with Conflicts" (SCPC), looks for the cover that minimizes the sum of the total cost of the selected subsets and the penalties due to conflicts. The problem finds application in different practical contexts including the optimal location of devices for pollution detection and the production of medicines with common active ingredients in the pharmaceutical sector. We introduce two different mathematical formulations for the SCPC, discuss some simple properties and provide a GRASP algorithm for its solution. The GRASP algorithm is made of two main phases: the former aims to build a good solution by means of random choices taken among the most promising ones, while the latter is a completely greedy local search that improves as far as possible the solution obtained after the first phase. Preliminary results on new benchmark instances show that the algorithm is effective and extremely efficient compared to solutions found by Gurobi in one hour.

Session: Combinatorial Optimization and Integer Programming II B3

Federica Laureana, The Generalized Minimum Branch Vertices Problem: Polyhedral Analysis and Branch and Cut algorithm

Edoardo Fadda, Assessment of New Multi-Covering Facility Location Models

Giorgio Sartor, A Benders-like decomposition for train timetabling: a real-life application in Norway

Matteo Fischetti, Benders cuts for the integrated layout and cable routing problem

The Generalized Minimum Branch Vertices Problem: Polyhedral Analysis and Branch and Cut algorithm

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Given an undirected graph $G = (V, E)$, where the set of vertices is partitioned into k clusters, $V1, ..., Vk$, the Generalized Minimum Branch Vertices (GMBV) problem consists in determining a tree in G, spanning exactly one vertex for each cluster, and with the minimum number of vertices having degree greater than two ([2]). These vertices are called branch vertices. When each cluster is a singleton, it reduces to the Minimum Branch Vertices (MBV) problem ([1], [3], [4]), therefore it is NP-hard. In this talk we present a Branch and Cut algorithm for the GMBV problem, which implements several facet-defining inequalities, and a procedure to reduce the size of the graph and provide an initial upper bound.

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Assessment of New Multi-Covering Facility Location Models

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Covering Facility Location problems can be found in almost all sectors. In many situations, it is important that facilities for critical services are located in a robust way against unpre-dictable events. This is the case, for example, of the healthcare sector, where some facilities (e.g., ambulances or first-aid centers) are supposed to provide critical services. Hence, an ac-tive stream of research has focused on proposing models and solutions that, although deter-ministic, explicitly address a coverage redundancy for the underlying service to face possible disruption or congestion of the already located facilities. In particular, two backup covering problems, BACOP1 and BACOP2 , and the Double Standard Model (DSM) , appear to be standard ways to support decisions in such situations. In this work, we first propose three new families of models, namely, k-BACOP1, k-BACOP2, and k-DSM, which generalize the three already mentioned classical double-level covering models from the literature to any possible kth level of coverage desired. Then, by implementing a comparative framework based on simulation and optimization , we assess the models' efficiency and the quality of the solutions returned by the proposed models through ad-hoc Key Performance Indicators. The experiments are conducted over many representative instances with different topological and demographic characteristics. They involve a static design and the dynamic simu-lation of disruption scenarios for the already located facilities.

A Benders-like decomposition for train timetabling: a real-life application in Norway

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We showcase a prototype for tactical train timetabling in the busiest and longest railway line in Norway. The software includes a fully interactive interface and it has been validated by the Norwegian railway infrastructure manager, Bane NOR. The underlying MILP model is based on a Benders like decomposition approach that exploits sophisticated delayed row (and column) generation techniques. The basic decomposition scheme comes from the previous work of Lamorgese and Mannino (2015), but here is significantly extended to cover further important details of train operations, such as turn around times and operational periods. During the yearly (tactical) timetabling process, the infrastructure manager loads an existing timetable (usually the one from the previous year) into our software, and uses the interactive interface to make modifications according to the preferences of the train companies for the next year. These modifications define a new timetable and may introduce several conflicts (i.e., infeasible train operations), which are usually very time-consuming to fix manually. Using this timetable as reference, our software constructs a new conflict-free timetable that is as close as possible to the reference one. In this particular railway line, the prototype is usually able to compute a conflict-free timetable for an entire year in less than a minute. This semi-automated workflow may save the infrastructure manager days if not weeks of work, providing more time to experiment with different scenarios, and improving the collaboration with train companies.

Benders cuts for the integrated layout and cable routing problem

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We address a very important problem in offshore wind farm design, namely, the combined optimization of the turbine location and of the connection cables required to bring the electrical power produced by the turbines to a given substation, and eventually to shore. We first describe a mixed-integer linear programming model that combines previous proposals from the literature. Then we improve it by a number of additional inequalities intended to strengthen its linear programming relaxation. In particular, we propose new classes of Benders like cuts derived from an induced-clique substructure of the problem. The validity of these cuts is established in a purely combinatorial way, without resorting to Benders' standard duality theory, and efficient separation procedures are proposed. The practical effectiveness of the proposed cuts is established through computational tests, showing that they do improve very significantly the dual bound provided by the standard model. We also present an exact Branch-and-Cut solver for the problem, which separates the new cuts at run-time. Computational results confirm that the new cuts are instrumental for the success of our exact solver.

Session: Networks Analysis and Design C1

Alessandro Hill, Expanding Students' Social Networks via Optimized Team Assignments

Naga Venkata Chaitanya Gudapati, Network Design with Service Requirements: Scaling-up the Size of Solvable Problems

Laura Calzada-Infante, Review of Dominance Network Analysis, a methodology to evaluate efficiency from a network perspective

Expanding Students' Social Networks via Optimized Team Assignments

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The class social network is a momentous factor when it comes to educational, personal and professional student success as well as achieving course learning outcomes. Students and teachers benefit from expanded network connectivity via augmented engagement, more inclusivity, and efficient diffusion of information. Moreover, student involvement is of particular importance in virtual teaching modes. In this interdisciplinary work, we present a novel method for positively influencing the class social network in order to create new ties. To this end, we develop an in-class grouping strategy based on sociocentric network analysis and optimization that pragmatically expands the students' social networks. In contrast to existing routines, our technique focuses on providing each individual student as many opportunities as possible to establish new ties with classmates. Based on the knowledge of existing connections, our procedure systematically maximizes the overall number of new ties that can be established during the course of a team project. Our data driven teaming approach is designed for practical use in class. We describe a process for surveying the class social network, which is used to feed the model that computes optimal team assignments. We show that the underlying difficult combinatorial problem of maximizing unrelated intra-team students can be modeled using a mathematical framework that respects the desired team sizes. Using an integer programming formulation for a variant of the bin packing problem, we demonstrate the efficient implementation within spreadsheets. We discuss model extensions to account for high density networks, team balancing, and team mate forcing and forbidding, allowing for hybridization using existing grouping techniques. In an empirical study, we provide evidence for the efficacy of our approach using data from 10 industrial engineering classes that had 253 students and 77 project teams in both face-to-face and virtual modes collected over the course of a year. In order to quantify the impact of our grouping method, we repeatedly surveyed the social networks in both types of classes - those having optimized teams and those having self-assigned teams. To better understand the theoretical potential for new ties, we directly compare our process to simulations of commonly used team assignment methods, random assignment, self-selection, and the opposing method, which maximizes existing intra-team ties. Through our method, we demonstrate how the number of new ties can be increased by an impressive 62% compared to only 17% when allowing students to self-assign to teams. The obtained results and the received student feedback strongly support the usefulness of our idea for adaptive class management and student contentment.

Network Design with Service Requirements: Scaling-up the Size of Solvable Problems

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Network design problems have been studied since decades as they can be used to model many real-life scenarios arising, e.g., in logistics, supply chain management, and telecommunications. In this paper, we consider a network design problem in which one has to ensure end-to-end connections with given service requirements associated to, e.g., delivery speed, reliability, and latency. We introduce a novel mathematical formulation for the problem in which variables are associated with feasible paths, and study column generation techniques for solving the linear relaxation of the model. By embedding these algorithms into an enumerative scheme, we obtain a branch-and-price algorithm, that we compare from a computational viewpoint with both commercial and open-source solvers to assess its performances. The computational experiments show that our algorithm is competitive with state-of-the-art solvers and is able to produce high quality solutions for medium and large instances in a reasonable amount of time

Review of Dominance Network Analysis, a methodology to evaluate efficiency from a network perspective

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The analysis of the efficiency of Operational Units is critical to determine the ones with the best performance and the potential improvement of the inefficient ones. In this field the contribution of Data Envelopment Analysis (DEA) is well known. However, DEA only projects the evaluated Operational Units onto the Efficient Frontier. Dominance Network Analysis is a novel methodology that benchmarks the performance of each Operational Unit with those of the rest creating a directed acyclic network. This network is composed of nodes that represent the Operational Units and weighted directed links representing the extant dominance relationship among them. Each link weights the relative inefficiency between the two connected Operational Units, in a similar way as DEA does to measure the relative inefficiency of an Organizational Unit and its target on the Efficient Frontier. Dominance Network Analysis evaluates the role and relative position of each Operational Unit of the sample. The methodology is flexible and can use all the concepts and techniques from the field of Complex Network Analysis, providing also significant visualization capabilities of the given multidimensional dataset. Dominance Network Analysis has been applied in different situations evaluating how the structure of the network changes. For instance, the network nodes are extended by considering three DEA technologies: FDH, VRS and CRS. Also, different relative inefficiency metrics have been used based on DEA additive inefficiency metrics such as Measure of Inefficiency Dominance and Proportional Inefficiency Measure. These alternatives have an impact on the shortest path for the inefficient Organizational Units to reach the Efficient Frontier.

Session: Logistic I C2

Claudia Archetti, Aggregated Formulations for the Inventory Routing Problem

Andrea Mor, The Bi-objective Long-haul Transportation Problem on a Road Network

M.Grazia Speranza, Efficient loading and unloading operations via a booking system

Claudio Sterle, A Location-Routing Based Solution Approach for Reorganizing Collection and Delivery Operations

Aggregated Formulations for the Inventory Routing Problem

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The Inventory Routing Problem (IRP) aims at defining a distribution plan for delivering goods from a supplier to a set of geographically dispersed customers over a given planning horizon. Customers demand has to be met and capacities of vehicles and customers warehouses have to be respected. Routing and inventory holding cost are faced and the aim is to determine the distribution plan that minimizes the total cost. We present aggregate formulations for the problem, where vehicle index is removed. We introduce the basic formulation where capacity and subtour elimination constraints are modelled through load variables. We show that, by projecting out the load variables, we obtain the General Fractional Capacity Cuts (GFCC). Then, we propose a multi-commodity formulation of connectivity constraints, involving a polynomial number of constraints, and we show that it is equivalent to the formulation with exponentially many constraints. Finally, we enhance the basic formulation through multi-star inequalities. We perform computational tests on benchmark IRP instances. Three methods are tested: compact formulation, branch-and-cut and Benders decomposition. The three approaches are compared with state-of-the art exact approaches for the IRP presented in [1] and [2]. The results show that our approaches provide much better lower and upper bounds, despite being able to close the gap in fewer instances.

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The Bi-objective Long-haul Transportation Problem on a Road Network

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In this work we study a long-haul truck scheduling problem where a path has to be determined for a vehicle traveling from a specified origin to a specified destination. We consider refueling decisions along the path, while accounting for heterogeneous fuel prices in a road network. Furthermore, the path has to comply with Hours of Service (HoS) regulations. Therefore, a path is defined by the actual road trajectory traveled by the vehicle, as well as the locations where the vehicle stops due to refueling, compliance with HoS regulations, or a combination of the two. This setting is cast in a bi-objective optimization problem, considering the minimization of fuel cost and the minimization of path duration. An algorithm is proposed to solve the problem on a road network. The algorithm builds a set of non-dominated paths with respect to the two objectives. Given the enormous theoretical size of the road network, the algorithm follows an interactive path construction mechanism. Specifically, the algorithm dynamically interacts with a geographic information system to identify the relevant potential paths and stop locations. Computational tests are made on real-sized instances where the distance covered ranges from 500 to 1500 km. The algorithm is compared with solutions obtained from a policy mimicking the current practice of a logistics company. The results show that the non-dominated solutions produced by the algorithm significantly dominate the ones generated by the current practice, in terms of fuel costs, while achieving similar path durations. The average number of non-dominated paths is 2.7, which allows decision makers to ultimately visually inspect the proposed alternatives.

Efficient loading and unloading operations via a booking system

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Urban distribution usually requires vehicles to stop at roadside for the driver to perform the last leg of the delivery by foot. The stops take place in designated areas, called loading/unloading (L/U) areas. In this talk, a booking system for the management of the L/U areas is studied as a way to eliminate double parking. In the proposed system, distributors book the L/U areas in sequence according to their preferences, but subject to the bookings that have already been placed. The problem to be solved by each distributor is a Traveling Salesman Problem with Multiple Soft Time Windows. The solution provided by the booking system is discussed and compared with the current use of the L/U areas.

A Location-Routing Based Solution Approach for Reorganizing Collection and Delivery Operations

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The spreading of the new electronic forms of communication has led to a fall of the postal volumes which is pushing the postal service provider companies to change and rethink their collection operations. More precisely, it is easy to understand that postboxes represent both a cost for the service providers and an opportunity for the users. Indeed, on the one hand, they require to be maintained and daily visited by a postman to collect the letters and, on the other hand, they are the main access points to the postal network, whose reduction could result in a deterioration of the quality of the service (Bruno et al., 2020). In this context, our work addresses the problem of reorganizing the collection operations of a postal service provider through the reduction of the number of postboxes located in an area. This reorganization has also to take into account the universal nature of the postal services and, consequently, the quality standards fixed by the regulatory authority. The problem is formulated as a location-routing problem (Drexl and Schneider, 2015) where the number of postmen employed for the collection operations is minimized and the accessibility of the postboxes for the users is guaranteed. Exact and heuristic solution methods have been developed and tested on instances based on real data sets (Boccia et al., 2020). The computational results show the effectiveness of the proposed methodologies. The work concludes with a discussion about the possibility of extending the proposed approach to the reorganization of the distribution and delivery activities through the usage of parcel lockers, whose usage is increasing with the continuous rise of e-commerce market.

Session: Logistic II C3

Nho Minh Dinh, Split and Unsplit Inventory Routing Problems

Diego Maria Pinto, Waste profit patterns optimization trough logistic and sorting models integration

Carlo Filippi, A Kernel Search Heuristic for a Fair Facility Location Problem

Split and Unsplit Inventory Routing Problems

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We study different policies for an Inventory Routing Problem in which time varying customer demands must be served by a fleet of vehicles from a depot over a time horizon. Delivery can be such that each customer is served by either one (unsplit) or multiple (split) vehicles on each day. Replenishment can be either maximum level (ML) or order-up-to level (OU). Our goal is to compare the four policies obtained by combining unsplit/split and ML/OU, in the worst case and on average.

Waste profit patterns optimization trough logistic and sorting models integration

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New advanced information systems, digital technologies and mathematical models are required to achieve the targets of the sustainability and circular economy paradigms. This trend expanded in particular with the growing interest in production sustainability, pollution, recycling and waste management in order to achieve economic growth and development while preventing their negative impact on the environment. In this scenario are both smart facilities, where data flows steadily between well connected work stages, and the opportunity of using that information to better support waste management, thus enabling circular economy objectives. Circular economy includes products, but also infrastructure, equipment and services offered by waste recycling centers where materials are collected and then sorted to be converted in secondary raw materials. Because circular economy imposes a new view of operations with the aim of zero waste, in order to obtain this result it is critical to adopt an holistic approach and to optimize every step of production and logistics processes. These targets are addressed in this work by the development of an integrated models framework that is fueled by data and supported by mathematical models and analysis techniques such as machine learning and decision models like those of operations research. In the presented framework each model output become an input of the following model. A mixed integer programming model is used to optimize the sorting operations while a pick-up and delivery routing model supports the logistic operations. In the end, a machine learning model performs process cost analysis once both logistic and sorting processes have been optimized. Decision makers can use those outcomes to support and verify management decisions, such as updating contracts of loss making customers or increasing service level in profitable locations. Validation of the approach as be done with data of a real test case with promising preliminary results.

A Kernel Search Heuristic for a Fair Facility Location Problem

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We consider an uncapacitated location problem where p facilities have to be located in order to serve a given set of customers, and we assume that a customer requesting for a service has to reach a facility at his/her own cost. In this setting, a central issue is that of fairness among customers for the accessibility to the services provided. Every choice regarding the location of facilities corresponds to a distance distribution of customers to reach an open facility. Minimizing the average of this distribution would lead to a p-median problem, where system efficiency is optimized but the fair treatment of users is neglected. Minimizing the maximum (worst-case) of the distribution would lead to a p-center problem, where the unfair treatment of users is mitigated but system efficiency is neglected. To compromise between these two extremes, we minimize the conditional β-mean, i.e., the average distance traveled by the 100 $x\beta\%$ of customers farther from a facility. We call Fair Facility Location Problem (FFLP(β)) the resulting optimization problem, which is formulated as a Mixed-Integer linear Program (MIP) with a proven integer-friendly property. We propose a heuristic framework to produce a set of representative solutions to the FFLP(β). The framework is based on Kernel Search, a heuristic scheme that has been shown to obtain high-quality solutions for a number of MIPs. Computational experiments are reported to validate the quality of the solutions found by the proposed solution algorithm, and to provide some general guidelines regarding the trade-off between average and worst-case optimization. Finally, we report on a case study stemming from the screening activities related to the pandemic triggered by the SARS-CoV-2 virus. The case study regards the optimal location of a number of drive-thru temporary testing sites for collecting swab specimens.

Invited Session: Equilibria, variational models and applications D1

Anna Thünen, Multiscale Control of Stackelberg Games with Infinitely many Followers

Rita Pini, Continuity and maximal quasi monotonicity of normal cone operators

Monica Bianchi, Brezis pseudomonotone bifunctions and quasi equilibrium problems via penalization

Gianluca Priori, On nested affine variational inequalities: the case of multi-portfolio selection

Annamaria Barbagallo, An Emission Pollution Permit System for Time-Dependent Transportation Networks Based on Origin-Destination Pairs

Multiscale Control of Stackelberg Games with Infinitely many Followers

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We present a linear–quadratic Stackelberg game with a large number of followers and we also derive the mean field limit of infinitely many followers. The relation between optimization and mean-field limit is studied and conditions for consistency are established. Finally, we propose a numerical method based on the derived models and present numerical results.

Continuity and maximal quasi monotonicity of normal cone operators

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The notion of maximal monotone operator dates back to the sixties and, since then, it has been extensively studied in literature. One of the main interest for maximal monotone operators is the strong relationship between convexity of a function and maximal monotonicity of its associated subdifferential operator. In recent years different generalizations of monotonicity have been proposed, both in the scalar and in the set-valued case, in finite and infinite dimensional spaces. Among them the most studied are, without a doubt, pseudomonotonicity and quasimonotonicity. Many nice properties of these classes of operators have been proved, but little effort has been devoted to the study of a suitable notion of maximality. To fill this gap, Hadjisavvas in 2003 introduced and studied maximal pseudomonotone operators on Banach spaces, while the notion of maximality for quasimonotone operators has been addressed in the recent works by Aussel and Eberhard (2013), and by Bueno and Cotrina (2019) In this work we define a new notion of maximality for a quasimonotone operator defined on a Banach space, different from the previous ones, that is based both on the notion of quasimonotone polar of an operator T and on its behaviour at the points in the interior of the effective domain of T. This property is enjoyed, in particular, by the adjusted normal cone operator to the sublevel sets of a quasiconvex, lower semicontinuous and solid function. The interest in studying the properties of this map is due to the crucial role it plays in characterizing quasiconvexity. In particular, the cone upper semicontinuity is proved in the domain of a function in case the set of global minima has non empty interior.

Brezis pseudomonotone bifunctions and quasi equilibrium problems via penalization

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In this talk we investigate quasi equilibrium problems in a real Banach space under the assumption of Brezis pseudomonotonicity of the function involved. To establish existence results under weak coercivity conditions we replace the quasi equilibrium problem with a sequence of penalized usual equilibrium problems. To deal with the non compact framework, we apply a regularized version of the penalty method. The particular case of set-valued quasi variational inequalities is also considered.

On nested affine variational inequalities: the case of multi-portfolio selection

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We deal with nested affine variational inequalities, i.e., hierarchical problems involving an affine (upper-level) variational inequality whose feasible set is the solution set of another affine (lower-level) variational inequality. We apply this modeling tool to the multi-portfolio selection problem, where the lower level variational inequality models the Nash equilibrium problem made up by the different accounts, while the upper-level variational inequality is instrumental to perform a selection over this equilibrium set. We propose a projected averaging Tikhonov like algorithm for the solution of this problem, which only requires the monotonicity of the variational inequalities for both the upper and the lower-level in order to converge. Finally, we provide complexity properties.

An Emission Pollution Permit System for Time-Dependent Transportation Networks Based on Origin-Destination Pairs

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In the paper an emission pollution permit system for a dynamic traffic equilibrium model based on origin/destination pairs is presented. The time dependent equilibrium conditions are expressed by an evolutionary variational inequality. Thanks to the variational formulation, existence and continuity results for equilibrium distributions are established.

Session: Nonlinear Optimization I D2

Matteo Lapucci, A Unifying Framework for Sparsity Constrained Optimization

Cecilia Salvatore, Optimization for Brain-Computer Interfaces

Behzad Pirouz, New Mixed Integer Fractional Programming Problem for Sparse Optimization

Manlio Gaudioso, On the use of the polyhedral k-norm in feature selection for SVM models

A Unifying Framework for Sparsity Constrained Optimization

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We consider the optimization problem of minimizing a continuously differentiable function subject to both convex constraints and sparsity constraints. By exploiting a mixed-integer reformulation from the literature, we define a necessary optimality condition based on a tailored neighborhood that allows to take into account potential changes of the support set. We then propose an algorithmic framework to tackle the considered class of problems and prove its convergence to points satisfying the newly introduced concept of stationarity. We further show that, by suitably choosing the neighborhood, other well-known optimality conditions from the literature can be recovered at the limit points of the sequence produced by the algorithm. Finally, we analyze the computational impact of the neighborhood size within our framework and in the comparison with some state-of-the-art algorithms, namely, the Penalty Decomposition method and the Greedy Sparse-Simplex method. The algorithms have been tested using a benchmark related to sparse logistic regression problems.

Optimization for Brain-Computer Interfaces

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A Brain-Computer Interface (BCI)[1] is a system that records central nervous system (CNS) activity and translates it into control commands for external devices. A common method to measure the CNS activity are EEGs. An example of BCI is the P300 Speller[2], a brain writer which allows people affected by severe diseases such as ALS to communicate with the outside. The P300 Speller consists of a 6x6 alpha-numeric matrix. During a trial, the user focuses their attention on a specific character of the matrix. Each trial consists of multiple iterations; during each iteration, all rows and columns of the matrix flash in a random order; when a row/column that contains the target character flashes, a specific brain pattern can be detected in EEGs. Classification algorithms such as Stepwise Linear Discriminant Analysis[3] and Support Vector Machines[4] can be used to detect target characters. In our work, we propose a new SVM-based training problem (M-SVM) specifically designed for the P300 Speller's paradigm. Then, we propose a new decision function, the Optimized-Score Based Function (OSBF), which gives scores to stimuli according to the confidence in their classification. Assigning scores to stimuli requires to solve a Mixed-Integer Linear Programming problem (MILP). BCIs can also be used in a collaborative environment to perform a group decision-making process[5]. In this framework EEGs are used to measure users' confidence in order to weigh individual opinions[6,7]. In our work, decision values resulting from a SVM are used to measure the user's confidence; our idea was to adapt the OSBF's MILP problem to assign each user a score that depends both on their decision value and on their reliability with respect to other subjects in the group. Results obtained in both applications were significantly above state-of-the-art performances. This shows that optimization methods can be successfully employed to build more efficient BCIs that can better suit for real-life scenarios.

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New Mixed Integer Fractional Programming Problem for Sparse Optimization

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We propose a novel Mixed Integer Nonlinear Programming (MINLP) model for sparse optimization, based on the use of the polyhedral k-norm. We put special emphasis on the application of sparse optimization in Feature Selection for Support Vector Machine (SVM) classification. We address the continuous relaxation of the problem, which comes out in the form of a fractional programming problem (FPP). In particular we consider two possibilities for tackling FPP, either reformulating it via a DC (Difference of Convex) decomposition or by adopting a multi objective reformulation. We present some numerical results obtained by using ad hoc linearization algorithms.

On the use of the polyhedral k-norm in feature selection for SVM models

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The polyhedral k-norm consists of the sum of k maximal components (in modulus) of any vector and has been recently used to deal with sparse optimization and sparsity-constrained optimization, where the problem is to find a minimum of a nonlinear function while controlling the number of the non-zero components of the solution. The problem is relevant, in particular, in the Machine Learning framework, when efficient classifiers are to be designed through the Feature Selection (FS) process, aimed at detecting the smallest number of attributes which are really relevant in view of classification quality. We will survey some different ways to embed k-norm minimization into FS, focussing, in particular, on the Support Vector Machine (SVM) paradigm. Models of Mixed Integer Nonlinear Programming will be examined together with some continuous formulations, both convex and non convex.

Session: Large Scale Nonlinear Programming D3

Andrea Cristofari, An almost cyclic 2-coordinate descent method with active-set identification

Damiano Zeffiro, Fast cluster detection in networks by first-order optimization

Giovanni Fasano, An improvement of the pivoting strategy in the Bunch and Kaufman decomposition, within Truncated Newton methods

An almost cyclic 2-coordinate descent method with active-set identification

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A block coordinate descent method is described for the minimization of a continuously differentiable function subject to one linear equality constraint and simple bounds on the variables. The working set is chosen by means of an almost cyclic rule that considers the distance of the variables from the bound, thus not requiring first order information. Convergence to stationary points is proved with different line search strategies, including the Armijo line search. Moreover, finite active set identification is established for nonconvex functions and, for strongly convex functions, complexity results on the number of iterations required to identify the active set are given. Numerical results are finally provided.

Fast cluster detection in networks by first-order optimization

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Cluster detection plays a fundamental role in the analysis of data. In this paper, we focus on the use of s-defective clique models for network based cluster detection and propose a nonlinear optimization approach that efficiently handles those models in practice. In particular, we introduce an equivalent continuous formulation for the problem under analysis, and we analyze some tailored variants of the Frank-Wolfe algorithm that enable us to quickly find maximal s-defective cliques. The good practical behavior of those algorithmic tools, which is closely connected to their support identification properties, makes them very appealing in practical applications. The reported numerical results clearly show the effectiveness of the proposed approach.

An improvement of the pivoting strategy in the Bunch and Kaufman decomposition, within Truncated Newton methods

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In this work we consider the solution of large scale (possibly nonconvex) unconstrained optimization problems. We focus on Truncated Newton methods which represent one of the commonest methods to tackle such problems. In particular, we follow the approach detailed in [4], where a modified version of the Bunch and Kaufman decomposition [1] is proposed for solving the Newton equation. Such decomposition is used within SYMMBK routine as proposed by Chandra in [6] (see also [7, 16, 17]) for iteratively solving symmetric possibly indefinite linear systems. The proposal in [4] enabled to overcome a relevant drawback of nonconvex problems, namely the computed search direction might not be gradient-related. Here we propose further extensions of such approach, aiming at improving the pivoting strategy of the Bunch and Kaufman decomposition and enhancing its flexibility.

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Invited Session: OPTMS 4 A4

Yihui Wang, Real-time integrated train rescheduling and rolling stock circulation planning for a metro line under disruptions

Federico Naldini, Optimization of Multi-Train Energy Consumption in Real-Time Railway Traffic Management

Nattanon Luangboriboon, Optimal Passenger Flow Management within Railway Stations via Alternative Graphs

Matteo Petris, A Decomposition Algorithm for the Real-Time Railway Traffic Management Problem

Real-time integrated train rescheduling and rolling stock circulation planning for a metro line under disruptions

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More and more unexpected events occur in metro systems, which may cause serious disturbances and even disruptions for the operation of trains. This paper studies an integrated train rescheduling and rolling stock circulation planning problem for the complete blockage situations in a metro line. We consider several key practical train operation constraints, including the maximum number of available rolling stocks, the turnaround constraints, the service connection constraints. This problem is viewed as a complex multi-objective mixed integer linear programming (MILP) formulation, where the objectives involve the deviations with respect to the timetable, the (partial) cancellations, and the headway deviations of train services. A two-stage approach is also developed to enhance the computational efficiency, where a smaller-size optimization problem is solved in the first stage, by considering a set of key turnaround stations only, while the original MILP problem is solved in the second stage by fixing some binary variables according to the first stage solution. In addition, we propose a heuristic technique that is based on introducing a new set of constraints to reduce the search space without eliminating potentially good solutions. Comprehensive experiments are investigated based on the practical data of Beijing Subway Lines, where the proposed integrated models and approaches yield much better solutions when compared with a widely used strategy, i.e., holding (waiting at station) strategy and the sequential approach. Moreover, the impacts of the complete blockage locations/durations and the effects of different weight settings in the multi-objective optimization are deeply analyzed.

Optimization of Multi-Train Energy Consumption in Real-Time Railway Traffic Management

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Traffic perturbations in railway systems may give rise to conflicts, which cause delays w.r.t. the timetable. Dealing with them requires solving the real-time Rail Traffic Management Problem (rtRTMP). A subproblem of the rtRTMP is the real-time Energy Consumption Minimization Problem (rtECMP). It defines the speed profiles along with the timing of multiple trains in a given network and time horizon. It takes as input the train routing and precedences computed by a rtRTMP solver and its objective is to minimize train energy consumption and total delay. In this paper, we propose an Ant Colony Optimization algorithm for the rtECMP and we test it on the French Pierrefitte-Gonesse control area with dense mixed traffic. The results show that in 30 seconds a remarkable exploration of the search space is performed before convergence.

Optimal Passenger Flow Management within Railway Stations via Alternative Graphs

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Due to the increasing passenger volume, many stations in city centres are overcrowded. Conflicts among passenger flows, i.e., more than one flow of passengers in the same area at any time, can present confusion, health/safety risks and significantly reduce the walking speed, thus reducing the station capacity, especially when dealing with bi-directional passenger flows. To best utilize the existing space in stations, passenger movements need to be smartly managed to avoid such conflicts. This research proposes an optimization tool for managing passenger flows inside complex and busy railway stations. Whilst much research has modelled the flow of passengers as continuous variables, this research considers the flow of passengers to be discrete and its direction to be changeable; we thus formulate it by using discrete optimization techniques. Platform numbers are announced based on the optimized timing regarding each group of passengers proceeding to/from a departure/arrival platform. We formulate this passenger management problem as a special Job Shop Scheduling problem (JSP) and solve it by using an Alternative Graph (AG) based solver, AGLibrary. Each station is divided into sub-areas, which are considered as resources, while each group of passengers is considered as a job in the JSP model. The goal is to schedule the platform number announcement times, to avoid conflicts between passenger flows and to allow trains to depart with a minimum delay. Due to the problem complexity and the need to find the best possible solution within a very limited computation time, effective algorithms are used based on AGLibrary. A practical case study in London is adopted to investigate the potential of the proposed tool. Preliminary results show that the conflicts between passenger flows can be significantly reduced, within a suitable computation time. We believe that the proposed tool can be used to support the decision makers to compute more informed and better optimized decisions.

A Decomposition Algorithm for the Real-Time Railway Traffic Management Problem

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Railway services are operated following a predefined timetable. However, their execution is often perturbed by unexpected events that make this timetable infeasible. Delay caused by these events is named primary delay, and it implies that trains occupy tracks at times that are different from the planned one. Depending on traffic and track layout, these late occupations may bring to conflicts, in which at least one train must slow down or even stop to preserve safe separation. This slowing down generates secondary delay, which may quickly propagate in the network. This problem is named real-time Railway Traffic Management Problem (rtRTMP). We propose a neighborhood-based traffic management algorithm, following to some extent the problem conception of [3]. As in the latter paper, we model the infrastructure microscopically. In particular, we precisely model the interlocking system which ensures correct train routing and safe separation through block sections, where only one train at a time is allowed. Our algorithm consists in making asynchronous traffic management decisions. Asynchronous decisions are made also in [2], where train movements are split in so called temporal *ticks* to assess the presence of deadlock in a single track network with passing loops. In our case, these decisions allow trains to reach their destination aiming at the minimization of delay propagation. Specfically, we identify the neighborhood of a reference train whenever a decision is to be made on its route or on the precedence with respect to another train. This neighborhood includes only the trains that may use track sections in common with the reference one, in the vicinity of the latter's current location and in the very near future. Traffic is then managed by applying an optimization approach as the one by [1], only considering trains in the neighborhood and the identified possibly common track sections. By doing so, alternative routes are taken into account, but they are as short as possible. This allows limiting the size of the instance and hence the optimization time. Moreover, whenever possible, it avoids making decisions that may have to be modified in the future, when the neighborhood is recomputed. However, routes must be long enough to guarantee that no deadlocks occur right out of the neighborhood due to the decisions made here. The algorithm starts identifying the concerned trains and their shortest but long enough routes. Then, it follows the principle that has proved to be successful in [1], simultaneously optimizing routes and schedules. We theoretically show that, in single track networks with passing loops, this algorithm guarantees the achievement of a deadlock-free network-level solution, if it exists.

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Invited Session: OPTSM 5 A5

Anna Livia Croella, Safe Places assignment for trains

Alessio Trivella, Decision making under uncertainty in public transport networks - The case of stochastic railway traffic control

Pieter Vansteenwegen, Demand-responsive feeder lines for suburban areas

Veronica Dal Sasso, Fast deadlocks detection between pairs of trains

Safe Places assignment for trains

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When major disruptions occur in a rail network, the infrastructure manager and train operating companies may be forced to stop trains until the normal status is recovered. Despite a large literature on disruption management (see Cacchiani et al. (2014), Corman and Meng (2015), Ghaemi et a. (2017)), the problem of finding a location where the trains can safely be parked during the critical situation has been rarely addressed. The ILP approach we developed, the Safe Place Assignment Problem (SPAP), serves the purpose of identifying, for each train, a location (a safe place) where the train can hold during the disruption, avoiding to disconnect the network and allowing a quick recovering of the original plan, at restart. The safe place assignment pursues three distinct and somehow conflicting objectives: to avoid that when the disruption is lifted trains are bound-to-deadlock; to leave some paths free of trains so that worker trains can reach the disrupted area; to "push" trains as far along their routes as possible, so as to mitigate the impact of the disruption in terms of train delays. We translate such conditions into constraints and objective of a suitable binary formulation of the problem. Two main application contests where tested: the disruption management, when a major blockage occurs in the network; and the partial plan recovering, when the train company does not have at hand a solution for the entire planning horizon. Computational results on a set of instances provided by a class 1 U.S. railroad show how the approach can be used effectively in the real-life setting, by returning optimal assignments in fractions of second.

Fast deadlocks detection between pairs of trains

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Among disruptive events that may happen on railways, deadlocks are one of the most severe, as they require time and costly operations to be resolved. Deadlocks are caused by a subset of trains that, given their current positions, cannot reach their destinations unless at least one of the trains is pushed back first. Given their severity, these situations should be prevented by all means. However, when they do occur, it is crucial to identify them as early as possible so that recovery operations can begin immediately and their impact on the network is minimised. In European railways deadlocks are relatively rare, because timetables are defined well in advance and, most importantly trains are usually short enough to fit within one station. This is not the case in North-America, and more in general in predominantly freight-hauling railways, where trains are instead typically very long and there is often little capacity. In this work we present an exact, pseudo-polynomial algorithm for identifying a deadlock between a pair of trains. Computational results in real-life instances show how this algorithm works very well in practice, and thus can be used as a basis for real-time applications. Moreover, we show that the problem of identifying a deadlock between two trains can be solved in polynomial time, making it, to the best of our knowledge, one of the very few cases of polynomially solvable deadlock detection problems.

Demand-responsive feeder lines for suburban areas

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In low demand areas, conventional public bus systems easily become too expensive to operate. Therefore, appropriate demand-responsive systems should be designed. We optimize and analyze the operation of a semi-flexible demand-responsive feeder bus system, connecting a low demand area to a city center or transportation hub. The feeder system is composed of a number of lines with a predefined initial route. These lines are operated during a number of consecutive operation periods. A mathematical model optimizes the possible detours and shortcuts that buses on these lines are allowed to use, assuming the demand for each bus stop during each operation period can be estimated accurately. Detours of at most one or two bus stops and all possible shortcuts in the initial route are allowed. The objective function is to minimize the passengers average travel time, including waiting time. Constraints limit the maximum travel distances of each bus. A simulation evaluates the system's performance for both the predefined initial routes and the semi flexible demand responsive routes. Two situations are considered: one where all passengers are assumed to be present at the bus stop from the beginning of each operation period and one where passengers arrive randomly during the operation period. The results show the impact of these two situations. Moreover, when the number of stops without demand during a certain operation period increases, the passengers travel times decrease when using the semi flexible service. Finally, the detours of at most two stops obtain better results in passengers average travel time than detours of at most one stop. However, a few passengers experience longer travel times due to the extended routes.

Decision making under uncertainty in public transport networks - The case of stochastic railway traffic control

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A major challenge in public transport is to improve the quality of operations by updating an offline timetable to the ever changing delays situation, in order to improve performance of the transport system. This relates to a series of control actions, such as changing times of events or rerouting vehicles, taken in real time and under uncertainty regarding the future evolution of the disturbances. Moreover, the way by which the system users (transport operators, travelers) react to the decision is also subject to uncertainty. After reviewing state of the art and challenges in incorporating uncertainty in public transport operations, we focus on the case of railway traffic control. We present modeling and algorithmic approaches to improve real time railway traffic operations going beyond the commonly accepted assumption of determinism and full certainty regarding the future operations. In particular, we explicitly model uncertainty in railway operations and future delays using probability distributions or stochastic processes, and leverage techniques from stochastic optimization to solve the resulting high dimensional stochastic control problem on a railway network.

Invited Session: OPTSM 6 A6

Lorenzo Castelli, Mitigating demand-capacity unbalances through inter-airline slot tradings

Zhouchun Huang, Optimal aircraft arrival scheduling model based on continuous descent operation in busy terminal maneuvering areas

Dilay Aktas, A demand responsive public bus system with short-cuts

Luigi De Giovanni,A matheuristic approach to preference aware air traffic flow management

Mitigating demand-capacity unbalances through inter-airline slot tradings

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When airspace capacity is reduced, some flights may be delayed through the allocation of air traffic flow management slots, in accordance with the FPFS rule. Although this reassignment seems the natural way to handle such a situation, the fact that different flights have generally different economical values suggests that other reallocation mechanisms may provide more convenient solutions from the airlines' cost perspective. For instance, each airline could propose a set of slot swap offers, with the Network Manager (NM) playing the role of the mediator and deciding which offers to match [1]. However, this mechanism requires a huge effort from the airlines to evaluate all possible offer combinations, a number which is exponentially growing with the size of their fleet. In addition, all airlines make their offers simply relying on their flights and their current schedule, without the possibility to fully exploit what is available on the market, as they have no information regarding other airlines' offers. With our Inter-airline Slot Swap Offer Provider model, we aim to invert this process: we allow airlines to assign preferences to their flights and let the NM instead to play the role of the airlines' broker, who, based on the preferences and ensuring no negative impact to all airlines, provides a set of ready-made offers that each airline can decide either to accept or refuse. Hence, a slot trade is represented by the matching of several offers of different airlines; if all the offers defining a trade are accepted then the corresponding slot swap eventually takes place, otherwise all the flights involved in the trade keep their initial position in the schedule.

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Optimal aircraft arrival scheduling model based on continuous descent operation in busy terminal maneuvering areas

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Continuous Descent Operation (CDO), an arrival procedure with low engine thrust settings or a low drag configuration, is playing a significant role in reducing fuel consumption, gas emission and noise for aircraft descending operations. In a busy airport Terminal Maneuvering Area (TMA) which usually have extremely high air traffic demand and severe congestion, it is unlikely to perform the CDO procedure due to the difficulty of predicting the CDO trajectory that satisfies airport arrival rate requirements for each landing aircraft. In this paper, we tackle such difficulty by developing a lateral path stretching method for aircraft pre-sequencing prior to merge points. First, we apply the method to optimize the CDO trajectory by designing a set of turning or parallel legs, each of which is composed of several waypoints. Second, we take into account the trajectory decisions for aircraft scheduling process to avoid the conflict among different aircraft trajectories. Our method is applied to the aircraft arrival scheduling in Guangzhou Baiyun International Airport, the biggest airport in China, and the results demonstrate its benefit in improving the scheduling efficiency in a busy TMA.

A demand responsive public bus system with short-cuts

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In this study, we introduce a demand responsive public bus system for the morning peak hours where much more people travel towards a city center than in the other direction. It is decided whether a bus should visit all the stops ahead or take a short-cut away from the city center so that it increases the frequency of the service towards the city center. When optimizing this system, it is taken into account that some additional time might be required, before the system can return to its conventional operation. We develop a Mixed Integer Quadratic Program to mathematically model this problem. Due to its complexity, only small sized problems can be solved optimally. Therefore, we also design a metaheuristic algorithm based on Variable Neighborhood Search that finds high quality solutions within reasonable time for real sized instances. The results of the benchmark instances show that the demand responsive system can improve the average passenger waiting time up to 10% compared to the conventional system.

A matheuristic approach to preference aware air traffic flow management

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The main objective of Air Traffic Flow Management (ATFM) is to assign 4D trajectories to flights to guarantee both safe operations and efficient use of airspace. In this talk, we present a new approach to ATFM that explicitly takes AUs routes' preference into account. A set of relevant trajectories is extracted from air traffic data repositories, using data analytics to learn the preference of each flight for each trajectory. The information feeds an Integer Linear Programming (ILP) model where variables assign a trajectory and a ground delay to each flight. For real-size instances, the number of trajectories leads to prohibitively large models and we propose a heuristic that, at each iteration, solves the ILP model restricted to a suitable subset of variables determined through machine learning techniques. The randomized selection comes from a tree classifier that considers features related to candidate variables, as well as to current solution and search state, and is preliminarily trained on reduced size instances. Computational results, compared to a heuristic based on column generation, show the ability of the proposed method to effectively solve realistic instances and sensibly reduce running times while preserving the quality of the solutions.

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Invited Session: OPTSM 7 A7

Bart van Rossum, A Column Generation Approach for the Integrated Crew Re-Planning Problem

Federico Bigi, A dynamic choice methodology for shunting policies in freight train operations

Raúl de Celis, Towards final en-route, arrival and runway traffic management and trajectory optimization in air transportation

Valentina Cacchiani, A Fixed Job Schedule Application in Train-unit Assignment

A Column Generation Approach for the Integrated Crew Re-Planning Problem

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Planned maintenance and construction activities are crucial for heavily used railway networks to cope with the ever increasing demand. These activities lead to changes in the timetable and rolling stock schedule (often for multiple days) and can have a major impact on the crew schedule, as the changes can render many planned duties infeasible. In this paper, we propose a novel integrated approach to crew re-planning, i.e., the construction of new duties and rosters for the employees given changes in the timetable and rolling stock schedule. In current practice, the feasibility of the new rosters is 'assured' by allowing the new duties to deviate only slightly from the original ones. In the Integrated Crew Re-Planning Problem (ICRPP), we loosen this requirement and allow for more flexibility: The ICRPP considers the re-scheduling of crew for multiple days simultaneously, thereby explicitly taking the feasibility of the rosters into account. By integrating the scheduling and rostering decisions, we allow for larger deviations from the original duties. We propose a mathematical formulation for the ICRPP, strengthen it using a family of valid cover inequalities, and develop a column generation approach to solve the problem. We apply our solution approach to practical instances from NS, and show the benefits of integrating the re-planning process.

A dynamic choice methodology for shunting policies in freight train operations

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The activity segment of wagon load - block train has declined significantly in the past years and its significant growth potential can only be fully achieved through automated solutions in order to speed up and reduce costs in the rail freight operations, achieving long-term economies of scale. In this context, this study examines the effect of different shunting policies for freight trains and their long-term impact on the rail network, merging both Integrated Rolling Stock and Train Unit Shunting Problem approaches. A shunting operation for freight trains is the action of moving one or multiple wagons inside a shunting yard. Hence, a shunting policy is understood as the way of choosing which wagon to remove and which one to include in the train with the aim of optimizing operational characteristics. This paper proposes a 3-phase dynamic choice methodology that allows to understand the impact of different shunting policies in optimizing the performance of intermodal rail operations. First, we implement a data-driven model to predict if a freight train, given certain features, will be delayed or not. This is done in the freight intermodal rail operations from the Luxembourg National Railway Company. Then, different types of shunting policies are explored and analyzed, based on wagon maintenance time and other metrics, and different indicators are computed to analyze their short- and long-term impact. Finally, a fuzzy analysis is carried out to merge the different indicators from the two phases. For each shunting policy, a degree of belongingness to each proposition is computed based on the different outputs for each phase. With the proposed methodology, simulations are carried out to examine its usefulness using a real schedule. The impact of this multi-policy method is then compared to the shunting policy used by the Luxembourg National Railway Company for its shunting operation, highlighting the indicators with the greatest impact on the cost.

Towards final en-route, arrival and runway traffic management and trajectory optimization in air transportation

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Air traffic management is a complex and combinatorial problem. There number of aircraft and air routes to be managed at specific air sectors and during specific time periods might be huge.

Management of final en-route traffic and terminal manoeuvring area feature additional complexity because air traffic converges to airports. In addition, capacity limitations at airports, e.g., number of available runways and operations constraints, further complicate the problem. All these features have to be managed in an integrated fashion to efficiently prevent bottlenecks.

This research introduces an optimization model that manages final en-route, approach and landing operations, deciding on terminal arrival route, runway assignment, and aircraft trajectory. The proposed integrated model leads to a mixed integer non-linear problem.

In order to solve the problem, a Benders decomposition based approach is proposed. The master model deals with runway assignment and route selection, making use of a set of binary variables, and the sub-model deals with the trajectory calculation problem, managing a set of continuous variables and minimizing a combination of fuel consumption and delay.

A Fixed Job Schedule Application in Train-unit Assignment

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We study a generalization of the Fixed Job Schedule Problem that arises in train-unit assignment, where a train-unit consists of a train with an engine and a set of wagons. In this generalization, a set of fixed jobs (train trips), each with its start time and end time, must be scheduled on a set of non-identical machines (train-units), each having a cost, and capable of executing one job at a time. Each job has a demand of resource (number of passenger seats), and each machine has a maximum resource capacity. Each job must be executed by a set of machines such that their overall capacity satisfies the job demand (i.e., train-units can be combined to provide more passenger seats). In addition, a setup time between the execution of two jobs on the same machine must be respected. The goal is to determine the minimum cost schedule. In [1], the problem in which at most two machines can be assigned to a job was investigated. In this work, we discuss two variants corresponding to two extreme cases: in the first one, exactly one machine is assigned to each job, while in the second one there is no limit on the number of machines assigned to each job. For these variants, we propose a heuristic algorithm, and test it on realistic instances of the train-unit assignment problem.

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Session: Combinatorial Optimization and Integer Programming III B4

Domenico Serra,A Genetic Approach for the 2-Edge-Connected Minimum Branch Vertices Problem

Carmine Sorgente, The Shortest Path with Mutual Exclusive Arc Conflicts problem

Renata Mansini, A new variant of Kernel Search for solving Mixed Integer Linear Programming Problems

Tiziano Bacci, DP-based formulations of the Unit Commitment Problem and the Convex Hull of Star-Shaped MINLPs

A Genetic Approach for the 2-Edge-Connected Minimum Branch Vertices Problem

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Given an undirected graph G, the Minimum Branch Vertices (MBV) problem consists of finding a spanning tree of G, containing the minimum number of branch vertices, namely vertices having a degree greater than two in the tree [1][2]. This talk addresses the 2-Edge-Connected Minimum Branch Vertices problem that is a variant of MBV in which the spanning subgraph have to be 2-edge-connected. The problem has been recently introduced and some exact approaches have been proposed in the literature [3]. In this talk, we provide a proof of NP-completeness of the problem and we introduce a genetic algorithm, which exploits some literature-provided procedures for efficiently checking and restoring the feasibility of the solutions. Moreover, some ad-hoc operators are designed to improve the solution values by reducing the number of branch vertices. The computational tests, carried out on benchmark instances, show that our genetic algorithm often finds the optimal solution in a short computing time.

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The Shortest Path with Mutual Exclusive Arc Conflicts problem

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In this talk, we introduce a NP-hard variant of the well-known shortest path problem, named Shortest Path with Mutual Exclusive Arc Conflicts (ME-SPAC) problem. Given a weighted and directed graph G, a source vertex s and a target vertex t, the classical shortest path problem consists of finding a path from s to t in G, which minimizes the sum of the weights of the selected arcs. Variants considering conflicting elements of other classical problems, like the bin packing problem, the knapsack problem, the maximum flow problem and the minimum spanning tree problem have been studied in the literature. In this talk, we consider conflicts between arc pairs for the shortest path problem: given a set of conflicting arc pairs, we denote by p_k the penalty to be paid in case of violation of the conflict c_k; a conflict is violated if both the arcs in the pair, or none of them, are selected. We introduce additional constraints to take these violations into account. The aim of the ME-SPAC problem is to minimize the overall cost of a path from s to t in G, which results to be the sum of the selected arcs weights, added to the penalties of the violated conflicts. We show that the considered variant of the problem is NP-hard and propose an Integer Linear Programming model reinforced by a separation procedure to address the exponential constraints of the model. Finally, a genetic algorithm has been designed and its solutions are compared with those provided by the model implemented in CPLEX.

A new variant of Kernel Search for solving Mixed Integer Linear Programming Problems

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Kernel Search (KS) is a well-known matheuristic framework for the solution of Mixed Integer Linear Programming (MILP) problems (see Maniezzo et al. [2]). Initially proposed in Angelelli et al. [1], the method is based on the identification of a subset of promising variables (the kernel set) and the partition of the remaining variables into buckets. More precisely, KS builds and solves a sequence of small MILP subproblems, each one taking into account the kernel set plus the additional variables belonging to a bucket. We introduce a new variant of Kernel Search where the solution of a problem is tackled through two phases (consisting of two sequential KS) in an adaptive way: a feasibility-oriented phase and a quality-oriented one. The first phase aims at (i) finding feasible solutions in a small amount of time possibly scrolling the buckets as many times as possible in a coarse way; (ii) estimating the difficulty of the problem instance to adapt the algorithm's structure to its solution. The goal of the second phase is complementary to the first one. The algorithm focuses on seeking higher-quality solutions and uses information collected from the first phase to improve its performance. Computational results obtained on the benchmark instances of the Multidimensional Multiple-choice Knapsack Problem show the effectiveness of the approach, able to find a large number of new best-known values.

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DP-based formulations of the Unit Commitment Problem and the Convex Hull of Star-Shaped MINLPs

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The Unit Commitment (UC) problem in electrical power production requires to optimally coordinate a set of power generation units over a short time horizon to satisfy a given energy demand at minimum (nonlinear) cost while satisfying several complex operational constraints (minimum and maximum power output, minimum up- and downtime, start-up and shut-down limits, ramp-up and ramp-down limits). We present the first MINLP formulation that describes the convex hull of the feasible solutions of the single-unit commitment problem (1UC) comprising all the above constraints and convex power generation costs. The new formulation has a polynomial number of both variables and constraints, and it is based on the efficient Dynamic Programming algorithm proposed in [1] together with the Perspective Reformulation technique proposed in [2].
The proof that the new DP-based formulation for (1UC) is exact can be extended to all star-shaped formulations, that is, MINLP formulations composed by a "core" MINLP system and "rays" MINLPs, each of which sharing a vector of variables with the "core" but not with any other "ray". The result is valid whenever each MINLP system is defined by convex functions and that some constraint qualification conditions are valid.
Since the exact DP formulation is rather large, we also propose four new formulations, based on partial aggregations of variables, which exhibit different trade-offs between quality of the bound and cost of the solving the continuous relaxation. Our results show that navigating these trade-offs may lead to improved performances.

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Session: Combinatorial Optimization and Integer Programming IV B5

Francesco Carrabs,A Biased Random-key Genetic Algorithm for the Set Orienteering Problem

Adriano Masone, Exact and heuristic approaches for the Intersection Inspection Rural Postman Problem

Demetrio Laganá, A two-phase hybrid algorithm for the periodic rural postman problem with irregular services

Claudio Gentile, New heuristics for the Max-Cut problem

A Biased Random-key Genetic Algorithm for the Set Orienteering Problem

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The Set Orienteering Problem [1,2] is a generalization of the Orienteering Problem where the customers are grouped in clusters, and the profit associated with each cluster is collected by visiting at least one of the customers in the respective cluster. The problem consists of finding a tour, over a subset of clusters, that maximizes the collected profit and which length is within a given threshold. In this talk we propose a Biased Random-Key Genetic Algorithm [3] for the problem in which three local search procedures are applied to improve the fitness of the chromosomes. Moreover, we define three rules useful to reduce the size of the instances and to speed up the resolution of the problem. Finally, we introduce some strategies to avoid redundant computations. The computational results, carried out on benchmark instances, show that our algorithm is significantly faster than the other algorithms, proposed in the literature, and it provides solutions very close to the best-known ones.

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Exact and heuristic approaches for the Intersection Inspection Rural Postman Problem

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Local governments inspect roads to decide which segments and intersections to repair. Videos are taken using a camera mounted on a vehicle. The vehicle taking the videos proceeds straight or takes a left turn to cover an intersection fully. We introduce the intersection inspection rural postman problem (IIRPP), which is a new variant of the rural postman problem (RPP) that involves turns. We develop integer programming formulations of the IIRPP based on two different graph transformations to generate least-cost vehicle routes. We also develop an RPP-based heuristic and a heuristic based on a modified RPP. Heuristic solutions are improved by solving integer pro-gramming formulations on an induced subgraph. Computational experiments show the effectiveness of the proposed exact and heuristic approaches. In particular, the best-performing heuristic is able to determine very good quality IIRPP-feasible routes on large street networks quickly.

A two-phase hybrid algorithm for the periodic rural postman problem with irregular services

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We deal with the periodic rural postman problem with irregular services (PRPP-IS) in which some links of a mixed graph must be traversed a given number of times. In particular, they must be serviced in some subsets of days (or periods) of a specified time horizon. The aim is to define a set of minimum-cost tours, one for each day of the time horizon, that satisfy the service requirements. For the PRPP-IS, we propose a two-phase algorithm by combining heuristics and mathematical programming. In the first phase, two different heuristics are used to construct feasible solutions: a multi-start constructive heuristic and a multi-start random assignement first and feasibility pump routing second heuristic. From these solutions some fragments (i.e., parts of tours associated with the various days) are extracted. The second phase determines a solution for the PRPP-IS by combining the fragments through an integer linear program. We show the effectiveness of this solution approach through an extensive experimental phase on benchmark instances.

New heuristics for the Max-Cut problem

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Max-Cut (or, equivalently, Quadratic Unconstrained Binary Optimization (QUBO)) is one of the most relevant and studied combinatorial optimization problems. In the last decade, it got even more popularity after some innovative hardware, implementing heuristics that are based on quantum annealing, have been commercialized. These systems (QPU) are not general-purpose computers; as a matter of fact, they are able only to provide good solutions to QUBO instances defined on Chimera graphs, but in amazingly short computing times. The availability of such systems propelled a great deal of research focused on transforming real-world optimization problems (machine learning among the many) to QUBO instances. The impact of the new technology became so strong that a QPU gained the cover page of TIME magazine in 2014.
A speedup factor of thousands or even a million times of QPU over some classical heuristics has been reported in the scientific literature. In contrast, Selby [2] proposes a heuristic that provides more accurate solutions than QPU in not much longer times. The heuristic is based on the so-called sub-graph sampling method. Essentially, the algorithm identifies a series of induced sub-graphs where Max-Cut is efficiently solvable due to their peculiar structure. Then the final solution is built from the solutions found on these sub-graphs. In particular, the special structure of the Chimera graphs is its relatively small tree-width. A recent study [1] has shown that the Selby heuristic outperforms QPU both for solution quality and computing times. However, recently announced new versions of QPU can handle instances on graphs more complex than Chimera, whose tree-width is substantially higher, making Selby's algorithm no longer applicable.
This fact motivates this paper where, sticking to the same sub-graph sampling method,some structures of the induced sub-graphs, other than the tree-width, are exploited.
In particular, two structures are considered: outer-planarity and the sign of the edge-weights, possibly after applying operations like subset contraction and switching that are commonly used in Max-Cut algorithms. The second structure makes it possible to apply the algorithm to any graph and not only to graphs with small tree-width like is the case for the algorithm of [2]. We tested the algorithm on toroidal grid graphs, on the Chimera graphs used in [1], and on other instances in the literature obtaining encouraging results.
For instance, we are able to find the optimal solution for 94.42% of the 1355 Chimera instances in less than 1.72 seconds when using 560 simultaneous threads. Also, running the algorithm with 560 different seeds per instance, we observed that the optimum is attained at least once every 20 repetitions.

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Session: Networks B6

Alice Calamita,Planning on wireless networks: optimization and technological aspects

Samuela Carosi, A decision support system for real time disruption management in local public transport

Daniele Manerba,Optimal design of redundant backbones in Bluetooth Mesh Networks

Planning on wireless networks: optimization and technological aspects

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The design of wireless networks consists in determining the optimal positioning of the antennas in order to meet the quality requirements requested by users throughout the territory. We discuss the modeling of this problem and the methods that can be adopted to solve such optimization models. In particular, we focus on the limitations of classical solvers such as Gurobi Optimizer, revealing the numerical and major optimization issues encountered when facing network planning on simulated datasets. Indeed, realistic antenna deployment optimization problems turned out to be large problems and, from the results over several experiments, affected by strong ill-conditioning due to the intrinsic nature of the data.

A decision support system for real time disruption management in local public transport

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Public transport companies are increasingly in need of tools allowing to promptly react to unforeseen events, such as vehicle breakdowns, road deviations, extension/reduction of the service periods, etc, that modify the demand or the distribution of the service among the planned resources (vehicles and drivers). In the last years, M.A.I.O.R. has developed, in collaboration with the Computer Science Department of the University of Pisa and the Department of Electronics, Information and Bioengineering of the Politecnico di Milano ([1, 2]), algorithms capable of supporting real-time decision making during disruption events. The main challenge that need be overcome is that all aspects of the solution-trips, vehicle and drivers duties-must be re-scheduled in an integrated fashion, as opposed to the sequential approach more prevalent when planning. In urban contexts, the new solution has to be compliant with new given frequencies/headways and to change as little as possible w.r.t. the planned one in order to ease the disruption management. We will describe the proposed approach, that aims at staying as close as possible to the new frequencies while maintaining the planned starting and ending time, location and vehicle of each single piece of work of all affected drivers. The approach exploits some of the methodologies introduced in [3], combining Lagrangian relaxation techniques within a matheuristic that allow to control execution times. Some results, obtained on real test cases, will be presented.

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Optimal design of redundant backbones in Bluetooth Mesh Networks

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A Bluetooth Mesh (BM) is a recent communication protocol supporting Internet of Things (IoT) applications in several sectors such as healthcare and automation. BM is mainly used in industrial settings to establish many-to-many device communication and allows creating large wireless networks without a centralized management [1]. The involved devices could be very heterogeneous in terms of power supply: some are directly plugged into the grid, some are battery-supplied, and some others are adaptable to both ways. In the BM protocol, any time a device wants to send a message, it transmits the message to all its neighboring devices. Until the message reaches its destination, the propagation is carried on by some chosen devices (relay nodes), which immediately broadcast the received messages to all their neighboring devices. However, since battery-supplied devices awake only once a while to transmit or receive, some other devices (friend nodes) must be assigned to them for maintaining the messages in a cache. Clearly, relay and friend configurations require additional power and can be applied only to plugged devices. Hence, a BM design problem consists in selecting a backbone, i.e. a set of relay nodes allowing all the devices to communicate with each other, and assigning friend nodes to battery-supplied devices, so as to minimize the power consumption of the entire network. In practice, this problem is mainly addressed heuristically [2], whereas we propose its first systematic study based on Mathematical Programming. Moreover, similar problems in the TLC network design literature look in general for a minimal tree-structured backbone that, therefore, intrinsically involves undesirable single points of failure [3]. Instead, to better deal with critical IoT processes, in this work, we investigate solutions guaranteeing a certain degree of redundancy in the network connectivity.

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Invited Session: Timetabling and Scheduling
B7

Claudio Crobu,Quality timetabling for Italian High-School

Andrea Schaerf, Comparing Exact and Metaheuristic Methods for a Real-World Examination Timetabling Problem

Marcello Sammarra, An overview of Lagrangian Relaxation techniques to truck scheduling problems in cross-docking distribution centres

Maurizio Boccia, Exact and heuristic approaches for an Automated Guided Vehicle Scheduling Problem with Battery Constraints

Quality timetabling for Italian High-School

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A variant of the High-School Timetabling problem is introduced to investigate the case of Italian schools. New requirements are defined to provide (i) equity in teachers' idle times, (ii) avoid consecutive days with heavy workload, (iii) limit daily multiple lessons for the classes and (iv) introduce fractional time units to differentiate entry and exit times. An integer programming model is presented for this problem, which is denoted by [IHSTP] (Italian High School Timetabling Problem). The new requirements cannot be expressed using the current XHSTT standard. Since IHSTP is hard to solve by a MIP solver, a two-step method is presented: the first step assigns teachers to lesson times and the second step completes timetabling assigning classes to teachers. A wide experimentation shows that the method is effective in solving this new problem and the simplified problem without the new requirements.

Comparing Exact and Metaheuristic Methods for a Real-World Examination Timetabling Problem

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We propose a portfolio of exact and metaheuristic techniques for the rich examination timetabling problem introduced by Battistutta et al. (2020). The problem includes several real-world features that arise in Italian universities, such as exams split in two parts, multiple rooms for one exam, and unavailabilities and preferences for periods and rooms. We develop CP and MIP models, the former one based on the MiniZinc modeling language. We use both exact and local-search based back-ends for MiniZinc and implement the MIP models in Gurobi. Finally, we extend the metaheuristic method based on Simulated Annealing of Battistutta et al. by introducing a new neighborhood relation. We compare the different techniques on the real-world instances provided by Battistutta *et al.*, available at `https://bitbucket.org/satt/examtimetablinguniuddata`, and we discuss the relative performance based also on the instance features.

An overview of Lagrangian Relaxation techniques to truck scheduling problems in cross-docking distribution centres

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Cross-docking terminals are distribution centres where products coming from suppliers are unloaded from the inbound trucks, grouped into full-load truck shipments, and directly loaded into the outbound trucks, to be delivered to the customers. This zero-inventory distribution policy requires a high degree of synchronization between trucks, so as to avoid congestion inside the terminal and guarantee short lead times to customers. In this talk we deal with the *truck scheduling* problem. We will show how Lagrangian Relaxation techniques can be successfully applied to this class of problems, under different setting, and how from the mathematical properties of the relaxed problem effective Lagrangian heuristic algorithms can be designed.

Exact and heuristic approaches for an Automated Guided Vehicle Scheduling Problem with Battery Constraints

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The introduction of automated guided vehicles (AGVs), due to their dexterity, efficiency, and flexibility, had a great impact on logistics leading to the creation of new business models. Nowadays, AGVs are frequently used in industries for the internal transportation of goods or pallets between various departments or locations within the same factory or for receiving, storage and sorting goods in shipment areas. The aim of an AGV-based internal transportation system is to transfer the right amount of the right material to the right place at the right time. Therefore, the determination of a good scheduling of the AGV tasks is essential to overcome delays in production and material handling processes. In this work, we study a scheduling problem arising from an internal transportation system of a company operating in the manufacturing field where AGVs subject to battery constraints are used for horizontal movement of materials. In this work, we propose an original integer linear programming (ILP) formulation to optimally solve the addressed problem and a three-step heuristic solution method. The results show the effectiveness of the proposed approaches and the impact of the AGV charging time on the handling process completion time.

Session: Mobility and Transportation C4

A centralized pedestrian advice framework compliant with Covid-19 outbreak restrictions

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Due to the COVID-19 pandemic, the focus on everydays mobility has been shifted from traditional means of transport to how to safely commute for work and/or move around the neighbourhood. Maintaining the safe distance among pedestrian becomes crucial in big pedestrian networks. Looking at personal goals, such as walking through the shortest path, could lead to congestion phenomena on both roads and crossroads violating the imposed regulations. We suggest a centralized multi-objective approach able to assign alternative fair paths for users while maintaining the congestion level as lower as possible. Computational results show that, even considering paths that are not longer than the 1to the shortest path for each pedestrian, the congestion phenomena are reduced of more than the 50%.

An Iterative Rounding approach to the Railroad Blocking Problem

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We present an optimization method for the railroad blocking problem, which is one of the main issues to address in the complex decision-making process entailed in railway freight transportation. A block is a set of commodities that travel between two nodes of the rail network as a logical unit. Blocks are formed in classification yards, i.e. hubs where commodities are grouped or separated. Setting up a block requires the allocation of one or more tracks, therefore the number and length of the tracks of a classification yard determine a bound on the number of outgoing blocks and a bound on the amount of cars grouped in each block.

Grouping commodities into blocks allows the freight-hauling company to increase efficiency in shipments, achieving economies of scope. However, this means that along their journey commodities may need to be "reclassified", i.e. separated and grouped into new blocks. This is a costly and time-consuming activity, hence the railroad blocking problem consists in finding a blocking plan that minimizes both transportation and intermediate handling costs.

To address this problem we rely on an integer linear programming model. However, real-life instances of the railroad blocking problem typically comprise hundreds of classification yards and thousands of individual commodities, which means that this kind of optimization problems usually involves an extremely high number of variables, beyond the current capacity of state-of-the-art solvers. For this reason, we employ an heuristic approach based on an iterative rounding procedure. This approach makes decisions supported by the solution of the linear relaxation and succeeds in significantly reducing the number of variables involved. We test this technique on data provided by a real rail transportation company, consistently finding good quality solutions (compared to the value of the linear relaxation) within a computational time of a few hours.

The Baggage Belt Assignment Problem

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We consider the problem of assigning flights to baggage belts in the baggage reclaim area of an airport. The problem is originated by a real-life application in Copenhagen airport. The objective is to construct a robust schedule taking passenger and airline preferences into account. We consider a number of business and fairness constraints, avoiding congestion, and ensuring a good passenger flow. Robustness of the solutions is achieved by matching the delivery time with the expected arrival time of passengers, and by adding sufficient buffer time between two flights scheduled on the same belt. We denote this problem as the Baggage Belt Assignment Problem (BBAP). We first derive a general Integer Linear Programming (ILP) formulation for the problem. Then, we propose a Branch-and-Price (B&P) algorithm based on a reformulation of the ILP model tackled by Column Generation. Our approach relies on an effective dynamic programming algorithm for handling the pricing problems. We tested the proposed algorithm on a set of real-life data from Copenhagen airport as well as on a set of instances inspired by the real data. Our B&P scheme outperforms a commercial solver launched on the ILP formulation of the problem and is effective in delivering high quality solutions in limited computational times, making it possible to use in daily operations in medium-sized and large airports. A full paper of our work is available at: `https://doi.org/10.1016/j.ejtl.2021.100041`.

Invited Session: Machine learning-based optimization and control for extreme metamaterials design C5

Danilo Costarelli, Neural Network Operators: Approximation Results

Federico Nutarelli, On dispersion curve identification

Pranath Kumar Gourishetty, Global optimization of a turbine design via neural networks and an evolutionary algorithm

Giorgio Gnecco, Multi-objective metafilter optimization

Neural Network Operators: Approximation Results

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The theory of neural network operators has been widely studied in last years in view of its connections with the well-known artificial neural networks. In the present talk we will present some recent constructive approximation results for the above family of operators. In particular we will show suitable asymptotic formulas, which are based on the so-called algebraic truncated moments of the density functions (kernels) generated by sigmoidal functions. As a direct consequence of the above asymptotic expansions we can prove some Voronovskaja formulas. Further, also operators with high order convergence have been studied by considering finite linear combination of the above neural network type operators. Several concrete examples of sigmoidal functions will be discussed in details, such as the logistic function and many others.

On dispersion curve identification

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In many physical applications, one has to deal with samples generated from possibly intersecting curves. For instance, when analyzing dispersive wave-propagation properties of periodic mechanical metamaterials [1], one simultaneously collects samples of several dispersion curves by computing the eigenvalues of a suitable Hermitian matrix - or the generalized eigenvalues of a pair of suitable Hermitian matrices - depending continuously on a real parameter, for various discrete choices of such a parameter. In this situation, the intersection of dispersion curves can arise in correspondence of the parameter values for which at least one eigenvalue has algebraic/geometric multiplicity larger than one. Assigning the curve samples correctly to such curves - where "correctly" may be interpreted as "in the smoothest possible way" - is a relevant preliminary step for a subsequent curve interpolation procedure, able to improve curve visualization in case of a small sampling frequency. In this work, we refine an algorithm previously developed in [2] for the problem of curve identification, by including a bipartite matching subproblem in it. Then, we apply it to dispersion curve identification. Numerical results demonstrate the improved effectiveness of the algorithm, e.g., in the case of the simultaneous intersection of several curves, which is common for this kind of application. Extensions based on the continuity of the eigenvectors and on the periodicity of the curves are also discussed.

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[2] Gnecco, G.: An algorithm for curve identification in the presence of curve intersections. Mathematical Problems in Engineering, vol. 2018, article ID 7243691, 7 pages (2018).

[3] G. Gnecco and F. Nutarelli were partially supported by the GNAMPA 2020 project "Trade-off between Number of Examples and Precision in Variations of the Fixed-Effects Panel Data Model".

Global optimization of a turbine design via neural networks and an evolutionary algorithm

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This work discusses an effective approach to find the optimal solution for constrained engineering design problems. Specifically, the computational platform herein implemented exploits a neural network and a differential evolution algorithm, and it leverages on a parametric finite element modelling for the fully automation of the design process. The presented approach is applied to the design of the rear flange of a low-pressure turbine casing for an aircraft engine, whose shape is optimized in order to reduce the manufacturing cost while preserving the overall integrity through the fulfilment of stress-based constraints.

Multi-objective metafilter optimization

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The spectral design of acoustic metamaterial filters - which are also known as metafilters - is often based on the formulation of either single-objective or multi-objective optimization problems (Bacigalupo et al., 2020; Gnecco and Bacigalupo, 2021). In these cases, the direct application of classical optimization algorithms to find the numerical solutions of such problems is often highly demanding from a computational point of view, because of the high complexity of the underlying physical models. Nevertheless, machine learning techniques can decrease this computational burden, e.g., by replacing the original objective functions or their gradients with more-easily computable approximations. In this framework, the application of an unsupervised machine learning technique - namely, principal component analysis - is presented here as a potentially effective preprocessing step able to generate, at a low computational cost, an approximation of the gradient of a suitable trade-off between the objective functions of a three-objective metafilter optimization problem. In this way, the successive application of a gradient-based iterative optimization algorithm is made faster. The three objectives represent, respectively, a low-frequency band gap, a high-frequency pass band, and a penalty term for the violation of the constraints of the optimization problem. Numerical results show the effectiveness of the proposed method, thanks to a significant reduction in the number of components of the gradient used by the algorithm to achieve numerical results comparable to the ones obtained when all its components are considered.

[1] Bacigalupo, A., Gnecco, G., Lepidi, M., Gambarotta, L.: Machine-learning techniques for the optimal design of acoustic metamaterials. Journal of Optimization Theory and Applications, vol. 187, pp. 630-653 (2020).

[2] Gnecco, G., Bacigalupo, A.: Convex combination of data matrices: PCA perturbation bounds for multi-objective optimal design of mechanical metamaterial filters. Submitted to Mathematical Foundations of Computing (2021).

Invited Session: Multi-Objective Mixed Integer Optimization C6

Aly-Joy Ulusoy, Multi-objective design for control of water networks by mixed integer programming

Giampaolo Liuzzi, A new method for mixed integer derivitave-free multiobjective optimization problems

Marianna De Santis, Detecting the efficient set of multiobjective integer quadratic programming problems

Pierluigi Mansueto, Improving the NSGA-II Algorithm with Descent Steps

Multi-objective design-for-control of water networks by mixed integer programming

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Optimal pressure management, which is critical to the reduction of leakage and probability of occurrence of pipe bursts, is one of the main challenges for water distribution network operators. The optimal design and operation of water distribution networks (WDNs) requires the consideration of multiple criteria, including the minimization of Average Zone Pressure (AZP) and Pressure Variability (PV), and the maximization of network resilience. The resilience of a WDN, which refers to its ability to maintain continuous customer supply, is commonly modelled in optimization problems as the pressure surplus (energy redundancy) in a WDN. In this study, we propose a multi-objective optimization framework to investigate the trade-offs between different operational objectives in WDNs. We investigate the problem of optimizing the locations for the installation of new pressure control valves or pipes, and the valve control settings, simultaneously. The resulting design-for-control problem is difficult to solve, and belongs to the class of non-convex multi-objective mixed integer non-linear programs (MINLPs). Previously published global optimization methods have investigated scalarization approaches [1] and multi-objective branch-and-bound [2], focusing on convex mixed integer problems. In this study, we develop a method to compute a superset of the non-dominated set of non-convex bi-objective mixed integer programs. The proposed algorithms are numerically evaluated considering case study networks with different sizes and levels of connectivity, including operational water networks from the UK.

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[2] Marianna De Santis, Gabriele Eichfelder, Julia Niebling, and Stefan Rocktaschel. Solving Multiobjective Mixed Integer Convex Optimization Problems. Siam Journal on Optimization, 30(4):3122-3145, 2020

A new method for mixed integer derivitave-free multiobjective optimization problems

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In this work, we consider multiobjective optimization problems with both bound constraints on the variables and general nonlinear constraints, where objective and constraint function values can only be obtained by querying a black box. Furthermore, we consider the case where a subset of the variables can only take integer values. We propose a new linesearch-based solution method and show that it converges to a set of stationary points for the problem. For what concerns the continuous variables, we employ a strategy for the estimation of the Pareto frontier recently proposed in the literature and which takes advantage of dense seuqnces of search directions. The subset of variables that must assume dicrete values are dealt with using primitive directions appropriately modified to take into account the presence of more than one objective functions. Numerical results obtained with the proposed method on a set of test problems and comparison with other solution methods show the viability and efficiency of the proposed approach.

Detecting the efficient set of multiobjective integer quadratic programming problems

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Multiobjective integer optimization refers to mathematical programming problems where more than one objective function needs to be optimized simultaneously and all the variables are constrained to be integer. We present a branch-and-bound algorithm for minimizing multiple convex quadratic objective functions over integer variables. Our method looks for efficient points by fixing subsets of variables to integer values and by using lower bounds in the form of hyperplanes in the image space derived from the continuous relaxations of the restricted objective functions. We show that the algorithm stops after finitely many fixings of variables with detecting both the full efficient and the nondominated set of multiobjective strictly convex quadratic integer problems. A major advantage of the approach is that the expensive calculations are done in a preprocessing phase so that the nodes in the branch-and-bound tree can be enumerated fast. We show numerical experiments on biobjective instances and on instances with three and four objectives.

Improving the NSGA-II Algorithm with Descent Steps

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We consider smooth Multi-Objective optimization problems with box constraints. Multi-Objective problems are commonly tackled by means of evolutionary algorithms. In particular, NSGA-II is, arguably, by far the most popular of these methods, being capable of obtaining high-quality approximations of the entire Pareto front by means of genetic operations. However, in recent years, descent-type approaches, which extend classical iterative methods in scalar optimization, have been proposed and can be shown to be more effective and efficient than genetic approaches on problems with good regularity properties or when the problem size grows. However, descent methods are typically designed to guarantee the Pareto-stationarity of the found solutions. Therefore, without convexity assumptions, they may lead to strongly sub-optimal solutions. We thus propose a Memetic variant of the NSGA-II algorithm that makes use of steepest descent steps to be consistently efficient and effective in the most general setting. We compare the performance of our proposed algorithm with that of the main state-of-the-art methods from both families of approaches on a large benchmark of problems. The experiments show the strength of our method with respect to the competitors.

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Invited Session: Recent Advances on Semidefinite Programming D4

Federico Battista, Dealing with inequalities in large scale semidefinite programs: a computational study

Nicolo Gusmeroli, BiqBin: an exact penalty solver for linearly constrained BQPs

Elisabeth Gaar, Utilizing SDP to Tackle a Conjecture from Graph Theory

Martina Cerulli, Solving a class of bilevel programs with quadratic lower level

Dealing with inequalities in large scale semidefinite programs: a computational study

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Semidefinite programs (SDPs) can be solved in polynomial time by interior point methods. However, when the dimension of the problem and the number of constraints gets large, interior point methods become impractical both in terms of computation time and memory requirements. First order methods, such as Alternating Direction Methods of Multipliers (ADMMs), turned out to be suitable algorithms to deal with large scale SDPs and gained growing attention during the past decade. In this talk, we focus on an ADMM designed for SDPs in standard form and extend it to efficiently deal with inequalities when solving SDPs in general form. Numerical results on random instances, as well as on instances coming from semidefinite relaxations of the stable set problem and the graph coloring problem are presented, showing the comparison with the state-of-the-art solver SDPNAL+.

BiqBin: an exact penalty solver for linearly constrained BQPs

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Angelika Wiegele

Binary quadratic problems (BQP) are very general and have several applications in different fields. We present a novel solver for this class of problems: BiqBin. It combines the algorithm EXPEDIS, an exact penalty method over discrete sets which transforms a linearly constrained BQP into a max-cut instance, and a semidefinite-based branch-and-bound solver, for obtaining the maximum cut of the resulting instance. We present the algorithm EXPEDIS, which penalizes the equality constraints and makes use of a penalty parameter obtained by solving some semidefinite program. This method also provides a threshold parameter, from which it is possible to determine whether the original problem is feasible. The resulting max-cut instance is solved with a branch-and bound algorithm. We obtain bounds by solving semidefinite relaxations, like in the current best max-cut solvers BiqMac and BiqCrunch. The improvement in our bounding routine is the addition of high-order clique inequalities with large violation to the relaxed problem. We develop a method for separating strongly violated pentagonal and heptagonal inequalities in a short amount of time. In conclusion we compare the performance of BiqBin with some of the current best solvers available, e.g., BiqCrunch, Gurobi, and CPLEX, showing the efficiency of our method.

Utilizing SDP to Tackle a Conjecture from Graph Theory

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In 1968 Vizing conjectured that the product of domination number of two graphs is always smaller or equal to the domination number of the product graph. Today, we still don't know whether this conjecture is true or not. In this talk we will investigate a new way of tackling Vizing's conjecture and discuss recent results. This approach starts by building an algebraic model of the conjecture with some parameters. Then it translates Vizing's conjecture for these parameters into the question of whether a specific polynomial is nonnegative over a specific ideal. Then the approach does another reformulation to the question of whether a specific polynomial is a sum-of-squares polynomial on a certain level of the sum-of-squares-hierarchy. Finally it uses semidefinite programming (SDP) to answer these kind of questions. We will give insight in the recent methods that have been used for developing new sum-of-squares certificates for particular parameters.

Solving a class of bilevel programs with quadratic lower level

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We focus on a particular class of bilevel programs (BPs), having no argmin operator, as in the usual formulation of BPs, but an inequality constraint linking upper and lower-level problems. BPs of this kind can be seen as reformulations of semi-infinite programming (SIP) problems, i.e. optimization problems with a finite number of variables, and an infinite number of parametrized constraints. The lower level has a possibly non-convex quadratic objective function, and a feasible set being a polytope not depending on the upper-level variables. In the formalism of Robust Optimization, we deal with quadratically perturbed constraints under a polytopic uncertainty set. The main principles to tackle nonlinear perturbation are briefly outlined in Section 1.4 of [1], but, to the best of our knowledge, the case of quadratic perturbations with a polytopic uncertainty set has not been addressed yet. In our work, we propose a new approach to solve this class of BPs based on the dualization of the quadratic lower-level problem, using Semidefinite Programming (SDP). It leads to a single-level formulation with a finite number of constraints, which can either be a convex or a SDP problem, depending on the parametrization of the lower level with respect to the upper-level variables. This approach is compared with a tailored cutting plane algorithm, which is proved to be convergent. A rate of convergence is given when the upper-level objective function is strongly convex, under a strict feasibility assumption. Such convergence rate is directly related to the iteration index, which is something new w.r.t. what is usually proved in SIP literature (see Theorem 4.3 in [2]). We test the proposed methods on two applications: the constrained quadratic regression and a zero-sum game with cubic payoff.

[1] A. Ben-Tal, L. El Ghaoui, and A. Nemirovski, "Robust optimization", Princeton University Press, 2009.

[2] R. Reemtsen, and S. Görner, "Semi-Infinite Programming", Springer US, Boston, 25, 1998.

Invited Session: Advances in Optimization under Uncertainty D5

Henri Lefebvre, A finite eps-convergence algorithm for 0-1 mixed-integer convex two-stage robust optimization with objective uncertainty

Lohic Fotio Tiotsop, Stochastic Programs embedding Discrete Choice Problems with unknown distributions and their Deterministic Approximation

Daniel Faccini, Robust and Distributionally Robust Optimization Models for Support Vector

Francesca Maggioni, Bounds for Multistage Mixed-Integer Distributionally Robust Optimization

A finite eps-convergence algorithm for 0-1 mixed-integer convex two-stage robust optimization with objective uncertainty

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In this work, we study optimization problems where some coefficients in the objective function are not known at decision time and the decision flow is modeled as a two-stage process. We show that two-stage robust models of this type can be solved by means of a branch-and-price algorithm, in which continuous variables may be selected for branching so as to tighten the optimality gap. The convergence of the method is proven to eps-optimality. The proposed approach generalizes a recent result from the literature that could be applied only in the linear case and in presence of linking constraints involving binary variables only. Indeed, our extension allows to address the much wider class of problems with convex constraints and general mixed-integer linking constraints. From a computational viewpoint, we also propose a generalized diving heuristic that is typically able to compute high quality solutions throughout the execution of the branch-and-price algorithm. We tested our method to two optimization problems: a capital budgeting problem with profit uncertainty, and a variant of the capacitated facility location problem with unknown travel costs and arc-setup costs.

Stochastic Programs embedding Discrete Choice Problems with unknown distributions and their Deterministic Approximation

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Despite their large application, Stochastic Programming (SP) models suffer from two severe drawbacks: the high computational burden of solving their deterministic equivalent versions and the need for precise knowledge about the probability distribution of the uncertain data. The former drawback is the great increase in the number of variables and constraints from the approximation of the probability space through a discrete set of scenarios. Obtaining such an approximation implies the latter drawback. In this work, we address both the drawbacks by properly exploiting the structure of a specific class of SP problems called two-stage SP models embedding Discrete Choice Problems (2sSP-DCPs), which appear in a wide range of situations. In 2sSP-DCPs, the second stage consists of a set of DCPs, each associated with one first-stage variable. Given the first-stage decisions, the decision-maker must select a single alternative among many subdivided into clusters and associated with stochastic utilities at the second stage. The objective is to maximize the expected total utility. Relying on the Extreme Value Theory [1], we derive a deterministic approximation of 2sSP-DCPs under very mild assumptions on the distribution of the uncertain data, assumed to be unknown. The efficiency of the framework, called EVTDA, does not depend on the number of considered scenarios. Instead, the whole uncertainty structure is modeled by only two numerical parameters that must be calibrated. The mild assumptions on the uncertain data and its gain in efficiency make the EVTDA an interesting asset in addressing large 2sSP-DCPs for which it is not trivial to get a probability distribution that effectively captures all aspects of the problem's uncertainty. Some results obtained on routing and knapsack problems [2,3] show that, when compared to SP solutions, the proposed EVTDA can generate high-quality solutions while saving about two orders of CPU time.

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[2] Fadda, E., Fotio Tiotsop, L., Manerba, D., Tadei, R.: The stochastic multipath traveling salesman problem with dependent random travel costs. Transportation Science, 54(5), 1372-1387, 2020.

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Robust and Distributionally Robust Optimization Models for Support Vector Machine

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In this talk, we present novel data-driven optimization models for Support Vector Machine (SVM), with the aim of linearly separating two sets of points that have non-disjoint convex closures. Traditional classification algorithms assume that the training data points are always known exactly. However, real-life data are often subject to noise. To handle such uncertainty, we formulate robust models with uncertainty sets in the form of hyperrectangles or hyperellipsoids, and propose distributionally robust optimization models enforcing limits on first-order deviations along principal directions. All the formulations reduce to convex programs. The efficiency of the new classifiers is evaluated on real-world databases. Experiments show that box robust classifiers might be overly conservative, whereas higher levels of accuracy can be achieved when moments of the distributions are assumed exploiting the available information via distributionally robust optimization methods.

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Bounds for Multistage Mixed-Integer Distributionally Robust Optimization

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Multistage mixed-integer distributionally robust optimization (DRO) forms a class of extremely challenging problems since their size grows exponentially with the number of stages. One way to model the uncertainty in a multistage setting is by creating sets of conditional distributions (the so-called conditional ambiguity sets) on a finite scenario tree and requiring that such distributions remain close to nominal conditional distributions according to some distance (e.g., phi-divergences or Wasserstein distance). In this paper, new lower bounding criteria for this class of difficult decision problems are provided through scenario grouping using the conditional ambiguity sets associated with various commonly used phi-divergences and the Wasserstein distance. Our approach does not require any special problem structure such as convexity and linearity. Therefore, while we focus on multistage mixed-integer DRO, our bounds can be applied to a wide range of DRO problems including two-stage and multistage, with or without integer variables, nested or non-nested formulations. Extensive numerical results on a mixed integer multistage production problem show the efficiency of the proposed approach over different choices of partition strategies, phi-divergences, and levels of robustness.

Invited Session: Stochastic Programming in Energy and Logistics D6

Paolo Paronuzzi, Chance Constrained Problems with Integer Scenario Variables

Paolo Brandimarte, Approximate dynamic programming for stochastic lot sizing problems

Luigi Di Puglia Pugliese, Crowd-shipping with uncertain travel time

Patrizia Beraldi, A Bi-level Stochastic Model for the Electricity Pricing Problem

Chance Constrained Problems with Integer Scenario Variables

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Chance-Constrained Mathematical Programs (CCP) are a class of stochastic optimization problems in which the feasible region depends on the realization of a random variable and the solution must optimize a given objective function while belonging to the feasible region with high probability. Under specific assumptions, these problems can be modeled as MINLPs. We propose a decomposition approach for the MINLP reformulation of CCP whereby we define a single master problem and one sub-problem for each possible realization of the random variable. We devise a Branch-and-Cut algorithm where we generate cutting planes as outer approximation point cuts, when possible. This approach generalizes the one proposed by Lodi et al. [1] that only applies to the case in which the scenario variables are continuous. Given an infeasible solution of the master problem, we distinguish between three different cases: a first case in which the method in [1] can be applied to generate a valid cutting plane, after the integrality constraint on the scenario variables has been relaxed; a second case that we address by mean of a novel procedure that returns a valid cut, when it exists; and a last case in which some kind of spatial branching is required in order to discard the infeasible solution proposed by the master problem. We discuss the theoretical convergence of the algorithm and present extensive computational experiments on a class of resource allocation problems.

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Approximate dynamic programming for stochastic lot-sizing problems

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Stochastic lot-sizing problems are a relevant application domain for optimization. Even in the single item case, demand uncertainty destroys the Wagner–Whitin property that makes the deterministic problem easy to solve. In a simple and uncapacitated setting, base-stock policies could do the job, but a more general approach, based on stochastic programming, may be needed when we have to deal with capacity constraints and specific demand patterns. Indeed, there is a fair amount of research based on stochastic programming models, for both small [1] and large [2] time buckets, which is the kind of problem we consider here. On the one hand, quite sophisticated solution methods have been proposed [4]; on the other one, different forms of decomposition have been applied. Fix-and-relax is a kind of time-based decomposition, used in [1,2]. An alternative and well-known decomposition is based on Lagrangean relaxation. In [6], progressive hedging is applied to a single-item stochastic lot-sizing problem. This is based on the dualization of non-anticipativity constraints. In a deterministic setting, the dualization of capacity constraints is also used when dealing with multi-item lot-sizing problems [4], as this results in a set of uncapacitated problems. In this paper, we consider the dualization of capacity constraints in a stochastic setting, and its interaction with approximate dynamic programming [3], which is another kind of time-based decomposition. The main aim is to allow for an adequate representation of uncertainty, which is quite critical as scenario trees grow exponentially. Out-of-sample tests, based on computationally intensive rolling horizon simulations, are an integral part of our research.

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Crowd-shipping with uncertain travel time

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We consider the problem of delivering parcels from a central depot to customers dislocated in an urban area. Time window is associated with each customer. We study the case in which ordinary people, named occasional drivers (ODs), may perform some deliveries by deviating from their routes for a small compensation. The considered shipping framework has been widely studied in the scientific literature [1, 2, 3]. The novelty of this work is that the travel time is represented by a random variable. We admit that both the vehicles and the ODs can miss the deliveries, paying a penalty cost. In other words, we consider soft time windows and formulate the problem with chance-constraints, imposing a maximum probability of arriving at each customer after the ending of the time window. In the case an OD misses a delivery, we consider two policies: 1) the parcel must be relocated at the central depot for future shipment; 2) the parcel is retained by the OD. In both cases, the compensation for the OD is reduced. We formulate an equivalent robust formulation by considering the budgeted uncertainty polytope [4, 5] that can be defined so that the robust solution guarantees the satisfaction of the probability constraints. We define optimal solution strategies, which rely on decomposition approaches. We propose two Benders decomposition-based solution strategies, with optimality and logic cuts, and a column-and-row generation procedure. In a computational study, carried out on benchmarks instance, we analyse the effect of the probability guarantee on the solution cost, by considering several penalty cost functions for the missed deliveries. In addition, we carried out a sampling analysis in order to compare the robust solutions with the nominal ones.

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A Bi-level Stochastic Model for the Electricity Pricing Problem

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This talk addresses the bi-level electricity pricing problem under uncertainty. We model the interaction between a retailer and a prosumer by a Stackelberg game and formulate it as a mathematical bi-level program. The retailer acts as leader and sets the electricity rates with the aim of maximizing the profit. The prosumer plays the role of follower and reacts to the retailer decision, managing the home energy system (composed of photovoltaic panels and an electricity storage device) so to minimize the electricity bill. The decision process is clearly carried out under uncertainty mainly related to the market prices and to the production from PV, that is affected by the weather conditions. We formulate the problem as a stochastic bi-level two-stage problem. A safety risk measure is introduced to take into account the risk aversion of the retailer. A tailored solution approach exploiting the specific problem structure has been designed and tested. The computational experiments carried out on real cases confirm the validity of the model as well as the solution approach.

Invited Session: In memory of Bruno Simeone D7

Paolo Serafini, Majority Judgment with partial information

Friedrich Pukelsheim, The tandem system: A new electoral frame for the European Parliament

Emilio Spedicato, ABS Methods, The first twenty years, Historical development and comments

Justo Puerto, Dynamically Second-Preferred p-Center Problem

Majority Judgment with partial information

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In this talk we deal with the problem of selecting a small number of delegates out of a large list of candidates by using Majority Judgment (MJ). Each voter has some information on a few candidates only and so each candidate is scrutinized by a small variable number of voters. In order to use MJ, all candidates should receive the same number of grades. Hence, we need to add a certain number of grades to each candidate. We present some axioms that should be respected for this addition to be considered fair. We introduce some possible addition methods and analyze them in terms of the axioms. It turns out that one of the proposed methods is perhaps best fit to deal with MJ with partial information.

The tandem system: A new electoral frame for the European Parliament

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The new tandem system provides a principled frame for the election of the European Parliament. It pays due tribute to the European level of the election rather than construing the event as a patchwork of separate elections per Member State. It equips europarties with power, visibility and influence to campaigning at the election rather than centring on domestic parties within Member States. It exposes the leaders of europarties as prime personnel for offices to be staffed in the new legislative period. From a structural viewpoint the tandem system proceeds in three steps. The first step apportions all parliamentary seats among europarties by aggregating the electorate's votes at Union level. Thus, with regard to the division of the Union's citizens by political persuasion, the tandem system obeys the One Person One Vote principle. The second step, disaggregation of the unionwide apportionment, allots the seats by Member State and europarty in a way safeguarding the preordained seat contingents of the Member States. Thus, with regard to the Union's socio-cultural layout by Member State, the tandem system respects the principle of degressive representation that is peculiar to the European Union. The third step assigns the seats of a party in a Member State to domestic candidates by means of the same provisions which the Member State has been employing in the past, thereby complying with the Union's principle of subsidiarity.

ABS Methods, The first twenty years, Historical development and comments

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ABS methods originated about 1980 from joint collaboration between three mathematicians: Spedicato, Abaffy (Hungary), Broyden (UK), as a class of methods for solving in finite number of iterations determined, underdetermined or overdetermined linear systems. The work later involved several other mathematicians, especially from China and Iran, and is available in some 400 papers and a few monographs, also in Russian and Chinese language. ABS methods have been extended to other problems (nonlinear systems, optimization problems, structured linear system...), providing a unified framework, where special methods are obtained via selection of the available parameters in the class. A remarkable result is the ABS approach to Diophantine linear equations, say the most important case of Hilbert tenth problem, where the ABS approach provides a new simple condition for existence of integer solutions and the computation in polynomial time of all such solutions; an approach later applied especially by the Iranian researchers, still now active, to several other problems, characterized by deriving integer solutions via the continuum approach. Work on ABS methods has comprised not only derivation and theoretical analysis (convergence, stability, error sensitivit...) of the algorithms, but has led also to a package, ABSPACK, for several problems. ABS codes have been also used successfully in real engineering problems, showing better stability and accuracy than well known commercial codes. The communication will consider results obtained mainly in the about twenty years that Spedicato devoted to such research areas, his interests later moving to other disciplines. ABS methods are now studied especially in Iran in the school of Nezam Mahdavi-Amiri. In Italy, main interest to ABS methods was shown by Ilio Galligani and Bruno Simeone.

Dynamically Second-Preferred p-CenterProblem

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The p-next center problem was introduced in [1]. The experimental results reported in that paper show that exact methods are limited and therefore some papers have proposed heuristics for the p-next center. In this model it is assumed that centers can fail, and thus, customers make their decision taking into account not only their most favorite centers but also a close second opportunity. These results have been applied to a well-known problem in software defined networks: the Controller Placement Problem. This problem consists in determining on a network the optimal location of controllers and assignment of the switches to the controllers. This talk elaborates upon the p-next center model. Here, we extend that model to deal with the Dynamically Second-preferred p-center Problem (DSpP). This problem aims at choosing at most p centers so that each demand point can visit at least two acceptable centers and the maximum sum of distances from any demand point to any of its preferred centers, plus the distance from any of the preferred centers to any of the centers the user prefers once he is there, is minimized. We present three different mixed-integer linear programming formulations for the problem. We study some strengthening using valid inequalities and some variable fixing criteria that can be applied when valid upper bounds are available. Finally, computational experience has been performed to compare their utility to solve DSpP using standard solvers for MIP.

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Invited Session: Health Care A8

Massimo Roma, A simulation-based optimization approach for the calibration of a discrete event simulation model of an Emergency Department

Andrea Mancuso, ILP formulation for surgery department management: a case study in a hospital in Naples

Roberto Aringhieri, Novel applications of the team orienteering problem in health care logistics

Marco Roma, A decomposition approach to the Clinical Pathway Deployment for chronic outpatients with comorbidity

A simulation-based optimization approach for the calibration of a discrete event simulation model of an Emergency Department

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The most widely used tool for studying patient flow through an Emergency Department (ED) is Discrete Event Simulation (DES). However, to achieve high reliability of such a DES model, an accurate calibration procedure is firstly required in order to determine a good estimate of the model input parameters. In this paper, a simulation-based optimization approach is used to estimate the incomplete data in the patient flow within an ED by adopting a model calibration procedure. The objective function of the resulting minimization problem represents the deviation between simulation output and real data, while the constraints ensure that the response of the simulation is sufficiently accurate according to the precision required. The approach we propose has been widely experimented on data from a real case study related to a large ED in Rome. The experimental results show that the model calibration allows recovering the missing parameters, thus leading to an accurate DES model.

ILP formulation for surgery department management: a case study in a hospital in Naples

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Healthcare management is a widely investigated research topic in OR literature. Among the others, great relevance has been given to the problem of optimizing the activities of the hospital surgery departments to ensure an effective and efficient usage of the operating rooms. This work arises from the research agreement between Department of Electrical Engineering and Information Technology of University "Federico II" of Naples and the "Betania Evangelical Hospital (BEH)", a small hospital in Naples. It is focused on the application of OR methodologies to support the BEH surgery department operating rooms. Given the BEH surgery department comprising several specialities which share a given number of operating rooms, we tackle the problem of determining the assignment of rooms and dates to a set of elective patient surgeries over a predefined planning horizon and, simultaneously, defining the scheduling of the surgeries of each day and room. The problem has been modelled by an ILP formulation, derived from Riise and Burke (2011), modified with several constraints which take into account multiple requirements such as: emergency management, surgery complexity and postponements, and patient's health conditions. The proposed formulation has been tested on several scenarios derived from real data provided by the hospital. Moreover, different speciality-to-room assignment policies have been analysed to provide useful managerial insights for effective usage of the hospital resources.

Novel applications of the team orienteering problem in health care logistics

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The team orienteering problem is a routing problem belonging to the class of the vehicle routing problems with profits. We present two problems arising in the health care logistics that are modelled as team orienteering problem. To the best of our knowledge, these are the first applications to health care logistics problems. The former is a problem arising in the digital contact tracing system as a measure for the containment of the Covid-19 pandemic. The latter is a problem arising in post-disaster management to transport the injured to hospitals. We discuss the novelty of some of their features with respect to the current literature. We present and discuss the mathematical formulation of a new variant of the team orienteering problem that includes such new features.

A decomposition approach to the Clinical Pathway Deployment for chronic outpatients with comorbidity

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Most chronic patients with comorbidities are cared for at home. Still, they must get treatments, consultancy, and tests at specialized medical units in a hospital setting, according to a given frequency set by their clinical pathways. As such demand is known in advance, it could be scheduled to ensure ideal frequency, avoid potential visit repetitions that arise in case of comorbidities, and minimize hospital access by pursuing decision coordination. Booking involves setting a date for each health service contained in the pathway, and fixing a time on that day, i.e. building a master plan that spans the planning horizon, and a specific daily agenda for each day. The master plan handles time constraints on the dates, while each daily agenda must comply with the staffing level at each care unit for that day and allow transfer time for patients receiving care at different units. Tackling the master plan together with the daily agendas is rather complex. We present a logic-based Benders decomposition approach where the Master Problem solves the master plan with respect to a relaxation of the units resource constraints, and the subproblems return *no-good* cuts to the master when their daily agenda problem is not feasible. We present an Answer Set Programming based approach for the Master Problem, as part of a broader project aimed to tackle the whole problem for the first time.

Session: Data Science I A9

Benedetto Manca, Binary Classification via Ellipsoidal Separation

Doncho Donchev, Risk Assessment in Transactions under Threat as POMDP

Enrico Gorgone, Sparse Optimization in Adversarial Support Vector Machine (SVM)

Antonio Fuduli, Spherical approaches for Multiple Instance Learning

Binary Classification via Ellipsoidal Separation

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Separating two finite set of points in an Euclidean space is a fundamental problem in classification. Customarily linear separation is used, but nonlinear separators such as spheres [1] have been shown to be possible and to have superior performances in some tasks, such as edge detection in images. We exploit the relationships between the more general version of the latter separation, where we use general ellipsoids rather than spheres, with the SVM model with quadratic kernel to propose a classification approach. The implementation basically boils down to adding a SDP constraint to the standard SVM model in order to ensure that the chosen hyperplane in the feature space represents a non-degenerate ellipsoid in the input space; this may result in efficiency problems but still allows to exploit many of the techniques developed for SVR in combination with SDP approaches. We test our approach on several classification tasks, among which the edge detection problem for gray-scale images, proving that the approach is competitive with both the spherical classification one and the quadratic-kernel SVM one without the ellipsoidal restriction.

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Risk Assessment in Transactions under Threat as POMDP

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This paper presents a theoretical model and algorithms for calculating the security risks for planning active counteractions in transaction processing under security threats. It is a part of an integrated cybersecurity framework, which combines AI-based planning of active counteractions with Machine Learning for the detection of security threats during transaction processing. The risk assessment is based on the optimal strategy for decision making which minimizes the security risks in controlled transactions modeled as Partially Observable Markov Decision Process (POMDP). By statistical reduction, this model is converted into a Markov Decision Process (MDP) with full information so that the algorithm for calculating the risks can use the standard dynamic programming. Although developed primarily for applications in fintech industry, this framework can be adapted to a wide range of business process workflows that incorporate both synchronous operations and asynchronous events caused by human errors, technical faults, or external interventions.

Sparse Optimization in Adversarial Support Vector Machine (SVM)

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Supervised classification models, such as SVM, aim at predicting the class membership of the incoming samples. Malicious inputs are designed to cheat a vulnerable classifier, leading to a wrong prediction. We focus our analysis on the search of the smallest perturbations of samples producing a failure of the classification process. The novelty of our approach is in the use of the zero-pseudo-norm, which consists in minimizing the number of attributes to be modified. We come out with an optimization problem whose objective function is a Difference of Convex functions (DC). We present the results of some preliminary experiments.

Spherical approaches for Multiple Instance Learning

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In a Multiple Instance Learning (MIL) problem the objective is to classify sets of items. Using the MIL terminology, such sets are called bags and the items inside them are called instances. Differently from the classical supervised learning, in a MIL problem only the label of each bag is known in the learning phase, whereas the labels of the instances inside the bags remain unknown. For solving these problems, in the literature there are three type of approaches: the instance-space approaches, the bag-space approaches and the embedding-space approaches, depending on the space where the bag separation is initially performed. We focus on the binary case, characterized by two types of bags and two types of instances, using the so-called standard MIL assumption, stating that a bag is positive if it contains at least a positive instance and it is negative otherwise. For solving this problem, we present a multi-sphere instance-space approach, which generates a finite and variable number of separating spheres such that, for each positive bag, at least one of its instances is inside at least a sphere and all the instances of each negative bag are outside every sphere. Numerical results are presented on some test problem drawn from the literature.

Session: Data Science II A10

Alessio Sortino, An Effective Procedure for Feature Subset Selection in Logistic Regression Based on Information Criteria

Antonio Consolo, Decomposition method for building randomized regression trees

Stefania Gubbiotti, Optimal sample size for evidence and consensus in phase III clinical trials

An Effective Procedure for Feature Subset Selection in Logistic Regression Based on Information Criteria

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In this work, the problem of best subset selection in logistic regression is addressed. In particular, we take into account formulations of the problem resulting from the adoption of information criteria, such as AIC or BIC, as goodness-of-fit measures. There exist various methods to tackle this problem. Heuristic methods are computationally cheap, but are usually only able to find low quality solutions. Methods based on local optimization suffer from similar limitations as heuristic ones. On the other hand, methods based on mixed integer reformulations of the problem are much more effective, at the cost of higher computational requirements, that become unsustainable when the problem size grows. We thus propose a new approach, which combines mixed-integer programming and decomposition techniques in order to overcome the aforementioned scalability issues. We provide a theoretical characterization of the proposed algorithm properties. The results of a vast numerical experiment, performed on widely available datasets, show that the proposed method achieves the goal of outperforming state-of-the-art techniques.

Decomposition method for building randomized regression trees

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Decision trees are off-the-shelf Machine Learning models which are used in a variety of fields of application for classification and regression tasks. Given the substantial progress in mixed-integer linear programming (MILP) and nonlinear programming, optimal decision trees have recently attracted renewed attention. In [1,2] a MILP formulation with a local search approach are proposed for constructing optimal multivariate deterministic regression trees. In [3,4] a novel continuous nonlinear optimization approach has been proposed to build multivariate randomized regression trees. For any given input vector, the prediction is a weighted combination of the leaf nodes outputs, where the weight is the probability that the vector falls in the corresponding leaf node. In this work, we investigate a variant of this model where, for every input vector and for every leaf node, the prediction is expressed as a linear regression of the input variables. The peculiarity is that we have a distinct prediction for each leaf node. We present a decomposition method together with an initialization strategy and a heuristic for the assignment of the input vectors along the branching nodes of the regression tree. The results on 10 datasets from the UCI and KEEL repositories indicate that our decomposition method together with the initialization strategy and the assignment heuristic provide promising results in terms of accuracy compared with the original approach [3]. The combination of the decomposition scheme with the assignment heuristic often allows to avoid getting stuck in poor solutions and the initialization strategy is substantially more robust with respect to random starting solutions. The comparison with the approach in [1,2] on the same datasets suggests that our model variant and decomposition method yield significant speed up in the training time while achieving comparable accuracy.

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Optimal sample size for evidence and consensus in phase III clinical trials

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Design and analysis of clinical trials imply decisions that often involve multiple parties. We focus here on one of the main design issues in phase III trials, that is the choice of the sample size, that influences the final probability of success of the experiment, i.e. showing evidence of superiority of a new treatment over the standard one. Bayesian Statistics allows one to exploit pre-experimental information and uncertainty that can be translated into probability distributions for the effects-difference parameter. Sometimes sources of prior knowledge can be in striking contrast (skepticism vs optimism), possibly leading to divergent final post-experimental conclusions. We propose a sample size criterion that controls not only the achievement of minimal evidence of superiority but also posterior consensus. The method is illustrated for trials involving binary outcomes with normal approximation for the log odds ratio with application to a comparative study of two interventions for diabetic patients with coronary artery disease.

Session: Vehicle Routing I B8

Massimo Paolucci, Comparing matheuristic approaches for the Electric Vehicle Routing Problem with Time Windows

Giusy Macrina, Electric Vehicle Routing Problem with time-dependent electricity charging costs

Maurizio Bruglieri, A GRASP with penalty objective function for the Green Vehicle Routing Problem with Capacitated Fuel Stations

Daniela Ambrosino, A rich vehicle routing problem in a city logistics concept

Comparing matheuristic approaches for the Electric Vehicle Routing Problem with Time Windows

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This work addresses the Electric Vehicle Routing Problem with Time Windows (E-VRPTW), which has been extensively studied in the recent years due to an increased attention to sustainability in transportation. E-VRPTW differs from the classical VRPTW because the service is provided by a fleet of Electric Vehicles (EVs). Since EVs have a reduced driving range due to the limited battery capacity with respect to their Energy Consumption (EC), possible stops at Recharging Stations (RSs) have to be considered. Among the different EC models introduced in the literature, we refer to that in [1], in which EC is a function of both the EV load and speed, so resulting more realistic. A further relevant feature for the proposed model is considering the EVs' speeds as decision variables. We present a cloneless Mixed Integer Linear Programming (MILP) model for this variant, without cloning the RSs, as done in most of the works in the literature, to avoid increasing the number of binary variables. Moreover, we design two different matheuristics both iterating the solution of reduced versions of the MILP model. In the first approach, subsets of the routing-variables are included exploiting a greedy randomized selection, whereas, in the second one a procedure called Randomized Kernel Search, inspired by the Kernel Search algorithm [2], is iterated. Finally, we compare the MILP model and matheuristics results on instances generated from a benchmark [3].

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The Electric Vehicle Routing Problem with time-dependent electricity charging costs

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The use of electric vehicles has rapidly increased in recent years and the practical adoption of electric fleets is expected to accelerate as many countries are committing to ambitious net-zero emissions targets in the next ten years. At the same time, the electricity grid load is experiencing higher volatility from renewable sources on the supply side as well as electric vehicle charging on the demand side and new variable pricing schemes are emerging to help balance the load. Hence, managing electric fleets sustainably and efficiently is a major challenge and it requires taking into account these new forms of electricity pricing. In this work, we study a variant of the vehicle routing problem (VRP) where a fleet of electric vehicles (EVs) is used instead of internal combustion engine vehicles, to serve a set of customers in an urban area. Partial battery recharges are allowed at charging stations, located throughout the city. Each charging station is characterized by a certain number of available chargers, a charging speed and several electricity prices which depend on the time of arrival at the charging station. In particular, we consider a schedule of electricity rates that are given at the beginning of the day, different for each hour. Hence, charging prices/costs are different and time-depending. We introduce and model the electric vehicle routing problem with time-dependent electricity charging costs. Then, we carry out a computational study to investigate the impact of time-dependent electricity charging costs on the solution quality.

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A GRASP with penalty objective function for the Green Vehicle Routing Problem with Capacitated Fuel Stations

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Recent concerns about the environment and climate change are prompting transportation companies to use Alternative Fuel Vehicles (AFVs) instead of traditional internal combustion engine vehicles. However, the AFVs have a limited driving range and since the Alternative Fuel Stations (AFSs) are usually not widespread on the territory, the routes of the AFVs have to be properly planned in order to prevent them from remaining without the sufficient fuel to reach the depot or the closest AFS. Given a fleet of AFVs, the Green Vehicle Routing Problem (G-VRP), introduced in [2], aims at routing them minimizing the total travel distance and possibly including stops at AFSs. Each AFV starts from a common depot and returns to it within a maximum duration, serving a subset of customers geographically distributed. Unlike the G-VRP, the G-VRP with Capacitated AFSs (G-VRP-CAFS), introduced in [1], more realistically assumes that each AFS has a limited number of fueling pumps and then prevents overlapping in refueling operations. In this work, we propose a Greedy Randomized Adaptive Search Procedure, properly guided by some theoretical results, to efficiently address also large-sized instances of the G-VRP-CAFS. Computational results, carried out on both benchmark instances and new instances with up to 100 customers, show the effectiveness and the efficiency of the proposed solution method.

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A rich vehicle routing problem in a city logistics concept

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In this paper we face a rich VRP (Drexl, M.,2012) for solving city logistic problems. Distribution activities in urban areas represent about 40In this work we are involved with a distribution company having the goal of optimizing the number of vehicles used to serve customers while at the same balancing their load. In particular, the problem under investigation can be defined as a multi-period VRP with a heterogeneous fleet of vehicles and time windows for serving customers. The fleet composition has to be daily defined searching for the best mix of subcontracting vehicles to add to the owned fleet. The number and type of vehicles to be used each day must be defined, together with the routes of the selected vehicles. Note that, together with the routing cost minimization, there is the need of balancing the number of routes to travel each day for serving customers. In fact, in order to get the most favorable contract from the transportation firms, the company has to balance the request for external trucks during the days of the week. This problem is faced by allowing split delivery within the considered weekly time horizon. The demand of each customer is partitioned into three different subsets, according to their priority, i.e., goods that must be shipped exactly the day they are required, goods that can be delayed one day and finally goods that can be delayed up to two days. We present a MILP model for the problem together with some pre-processing procedures able to reduce the size of the considered real instances of the problems. The first results of our computational experimentation are reported.

Session: Vehicle Routing II B9

Roberto Montemanni, Heuristics for the Flying Sidekick Traveling Salesman Problem

Massimo Di Francesco, A heuristic algorithm for a multicommodity location-routing problem

Ornella Pisacane, The VRP with Mixed Fleet of Electric and Traditional Vehicles and Congestion Charge

Fausto Errico, Off-line approximate dynamic programming for the vehicle routing problem with stochastic customers and demands

Heuristics for the Flying Sidekick Traveling Salesman Problem

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The use of drones in urban logistics is gaining more and more interest. In this paper we consider the flying sidekick traveling salesman problem, where some customers require a delivery and they can be served either by a truck or by a drone. The aim is minimizing the total time required to service all the customers. In this talk we discuss some algorithms based on branch and bound for the problem. A first contribution is an exact algorithm characterized by not completely specified solutions in the search tree, that are later fully determined by solving an Assignment Problem. Such a choice limits the size of the search tree, but on the other hand tends to weaken lower bounds. Experimental results show that the choice pays off for instances of limited size, leading to very good and consistent results in terms of speed for instances up to 10-15 customers. The same branch and bound algorithm is also effectively used as a subroutine for a heuristic algorithm, which is the second contribution of this work. The idea is to iteratively optimize overlapping chunks of a solution with the exact algorithms. Again, experimental results prove that such a heuristic approach is extremely competitive on large instances, being able to effectively deal with instances with up to 229 customers in a relatively short time.

A heuristic algorithm for a multicommodity location-routing problem

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We investigate a location-routing problem motivated by freight distribution from a port. A fleet of containers must moved from the port to satellites, where pallets are unpacked from containers, transhipped to different vehicles and moved to their final destinations. We must select satellites and vehicles, assign containers to satellites, determine the routes of the selected vehicles and the flows of pallets. Since the transportation service is highly customized, this problem is modeled as a multi-commodity location-routing problem, in which each destination of pallets is a commodity. We propose an iterative solution method in which the overall problem can be divided at each step into two subproblems: (i) the first we determine satellites, assign containers to satellites, select and assign CCVS and PCVs to satellites; (ii) in the second we solve a network design problem with routing constraints to determine the paths of vehicles and pallets from satellites to customers. Finally, we check the viability of the method in computational experiments.

The VRP with Mixed Fleet of Electric and Traditional Vehicles and Congestion Charge Zones

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According to the European Environment Agency, the transport sector consumes about one third of the total energy in Europe. Indeed, this sector is responsible for a great part of the greenhouse gas emissions, significantly contributing to climatic changes. In fact, European policies are incentivizing the transport companies to integrate their fleet, mainly consisting of Internal Combustion Engine Vehicles (ICEVs), with Electric Vehicles (EVs). In addition to several benefits over the ICEVs, EVs have free access to Congestion Charge (CC) zones, for which the ICEVs pay a toll. However, their acquisition cost is still high compared to that of ICEVs. So, a company may benefit from using a mixed fleet. We introduce a new Vehicle Routing Problem to determine both the fleet composition and route plans at minimum total operational cost. The EVs can recharge (also partially) at the stations en-route but with a higher energy price than that at the depot. The vehicles serve the customers respecting their time windows and return to the depot within a maximum duration. The problem is formulated as a Mixed Integer Linear Program and solved by an Adaptive Large Neighborhood Search method. Numerical tests were performed on realistic instances based on Milan road network to investigate the impact of CC on the routing decisions and to provide managerial insights.

Off-line approximate dynamic programming for the vehicle routing problem with stochastic customers and demands

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In this talk we focus on a version of the vehicle routing problem where customers' presence and demand are stochastic. In particular, we assume that a fleet of vehicles must complete the service within a given time limit. The objective is to maximize the serviced demand while fulfilling the capacity limit of the vehicles. We call this problem the vehicle routing problem with stochastic customers and demands (VRPSCD). Differently from most of the literature on stochastic vehicle routing problems, this work proposes a decentralized decision-making framework where vehicles autonomously and dynamically plan their routes, according to the information revealed during operations. We formulate the problem in terms of a Markov Decision Process. In this context, the decentralized framework enables the possibility to suitable aggregate and eliminate symmetries in both state and action spaces, resulting in a remarkably more tractable problem. To solve the VRPSCD, we develop a Q-learning algorithm where value functions are implemented as a deep-neural network. Results demonstrate that our method significantly outperforms two commonly adopted heuristics for VRPSCDs. Moreover, we show that our approach can compete with specialized methods developed for the particular case of the VRPSCD where customers' locations are known in advance (Goodson et al., 2016). Finally, we show that the Q-learning algorithm can be trained on different instance types, thus obtaining policies providing high-quality performances on a large spectrum of problem realizations.

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Session: Logistic III B10

Sara Stoia, A Stochastic and Dynamic Pickup and Delivery Problem with Time-Dependent Travel Times

Olivier Gallay, Truck-and-Drone Parcel Delivery in the Alps

Giacomo Lanza, A fast heuristic approach for the assignment and sequencing storage location problem under a two level storage policy

Veronica Asta,Port Rail Shunting Optimization Problems

A Stochastic and Dynamic Pickup and Delivery Problem with Time-Dependent Travel Times

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Delivery services are prominent within the grocery and restaurant domain (e.g. Grubhub, Chomp, Uber Eats), focusing on the delivery of food within a relatively immediate deadline or within a specified time window later in the day. While the demand pattern and consumer behavior for non-food items differs than that of perishable food items, similar online service platforms (Kanga, Renren, Kuaidi, Deliv) have been developed for electronics, clothing, health and beauty products, and even white goods. A single e-platform serving a wide range of local businesses could provide the volume and smooth the non-stationary demand pattern typical of restaurant delivery. There is an opportunity for local brick-and-mortar companies to utilize such an e-platform to support "shop local" initiatives and avoid a "retail apocalypse." The global COVID-19 pandemic has altered consumer behavior (perhaps permanently) and local brick-and-mortar stores may need to serve as showrooms (for in-person shopping) and/or dark stores (warehouses), with employees serving as salespeople and/or as order-pickers. We assume that a third-party logistics (3PL) company receives the customer requests stochastically throughout the day and dispatches these requests to available vehicles, using a fleet of dedicated vehicles and a fleet of crowdsourced vehicles. In our problem, we consider two aspects of the logistical design of a delivery system: cost and service. As labor costs represent a major component of operating costs, we consider a formulation that prioritizes these. Along the service dimension, we focus on on-time delivery with particular modeling of time-dependent travel times. To represent the stochastic nature of the arrival of customer requests, we model the problem as a Markov decision process (MDP) over finite, discrete-time horizon. Preliminary computational results are presented for some instances from Ulmer et al. [2020] in both in their original form and in modified form to consider requests with a varying (non-food item) demand pattern.

Truck-and-Drone Parcel Delivery in the Alps

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In this paper, we consider a parcel-delivery situation encountered in practice by a logistics provider in France, involving a truck and a drone. Whereas the majority of the deliveries take place in the valley, some parcels have to be delivered to a remote place located in a mountainous area with poor accessibility. These remote deliveries can be performed by a drone launched from the truck located in the valley. We study this parcel-delivery configuration and extend it by allowing the truck to launch and retrieve the drone from multiple positions in the valley. We propose a strengthened Mixed-Integer-Linear Programming model, and we solve it for instances with up to 23 parcels. We compare our results with those of a classical delivery framework involving a truck only and we highlight the practical relevance of using drones in this mountainous context.

A fast heuristic approach for the assignment and sequencing storage location problem under a two level storage policy

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We consider a storage allocation problem which combines storage location assignment with sequencing decisions about the assigned storage locations, and which originates from a real-world application context. We propose a very efficient successive constrained shortest path method, which outperforms a matheuristic approach recently proposed in the literature in terms of both the computational time required and regarding the quality of the solutions found.

Port Rail Shunting Optimization Problems

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The work focuses on the link between rail and sea transportation modes that happens in the maritime port area. The study deals with the management of rail operations, here called rail shunting operations, to be performed in the port area. Two optimization problems arise. The first is the Port Rail Shunting Scheduling Problem (PRSSP) for planning the operations. The second is called Port Rail Shunting Re-Scheduling Problem (PRSRP) and deals with the re-scheduling of the same operations in case of unpredictable events. Given that these problems have been rarely addressed in the literature, the literary review focused only on papers with useful aspects for approaching these problems. After the in-depth study on the concerning papers, we concentrated on an innovative use of the space-time networks as solution approach structure for both the problems. A network flow model based on an operation-time-space network for solving PRSSP has been developed. It has been tested using random generated instances providing good results. The same model has been extended for solving PRSRP and the tests gave good results too. Both the developed models have been applied to the real case of a port area located in Italy. Real data have been used and the tests on the case study provided good results confirming both the possibility to apply the proposed approach in real contexts and the utility of the models as decision support systems for this process.

Invited Session: Machine Learning-based optimization C8

Valerio Agasucci, An Actor-Critic algorithm with GNN to solve the train dispatching problem

Matteo Salani, Dual-Stage Iterative Optimization Integrating Machine-Learning-Assisted QoT Estimation in Elastic Optical Networks Planning

Marta Monaci, An Actor-Critic algorithm with Deep Double Recurrent agents to solve Job Shop Scheduling

Federico D'Onofrio, Feature Selection in the diagnosis of complex diseases: an SVM Mixed Integer approach versus a SHAP driven model

An Actor-Critic algorithm with GNN to solve the train dispatching problem

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In railway systems, delays occur daily, leading to a mismatch between scheduled arrival time and actual arrival time. When the delay of one train is propagated to others, a loss in service quality arises, increasing costs and decreasing the quality of the service. Dispatchers monitor the traffic minute by minute, taking re-scheduling and re-routing decisions in near real-time. This is the train dispatching problem. Many exact algorithms are presented in the literature, but the computational effort often exceeds the time window available to solve them. In this talk, we propose a Deep Reinforcement Learning framework able to solve the problem in a time compatible with the application, while handling railway rules which could otherwise be hard to model. The approach belongs to the family of Actor-Critic methods, characterized by two operators: the Actor, which gives a measurement (in terms of the probability distribution) on how good an action is, and the Critic, which estimates the value associated with each state. For both Actor and Critic, we choose to exploit the graph structure of the railway network by adopting Graph Convolutional Neural Networks as estimate models. Results show that the algorithm performs better than other learning-based approaches, like matrix-based Q-learning and Deep Q-learning.

Dual-Stage Iterative Optimization Integrating Machine-Learning-Assisted QoT Estimation in Elastic Optical Networks Planning

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With the emergence of Elastic Optical Networks (EONs), Machine Learning (ML) is being intensively investigated as a promising methodology to address complex network management tasks, including e.g., fault prediction and management, Quality of Transmission (QoT) estimation, and automatic adjustment of transmission parameters. Though several ML-based solutions to accomplish specific management tasks have been proposed, how to integrate the outcome of such ML models inside Routing and Spectrum Assignment (RSA) models (the fundamental resource allocation problem in EON) is still an open research problem. In this study, we propose an iterative RSA optimization framework that incorporates the QoT estimations provided by a ML regressor (used to define lightpaths' reach constraints) into a Mixed Integer Linear Programming (MILP) formulation. The framework devises a two-stage iterative procedure. The first phase minimizes overall spectrum occupation, whereas the second phase maximizes the minimum guardband size between neighbor channels, without increasing the overall spectrum occupation obtained in the previous phase. Moreover, after the second phase, reach constraints are added for the next round of iteration based on the outcome of the previous optimization round, in order to exclude from the set of feasible solutions those lightpaths that exhibited unacceptable QoT. In our illustrative numerical results carried on realistic EON instances, the proposed framework achieves spectrum occupation savings up to 48.1% (around 33% on average) in comparison to traditional MILP-based RSA frameworks that use conservative reach constraints based on margined analytical models.

An Actor-Critic algorithm with Deep Double Recurrent agents to solve Job Shop Scheduling

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There is a growing interest in integrating Machine Learning techniques and optimization to solve challenging optimization problems. In this work, we propose a Deep Reinforcement Learning methodology for the Job Shop Scheduling Problem (JSSP). The aim is to build up a greedy-like heuristic able to learn on some distribution of JSSP instances, different in the number of jobs and machines. The need for fast scheduling methods is well known, and it arises in many areas, from transportation to healthcare. We exploit the efficacy of Actor-Critic techniques, where the action taken by the agent is influenced by policy considerations on the value function. The procedures are adapted to take into account the challenging nature of JSSP since the state and the action space change not only for every instance but also after each move. For this reason, the agent estimation function is a Deep Neural Network composed of two incident LSTM models. Preliminary tests show that the model reaches good solutions in a short time, finally proving that is possible to generate new greedy heuristics just from learning-based methodologies. Benchmarks have been generated in comparison with commercial solvers. As expected, the model is able to generalize, to some extent, to larger problems or to instances originated by a different distribution of the processing times.

Feature Selection in the diagnosis of complex diseases: an SVM Mixed Integer approach versus a SHAP driven model

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Machine Learning (ML) methods are increasingly and widely used in the medical field to improve the prognosis and diagnosis of diseases and to increase the effectiveness of medical treatments. For predictive models of complex diseases, it is important to have a features ranking or to identify which are the elements that most affect the outcome to have good predictions. Identifying the most relevant features allows making the predictions more explainable and easier to interpret for the end-user and in particular for the doctors that can thus understand the relevant aspects of the disease not yet known. However, most ML models are black box models that lack interpretability. To overcome this limit, SHAP (SHapley Additive exPlanations) is one of the Explainable AI tools that have been recently proposed in the literature (Lundberg & Lee, 2017). This tool is based on the Shapley values that allow making a fair allocation of features importance given a particular model classification. We compare the performance of SHAP tool with other SVM-based models that perform feature selection. Among the several proposed in the literature, Mixed Integer linear SVM models perform linear SVM classification while selecting the most relevant features e.g. through a budget constraint (Labbé et al., 2017, Mangasarian & Wright, 2007). These models are mainly based on the minimization of the L1-norm of the weight vector w. We generalize to the case of the L2-norm and we consider possible extensions to the nonlinear case using kernels. The aim is to compare both the computational complexity of the different models and the robustness in selecting the most relevant clinical features.

Session: Energy C9

Giovanni Micheli, Expansion Co-Planning of Electricity and Gas Systems with High Shares of Renewables and Bi-Directional Energy Conversion under Fuel and Carbon Price Uncertainty

Mauro Escobar, Power network design with line activity

Maria Teresa Vespucci, Optimization models for the operation of active power distribution networks and their participation to the ancillary service market

Martina Fischetti, Mathematical models for wind farm installation

Expansion Co-Planning of Electricity and Gas Systems with High Shares of Renewables and Bi-Directional Energy Conversion under Fuel and Carbon Price Uncertainty

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Natural gas may play a key role in achieving energy sustainability goals, accommodating large shares of intermittent renewable energy sources. First, thanks to the fast-response capability, natural gas-fired power plants can rapidly respond to changes in the demand or supply for electricity, regulating peak loads and providing security in power systems. Second, the emerging Power-to-Gas (PtG) technology allows converting surplus renewable generation into gas fuel, which can be stored in the natural gas network and used later for electricity production. The deployment of gas-fired power plants and PtG plants increases the interconnection between electricity and gas systems and requires an integrated planning framework that could accurately consider this coupling. This contribution provides a comprehensive formulation for the expansion co-planning of integrated energy systems with high penetration of intermittent renewable energy sources and bi-directional energy conversion. Since expansion plans are usually made for a long-term horizon, the system conditions are generally uncertain at the time the expansion plans are decided. In this work, we focus on the uncertainty of fuel and carbon prices and we define expansion decisions using a two-stage stochastic programming model, with the first stage representing the investment problem and the second stage being the operational problem. To keep the problem computationally tractable, we apply a clustering analysis on input data to select a set of representative days and we implement a multi-cut Benders Decomposition algorithm, decomposing the stochastic model both by year and by scenario. We then apply the proposed analysis to the Italian integrated electricity and gas system to evaluate the achievement by 2040 of sustainability goals set by the European Commission. Empirical results show how solar technology could play a key role in the achievement of these policy targets, being the main technology installed by the model.

Power network design with line activity

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We discuss the problem of optimally designing a power transportation network with respect to line activity. We model this problem as an alternating current optimal power flow with on/off variables on lines. We formulate this problem as a nonconvex MINLP in complex numbers, then we propose two convex MINLP relaxations. We test our formulations on some small-scale standard instances.

Optimization models for the operation of active power distribution networks and their participation to the ancillary service market

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Power systems are facing a significant revolution in terms of energy generation and consumption. In particular, the generation centre of mass is gradually moving from transmission to distribution system, while new load typologies are supplied and demand response is attracting investors. For this reason, the management/planning of power distribution networks is becoming more complex and control strategies based on optimization have to be adopted also by Distribution System Operators. In order to foster increasing shares of renewable generation at distribution level, it is necessary to introduce control strategies to avoid voltage and loading congestions. Control strategies are also needed to facilitate the provision of ancillary services to the transmission grid by distributed resources. Centralized control solutions are often the best choice for an optimal management of distribution networks, but they require monitoring vast network areas and many grid nodes, which may be unaffordable. For this reason, some portions of the network (i.e. LV nodes) can be operated in an unsupervised way, and the fundamental control functions are operated by local automatic volt var controllers. These controllers also impact on the supervised network portions, therefore centralized architectures should take their effects into account in order to compensate them. The proposed optimization model analyses the behavior of distribution grids with a hybrid control strategy (i.e. where automatic local controllers are implemented in some portions, while some generators and distribution transformers are controlled by the network operator) and compares it to situations in which either central control only or local controllers only are activated.

Mathematical models for wind farm installation

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The increased focus on renewable sources of energy and the increasing competition in the wind energy business have brought new attention to optimization and cost saving initiatives in all the lifetime of wind farms. In this work, in particular, we focus on the optimization of the installation phase of offshore wind farms. This is the task of constructing wind turbines at sea and connecting them through cables. This is a complex task that requires expensive specific vessels and thus involve high costs. These costs need to be considered in addition to revenues from operating the constructed turbines: as soon as a turbine is built and connected to the grid, indeed, it produces energy that is sold to the market. Our goal is to optimize the scheduling and routing of installation vessels taking both immediate costs (such as vessel rental) and production revenues into account. We developed original Mixed Integer Linear Programming models to solve the challenge subject to real-world constraints, as presented by our industrial partner Vattenfall. We also considered uncertainties in the weather forecast and how to generate a schedule that is more robust to weather changes.

Session: OR Applications and Experiences
C10

Alice Raffaele, Teaching Operations Research before University: the ROAR Experience (Part I)

Mario Benini, Planning models for crop rotation in agriculture

Alberto Santini, Energy efficient automated vertical farms

Pier Giorgio Villani, Knowledge before solutions: some reflections on a successful O.R. case study

Teaching Operations Research before University: the ROAR Experience (Part I)

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Operations Research (OR) is a discipline of applied mathematics usually taught at university level. Nevertheless, during the last years, various initiatives have been developed to introduce OR to younger students such as Grades 9-12 [1]. Taking a cue from these, we designed Ricerca Operativa Applicazioni Reali (ROAR, i.e., Real Applications of Operations Research), a learning path for higher secondary schools. ROAR relies on active learning and constructionism [2]. It is composed of three didactic units, addressed to Grades 10, 11, and 12, respectively, that offer examples and problems closely connected with students' everyday life or with the Italian reality, balancing mathematical modelling and algorithmics. ROAR aims to improve students' interest, motivation and skills related to STEM disciplines, by an innovative way of integrating mathematics and computer science through OR. The implementation of ROAR started in Spring 2021 as a three-year project-work that fit into a Percorso per le Competenze Trasversali e l'Orientamento (PCTO, i.e., Path for Transversal Skills and Orientation) activated at the scientific high school IIS Antonietti in Iseo (Brescia, Italy). In this talk, we describe how we carried out a teaching experimentation of the first didactic unit and share our results. We show how we introduced OR and the basics of linear programming by focusing on modelling real situations and problems. We explain the teaching methodology adopted to involve students in an active way (e.g., cooperative learning and authentic tasks [3]). We present some digital tools used, such as Excel Solver, to make students solve and evaluate problems from the perspective of managerial decisions. Moreover, since because of COVID-19 we could not hold our lectures entirely in the classroom, we discuss advantages and disadvantages related to distance learning. Finally, we anticipate something about the second didactic unit, that we will conduct in January 2022 with the same students.

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Planning models for crop rotation in agriculture

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In this work, a tool that can help farm management in terms of crop rotation planning for the annual crops is proposed. This tool can be useful to solve problems related to the allocation of different crops to different fields of an arable land on periods (years or semesters) of a given time horizon [3]. In this context, planning and location decisions concern crop choice, crop spatial distribution within the farm arable land and crop temporal successions over time periods. Such decisions can be critical since they modify farm productivity and profitability in the short and long run. In fact, different crop rotation schemes on a given field may lead to different production volumes and profits over years. In the literature, decision support systems, and mathematical programming and network flow models have been proposed for crop rotation planning problems [1,2,4]. We present a Mixed Integer Linear Programming model in which all the operational constraints and crop rotation schemes have been included. For each hectare of the arable land, the model is able to take into account both the rotation requirements and the specific constraints for each crop, considering all suitable combinations of crop sequences. The objective is the maximization of the overall potential profit across agrarian seasons. A preliminary test campaign on real data is presented.

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Energy efficient automated vertical farms

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In this paper we study the problem of scheduling operations in an automated vertical farm (AVF), with the objective of reducing energy consumption. In a vertical farm crops grow indoor, stacked in tall silos under controlled conditions including watering, lighting, temperature and ventilations. In an AVF, humans operators don't interact with the crops while they are growing. Rather, an elevator visits the crops and performs routine tasks such as watering or scanning for pests, during their respective time windows. We focus on the optimisation of the elevator operations with the aim of reducing its travelled distance and, thus, its energy consumption. We propose several mixed-integer linear programming formulations for this problem, study their respective strength and weaknesses, and perform a computational campaign on realistic instances.

Knowledge before solutions: some reflections on a successful O.R. case study

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This paper describes how a capacity planning problem arising in health care services design and optimization was successfully tackled with mathematical programming techniques. What made the project successful was not the design of a sophisticated algorithm providing optimal solutions, but rather the iterative development of an integer linear programming model of the problem, solved by a general-purpose MILP solver. This approach was made possible by the characteristics of the mathematical model itself and the user-friendly tools that were used. As a result, the problem expert could autonomously challenge and improve the model and the data in a countless number of iterations with little or no intervention of the O.R. expert. This allowed to reduce the development cost to zero and the development time to a few days.

Session: Game Theory I D8

Markus Sinnl, Interdiction Games and Submodularity

Daniele Patria,Using the Frontier Partitioner Algorithm to detect pareto-optimal solutions of portfolio optimization problems

Laura Levaggi, Properties of Stackelberg equilibria in potential games

Marcello Sanguineti, Comparing Features for Detecting the Origin of Movement based on a Graph-Theoretical Cooperative Game Model

Interdiction Games and Submodularity

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In this talk, we address zero-sum Interdiction Games where the objective is a monotone and submodular set function. Given a ground set of items, the leader interdicts the usage of some of the items by the follower who seeks to maximize a submodular set function over the uninterdicted items. This class of games finds a wide range of applications including the interdiction versions of maximal covering, facility location, bipartite inference and concave utility function maximization problems. We propose an exact branch-and-cut algorithm for these kind of interdiction games. The algorithm is based on interdiction cuts which allow to capture the follower's objective function value for a given interdiction decision of the leader and exploit the submodularity of the objective function. We also present extensions and liftings of these cuts and discuss additional preprocessing procedures. We test our solution framework on the weighted maximal covering interdiction game and the bipartite inference interdiction game. For both applications, the improved variants of our interdiction cut perform significantly better than its basic version. For the weighted maximal covering interdiction game for which a mixed-integer bilevel linear programming (MIBLP) formulation is available, we compare the results with those of a state-of-the-art MIBLP solver. While the MIBLP solver yields a minimum of 54

Using the Frontier Partitioner Algorithm to detect pareto-optimal solutions of portfolio optimization problems

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In this talk, we deal with portfolio optimization problems considering the classical bi-objective model where we aim at maximizing the expected returns and minimizing the covariances of different eurostoxx financial assets, simultaneously. In the instances we consider, both the expected returns and the covariances are computed by averaging the data obtained during a timespan of 264 weeks (from 10-Mar-2003 to 24-Mar-2008 with one observation for each week). The variables are constrained to be integer so that we end up with a bi-objective integer nonlinear model that is addressed by a criterion space search algorithm, the Frontier Partitioner Algorithm (FPA). A comparison between FPA and the well-known epsilon-constraint method is shown considering instances of different sizes in terms of the number of assets taken into account.

Properties of Stackelberg equilibria in potential games

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Several notions of Stackelberg equilibria (SE) are possible when the follower's best response is a multivalued map, but in general the different sets of equilibria are not well-behaved with respect to existence or approximation procedures, or both. In this work the properties of Stackelberg equilibria of hierarchical potential games and of their approximations are studied. Relations between approximate SE and approximate maximum points of the potential function are analysed, showing the relations between the well-posedness of the optimisation of the potential and that of the Stackeberg problem. A generalization to multicriteria games is also discussed.

Comparing Features for Detecting the Origin of Movement based on a Graph-Theoretical Cooperative Game Model

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Computational models based on cooperative games on graphs are exploited to detect the origin of full-body human movement, as it is perceived by an observer, and track its propagation. To deal with movement analysis, a transferable-utility game is built over a skeletal representation of the human body, based on a characteristic function related to how movement features change on adjacent vertices of the graph (joints), which are also the players of the game. Mathematical properties of the game are interpreted in terms of the analysis of movement. The Shapley values of the joints are evaluated and used to extract a higher-level feature (called Origin of Movement), which provides an estimate of the joint from which movement originates or propagates. The method developed in [1,2] is further refined (as in [3]) by considering a larger set of movement features. Based on a machine-learning approach, feature ranking is performed in order to find the feature with the best prediction capability about the origin of movement and its propagation. A time-series analysis of the Origin of Movement feature is also proposed as a tool to discriminate between different kinds of movements. This research has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824160 EU (Project EnTimeMent) and from the Universit'a Italo Francese (project GALILEO 2021 no. G21 89).

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Invited Session: OPTSM 8 D9

Alessandro Bombelli, The ground handler dock capacitated pickup and delivery problem with time windows (GHDC-PDPTW): mathematical formulations and solution method

Ling Xu, Integrated optimization of bus line planning and lane reservation

Frane Tadić, Urban traffic management - a case study of the city of Rijeka

Luis Cadarso, Airline Tail Assignment Optimization at Vueling Airlines

The ground handler dock capacitated pickup and delivery problem with time windows (GHDC-PDPTW): mathematical formulations and solution method

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We study a typical problem within the air cargo supply chain, concerning the transportation of standard unit load devices (ULDs) from freight forwarders' to ground handlers' warehouses. First, ULDs are picked up by a set of available trucks at the freight forwarders' premises within a time window. Next, they are delivered to the ground handlers, also within a time window, and discharged according to a LIFO policy. Due to space constraints, ground handlers have limited capacity to serve the trucks and waiting times may arise, especially in case freight forwarders do not coordinate their operations. Therefore, in this paper we consider a collaborative framework where this transportation is coordinated by a central planner. The goal of the planner is to find a proper routing and scheduling that minimizes the sum of the transportation and waiting times at the ground handlers' warehouses, while satisfying the capacity of the trucks. We propose two mathematical formulations, one based on the routing and the other based on the packing aspect of the problem. To solve large instances of the problem, an Adaptive Large Neighborhood Search algorithm is also developed. With numerical experiments, we compare the performances of the two models and the metaheuristic, and we quantify the benefits of the proposed framework to reduce waiting times.

Integrated optimization of bus line planning and lane reservation

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Bus service, as an indispensable component of public transit systems, has been widely used in many cities worldwide to assure urban transportation. For a bus service system, a well-designed bus transit network is critical to achieve high attractiveness and low operation cost. Bus line planning is to determine the number of lines and their routes to satisfy passenger demands. Rapidness and reliability are important and crucial factors in in influencing the passengers' choices on bus service. However, more and more congested urban traffic makes them become increasingly impossible even if bus lines are well designed.
To provide rapid and reliable bus service, we propose to integrate bus lane reservation into bus line design that yields a new bus line planning and lane reservation integrated optimization problem. It aims to minimize the total travel time of passengers including transfer time and the lane reservation negative impact, simultaneously.
For the problem, we first present a bi-objective integer nonlinear program and show that its complexity is NP-hard. Then the proposed model is equivalently transformed into a mix-integer linear one, which is further strengthened by explored valid inequalities. To solve the proposed bi-objective model, we explore problem properties to reduce search space, and propose an iterative and fuzzy method based on "-constraint to yield the Pareto frontier and suggest a preferred solution for decision-makers. Experimental results on a case study and randomly generated instances demonstrate the effectiveness and efficiency of the proposed model and algorithm. Useful decision support is provided to realize a fast and reliable bus transit system in practical applications.

Urban traffic management - a case study of the city of Rijeka

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The scientific research project Connected Traffic will establish quality solutions in urban and multimodal transport of the city of Rijeka and promote sustainable, clean and energy-efficient modes of transport. The aim of this paper is to present research and development activities as well as the existing results of the Connected Traffic project related to the improvement of traffic management in the city of Rijeka

. In order to ensure the sustainability of urban transport in the city of Rijeka, the application of energy efficiency measures and the reduction of primary energy consumption and emissions of carbon dioxide and other harmful gasses is required. The methodology applied in research activities consists of modelling the transport netwok of the city of Rijeka, measuring and analyzing traffic, meteorological and environmental parameters in order to achieve the base traffic scenario and performing the traffic simulations of different corridors and sections.

The research development will improve the work of the traffic management center in the city of Rijeka through the Center for Monitoring and Management of Integrated Traffic. Thus, a platform for data aggregation in the decision-making function in urban transport and urban mobility will be implemented ensuring the automatic and real-time distribution of data to all traffic participants. For urban traffic flows simulation at corridors and sections in the city of Rijeka the software Aimsun 8.1. for traffic planning, simulation and prediction is used.

Airline Tail Assignment Optimization at Vueling Airlines

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Airline planning is a field rich in combinatorial optimization problems. Flights and airports make up the network where aircraft and passengers fly. In order to schedule aircraft, assignments of fleet types to flights and of aircraft to routes must be determined. The former is known as the fleet assignment problem while the later is known as the aircraft routing problem in the literature. Aircraft routing is usually addressed as a feasibility problem whose solution is needed for constructing crew schedules. Note that all these problems are usually solved from 4 to 6 months before the day of operations. Therefore, there is limited information regarding each aircraft's operational condition. The tail routing problem, which has received limited attention in air transportation literature, is solved when additional information regarding operational conditions is revealed aiming at determining each aircraft's route for the day of operations accounting for the originally planned aircraft routes and crew schedules. Therefore, it is a problem to be solved close to the day of operations. We propose a mathematical programming approach based on sequencing that captures all operational constraints and maintenance requisites while operational costs are minimized and schedule changes with respect to original plans are minimized. Computational experiments are based on realistic cases drawn from a Spanish airline, which features a network with more than 1000 flights and more than 100 aircraft.

Invited Session: Robust Combinatorial Optimization D10

Jannis Kurtz, New Algorithms and Complexity Results for Min-max-min Robust Combinatorial Optimization

Enrico Bettiol,An oracle-based framework for robust combinatorial optimization

Emanuele Concas, A Granular Tabu Search algorithm for the Bike Rebalancing Problem

Paolo Ventura, An exact approach for the Robust Block Relocation Problem

New Algorithms and Complexity Results for Min-max-min Robust Combinatorial Optimization

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In this talk we investigate the min-max-min robust optimization problem applied to combinatorial problems with uncertain cost functions which are contained in a convex uncertainty set. The idea of the approach is to calculate a set of k feasible solutions which are worst-case optimal if in each possible scenario the best of the k solutions would be implemented. It is known that the min-max-min robust problem can be solved efficiently if k is at least the dimension of the problem, while it is theoretically and computationally hard if k is small. While both cases are well studied in the literature nothing is known about the intermediate case, namely if k is smaller but close to the dimension of the problem. We approach this open question and show that for a selection of combinatorial problems the min-max-min problem can be solved exactly and approximately in polynomial time if some problem specific values are fixed. Furthermore we approach a second open question and present the first implementable algorithm with pseudopolynomial runtime for the case that k is at least the dimension of the problem. The algorithm is based on a projected subgradient method where the projection problem is solved by the classical Frank-Wolfe algorithm. Additionally we derive the first branch & bound method to solve the min-max-min problem for arbitrary values of k and test both algorithms on knapsack and shortest path instances. The experiments show that despite its theoretical impact the projected subgradient method cannot compete with already existing methods. On the other hand the performance of the branch & bound method scales very well with the number of solutions.

An oracle-based framework for robust combinatorial optimization

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We propose a general solution approach for min-max-robust counterparts of combinatorial optimization problems with uncertain objective function. We focus on the discrete scenario case, but our approach can be extended to other types of uncertainty sets such as polytopes or ellipsoids. Concerning the underlying certain problem, the algorithm is entirely oracle-based, i.e., the approach only requires a (primal) algorithm for solving the certain problem, but no other information is needed about the latter. The idea of our approach is to solve the straightforward convex relaxation of the problem by a simplicial decomposition approach, the main challenge being the non differentiability of the objective function in the case of discrete or polytopal uncertainty. We then embed our approach into a branch-and-bound framework. Numerical results on instances from the minimum spanning tree and the traveling salesman problem are presented.

A Granular Tabu Search algorithm for the Bike Rebalancing Problem

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We have developed an heuristic algorithm to solve the Bike Rebalancing Problem (BRP). The BRP is a classical problem of a shared bike service. At the end of the day, each station of the bike sharing system may contain a number of bikes which can be a smaller, equal or greater than the optimal value. The optimal value is the number of bikes needed in the station at the beginning of the day after. The rebalancing problem consists in pickup bikes from stations with a greater number of bikes and to delivery them to the nodes with a smaller number of bikes. It is performed by a fleet of one or more vehicles, each one has a maximum capacity and starts its trip from the depot with an empty, a partially or a fully load. Each station may be visited only once, while the vehicle may return to the depot several times. The objective is to determine the best path for the vehicle by minimizing the cost of the rebalancing route. It is quite clear that if we relax the routing constraints the underlying problem is the classical transportation problem.
In this talk, we present a new algorithm for solving the static rebalancing problem. The proposed approach uses the optimal solution obtained by solving the associated transportation problem. The solution of the transportation problem provides the clusters of pickup and delivery nodes. Moreover, the solution of the transportation problem provides us the set of arcs to be used for transferring bikes from pickup nodes to delivery nodes and the reduced cost of the whole set of arcs: those used and those not chosen to be part of the optimal solution. Therefore, the reduced costs are used in the Granular Tabu Search to scale down the size of the solution space obtained applying the local search procedures, such as 2-opt, move and swap. We evaluated our method using real data instances and it proved to be faster than exact methods (e.g. Branch and Cut) and competitive compared to other heuristics.

An exact approach for the Robust Block Relocation Problem

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The Block Relocation Problem consists of finding a way to retrieve, according to a fixed order, a set of containers piled into stacks in a yard bay such that the total number of moves is minimized. The hypothesis according to which the retrieval order of each container is known a priori is rather unrealistic in port logistics. Therefore, here we study a robust variant of the problem that is more plausible in realistic scenarios. In particular, we consider the situation in which containers are partitioned into batches. The retrieval order between batches is known while the containers belonging to the same batch can be retrieved in any possible sequence. For this variant of the problem, we propose a new exact approach based on an integer programming formulation. Computational experiments, conducted on instances taken from the literature, show that the new method outperforms the state-of-art exact procedures.

Session: Data Science III A11

Rosita Guido, Hyper-Parameter Optimization in Support Vector Machine on unbalanced datasets using Genetic Algorithms

Edoardo Amaldi, On sparse randomized classification trees

Antonio M. Sudoso, SOS-SDP: an Exact Solver for Minimum Sum-of-Squares Clustering

Annabella Astorino, Polyhedral separation in Multiple Instance Learning problems

Hyper-Parameter Optimization in Support Vector Machine on unbalanced datasets using Genetic Algorithms

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Hyper-parameter optimization and class imbalance are two challenging problems for machine learning in many real-world applications. A hyper-parameter is a parameter whose value is used to control the learning process and it has to be tuned in order to reach good performance. The class imbalance occurs when one class contains significantly fewer instances than the other class. Common approaches for dealing with class imbalance problems involve modifying the data distribution or modifying the classifier. This paper presents an optimization framework that considers two evaluation measures, i.e., accuracy and G-mean, by optimizing a cost-sensitive Support Vector Machine and its hyper-parameter by a genetic algorithm. Experimental results on two benchmark datasets show that the proposed method is effective and efficient in comparison with the commonly used grid search method.

On sparse randomized classification trees

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Decision trees are widely-used classification models because of their interpretability and good accuracy. However, if allowed to grow large, they sometimes tend to overfit the data and loose interpretability. Since designing optimal decision trees is NP-hard, classical methods such as CART are based on greedy approaches. During the last decade, growing attention has been devoted to build optimal classification trees by leveraging the remarkable advances in the solution of mixed-integer linear and nonlinear optimization problems (see e.g. [1,4] and the references therein). We investigate the recent nonlinear continuous optimization formulation proposed in [2,3] for building sparse optimal randomized classification trees. Sparsity is important not only for feature selection but also to improve interpretability. We first describe alternative methods to sparsify randomized classification trees based on concave approximations of the l0 norm rather than on $l1$ and $l\infty$ regularization. The results obtained on 24 datasets from the UCI Machine Learning and KEEL repositories indicate that one alternative sparsification method compares favorably with the original approach. Then we derive bounds on the VC dimension of randomized and deterministic multivariate classification trees. Finally, since building sparse randomized classification trees for large scale datasets is computationally challenging, we propose two simple variants of a general decomposition scheme. Experiments on some larger datasets suggest that the proposed decomposition methods are able to significantly reduce the training times without compromising the accuracy.

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SOS-SDP: an Exact Solver for Minimum Sum-of-Squares Clustering

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The minimum sum-of-squares clustering problem (MSSC) aims to partition n observations into k clusters so that the sum of squared distances from each data point to the cluster centroid is minimized. Due to the NP-hardness of the MSSC, the computational time of globally optimal algorithms quickly increases with the problem's size. Besides the importance of finding optimal clustering solutions, certified optimal solutions are also extremely valuable as a benchmark tool. In this light, we propose SOS-SDP, an exact solver for the MSSC problem based on the branch-and-bound technique [1]. SOS-SDP is the first semidefinite programming-based branch-and-bound algorithm for MSSC using the Peng-Wei SDP relaxation [2] and a cutting-plane procedure for strengthening the lower bound. Furthermore, we exploit the SDP solution for a smart initialization of a constrained version of k-means, which is known to be sensitive to the choice of the initial centroids. Numerical experiments demonstrate that this initialization procedure yields high-quality upper bounds. In the branching procedure, we incorporate instance-level must-link and cannot-link constraints to express knowledge about which instances should or should not be in the same cluster. Our way of branching allows us to preserve the structure of the problem and to decrease its size while going down the branch-and-bound tree. The obtained results show that SOS-SDP allows to successfully solve for the first time generic instances with up to 4000 data points and with more than 20000 features.

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Polyhedral separation in Multiple Instance Learning problems

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Multiple Instance Learning (MIL) is a variant of traditional supervised learning where the main difference is in the nature of the learning examples. In fact, each example is not represented by a single vector of features but by a set (called bag) of feature vectors (called instances). The classification labels of the training bags are known whereas the labels of the instances inside them are unknown. The task of MIL is to learn a model that predicts the labels of the new incoming bags together the labels of the instances inside them. In this work we tackle the MIL problem for the binary case by constructing a polyhedral classifier on the basis of positive and negative training examples. In particular, the idea is to generate a polyhedral separation surface characterized by a finite number of hyperplanes such that, for each positive bag, at least one of its instances is inside the polyhedron and all the instances of each negative bag are outside. We come out with nonlinear nonconvex nonsmooth optimization problems of DC (Difference of Convex) type that we solve by adapting the DCA algorithm. The results of our implementation on a number of benchmark classification datasets are presented.

Session: Optimization and complexity A12

Nicolas Zufferey, Local Search for Aircraft-Landing Planning

Adrien Cambier, Optimal scheduling of an upon-request passenger transport service through electric autonomous vehicules

Pierre Hosteins, Complexity of the Multilevel Critical Node Problem

Local Search for Aircraft-Landing Planning

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In collaboration with EUROCONTROL (the European Organisation for the Safety of Air Navigation), the considered Aircraft Landing Planning (ALP) problem aims at minimizing delays (with respect to the published airline schedules) while satisfying the separation constraint (which imposes minimum threshold times between planes, ranging from 90 to 240 seconds). In this study, the landing sequence of the planes has to be determined first, and subsequently their associated landing times and Holding-Stack Patterns (HSPs) needed to meet such landing times. HSPs consist of making a plane wait for its planned landing time by making circular patterns close to the airport. The uncertainty due to winds is taken into account in the simulation procedure (it has an impact on the arrival times). The proposed solution method is a descent local search with restarts. It is quick enough with respect to implementation in real situations as it can be applied within seconds. Furthermore, the obtained results show that the delays can be reduced by approximately 50% on average when compared to a common practice rule.

Optimal scheduling of an upon-request passenger transport service through electric autonomous vehicules

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In this work, we are interested in the real-world application of using electric autonomous vehicles for transporting customers. More specifically, we study an upon-request customer transport service, which will be the modus operandi of the considered line in off-peak hours (peak hours being served by a classical fixed timetable). The line is fixed in sense of customers could be picked and dropped off only on the considered infrastructure, however it could be anywhere on the line. Customers also have either a preferred departure or arrival time. Our problem consists in maximising the level of service for the customers (minimum travel times, minimum gaps with preferred dates) while minimising the fleet utilisation (and therefore operating costs). We have to manage the assignment of customers to shuttles, as well as the shuttle's operation. Since the shuttles travel on dedicated infrastructure, we model the problem at the microscopic level, handling the occupation of the infrastructure by each individual shuttle, even handling the take over between shuttles. We also take care of possible charging of the shuttles at depots. This microscopic modelization hence brings some new features specific for this type of problem which do not usually appear in guided transport traffic management (e.g. railways) or road transportation problems. We model the whole problem as a MILP, and will focus in the presentation on the modeling of these specific features. We will present and discuss numerical experiments on the MILP, assessing its limitation in terms of solving real-life instances provided by the French company SNCF. We will then present a heuristic algorithm scheme aiming to overcome this limitation and provide good quality solutions for the real-life instances.

Complexity of the Multilevel Critical Node Problem

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In this work, we will focus on the Multilevel Critical Node problem (MCN), which is a trilevel network interdiction problem. Let $G = (V, A)$ be a graph with a set V of vertices and a set A of arcs. In MCN there are two players, a defender and an attacker. First, the defender selects a subset of vertices $D \subseteq V$ to vaccinate subject to a budget limit Ω; second, the attacker selects a subset of vertices $I \subseteq V \setminus D$ to (directly) infect subject to a budget limit Φ; third, the defender selects a subset of vertices $P \subseteq V \setminus I$ to protect subject to a budget limit $\wedge$. A directly or indirectly infected vertex v propagates the infection to a vertex u, if $(v, u) \in A$ and u is neither a vaccinated nor a protected vertex. The goal of the defender is to maximize the total benefit of saved vertices (i.e., not infected), while the attacker aims to minimize it. We will provide reductions from the Knapsack Interdiction Problem (KIP) to prove that the decision version of both bilevel subgames of MCN with arbitrary weights are $\sum 2p$-complete (where $\sum 2p = NP \wedge NP$), i.e. are complete for the second level of the Polynomial Hierarchy. These results will then be generalized to demonstrate the $\sum 3p$-completeness of the decision version of the full trilevel MCN with arbitrary weights using an extension of the KIP to three decision levels, whose $\sum 3p$-completeness is derived from the 3-Alternating Quantified Satisfiability Problem.

Session: Scheduling B11

Roberto Ronco, Scheduling on Identical Parallel Machines with Time-of-Use Costs

Alessandro Agnetis, Time-critical testing and search problems

Lixing Yang, Integrated Backup Rolling Stock Allocation and Timetable Rescheduling with Uncertain Time-Variant Passenger Demand Under Disruptive Events

Lorenzo Di Rocco, Scheduling K-mers Counting in a Distributed Environment

Scheduling on Identical Parallel Machines with Time-of-Use Costs

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In the latest years, energy-efficient scheduling has become an increasingly compelling and relevant matter due to both the rising global pollution levels and the growing interest of the industry towards sustainable manufacturing [1]. Specifically, many efforts have been devoted towards scheduling with the Time-of-Use (TOU) energy consumption model [2]. A scheduling horizon subject to a TOU policy is partitioned into different time slots, each one characterized by a different cost. The typical goal is to assign jobs to available machines in order to minimize the total energy consumption together with other possible objectives, such as the makespan or the total weighted tardiness. In this work, we consider the problem of scheduling a set of independent jobs on a set of identical, parallel machines with the objective of simultaneously minimizing the makespan and the total energy consumption. In more detail, we build upon [3] and provide an enhanced heuristic as well as a novel mixed-integer programming formulation. Finally, we show the effectiveness of the proposed solution approaches by reporting results from experimental tests performed on large size instances.

[1] K. Gao, Y. Huang, Ali Sadollah, and L. Wang. A review of energy-efficient scheduling in intelligent production systems. Complex Intell. Syst., 6:237-249, 2020.

[2] K. Train and G. Mehrez. Optional time-of-use prices for electricity: Econometric analysis of surplus and pareto impacts. RAND J. Econ., 25:263-283, 1994.

[3] D. Anghinolfi, M. Paolucci, and R. Ronco. A bi-objective heuristic approach for green identical parallel machine scheduling. Eur. J. Oper. Res., 289(2):416-434, 2021.

Time-critical testing and search problems

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In this talk, we introduce a problem in which the state of a system needs to be determined through costly tests of its components by a limited number of testing units and before a given deadline. We also consider a closely related search problem in which there are multiple searchers who want to find a target before a given deadline. These natural generalizations of the classical sequential testing problem and search problem are applicable in a wide range of time-critical operations such as machine maintenance, diagnosing a patient, and new product development. Our results include: The proof that both problems are NP-hard, a pseudo-polynomial dynamic program for the special case of two time slots, a partial-order-based as well as an assignment-based mixed integer program for the general case, an experimental comparison between the two formulations on the testing and the search variant, a pairwise-interchange-based local search procedure capacble of efficiently finding near-optimal solution.

Integrated Backup Rolling Stock Allocation and Timetable Rescheduling with Uncertain Time-Variant Passenger Demand Under Disruptive Events

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Andrea D'Ariano

Railway traffic management focuses on regulating train movements and delivering improved service quality to passengers; however, such efforts are subject to many uncertainties in terms of disruptions and passenger demand on a rail transit line. In contrast to most existing studies, which focus on the rescheduling of passenger timetables in a deterministic framework, this study proposes a two-stage stochastic optimization model for allocating backup trains to storage lines to reschedule the timetable and serve passengers delayed by disruptions. The first stage is an assignment problem to determine the optimal plan for the allocation of backup trains to storage lines to achieve a good trade-off between the investment cost for the backup trains and the expected travel time of delayed passengers across different stochastic scenarios. The second stage is formulated as a network flow model to optimize the timetable of the delayed trains on the tracks and the backup trains from the storage lines such that the passenger travel time is minimized under each stochastic scenario. To improve the efficiency of convergence, we develop an improved L-shaped method with several accelerating techniques. Among these, we show that the classical integer L-shaped cut can be tightened given the property of the second-stage problem, which can also be generalized to other two-stage integer stochastic programs. Real-world case studies based on historical data from the Beijing metro verify the effectiveness of the proposed approach in reducing the travel time for passengers.

Scheduling K-mers Counting in a Distributed Environment

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Lavinia Amorosi
Sapienza University of Rome;
Umberto Ferraro Petrillo

Alignment-free algorithms are used in bioinformatics to efficiently evaluate the similarity between pairs of genomic sequences. They work by extracting and aggregating features from sequences under investigation and, then, by comparing them using alignment-free functions. When working on very large collections of huge sequences, it is possible to improve the performance of these algorithms by executing the extraction and the aggregation steps, in parallel, over the computing nodes of a distributed system. In this paper, we address the problem of finding the optimal schedule to use for assigning to computing nodes the features to be aggregated, in order to minimize the maximum aggregation time. We consider, to this end, one exact mathematical programming approach and two approximated ones, based on the Longest Processing Time (LPT) heuristic. These have been implemented using Python and the Gurobi solver, and compared against an implementation of the algorithm used by the Spark distributed computing framework for assigning tasks to computing nodes. Experiments have been run on some large collections of genomic sequences well-known in literature. Results show that the proposed approaches perform favourably with respect to the default scheduling strategy adopted by Spark, at least in terms of quality of the solution. In particular the exact approach, run up to the time limit, allows to reduce the makespan up to 77.11%, when considering the largest instance tested. However, the required computational time of the exact approach is not compatible with its online application. The approximated approaches appear more promising in terms of computational time, while providing good quality solutions that, at least in these first tests, are often equal or very close to the ones obtained with the exact approach.

Invited Session: Advances in Variational Inequalities and Equilibrium Problems B12

Gabriella Colajanni, Multi-layer 5G network slicing with UAVs: an optimization model

Attilio Marcianó, Infinite dimensional duality and applications to equilibrium

Fabio Raciti, A variational inequality approach to a class of network games with local complementarities and global congestion

Daniele Sciacca, A two-stage variational inequality formulation for a game theory network model for hospitalization in critic scenarios

Giorgia Fargetta, Closed-Loop Supply Chain Network Equilibrium with online second-hand trading

Multi-layer 5G Network Slicing with UAVs: an optimization model

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In this paper, we present a network-based optimization model describing a closed-loop supply chain for the provision of 5G network slices on demand to users and devices on the ground. The three-tier supply chain network consists of a fleet of pre-existing UAVs, to which others can be added, managed by a fleet of UAV controllers, whose purpose is to perform services requested by users and devices on the ground. The aim of this paper is to provide a constrained optimization problem through which the providers' profits are maximized, determining the optimal distributions of request flows, the optimal distributions of executed services and the optimal reliability level of pre-existing UAVs of the fleet. We also derive the associatedVariational inequality formulation of the problem and, finally, a numerical example is performed to validate the effectiveness of the model.

Infinite dimensional duality and applications to equilibrium problems

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The paper deals with the strong duality between an infinite dimensional convex optimization problem with nonlinear constraints and its Lagrange dual formulation (see [1]). In particular, we consider the nonconstant gradient constrained problem and, by means of this theory, we are able to show that the associated infinite dimensional variational inequalitiy on a convex feasible set is equivalent to a system of equations, expressed in terms of the Lagrange multipliers associated to the problem ([2-3]).

[1] P. Daniele, S. Giuffré, A. Maugeri: Remarks on general infinite dimensional duality with cone and equality constraints, Comm. Appl. Analysis 13/4 (2009) 567-578.

[2] S. Giuffré: Lagrange multipliers and non-constant gradient constrained problem, J. Diff. Equations 269/1 (2020) 542-562.

[3] S. Giuffré, A. Marcianó: Duality Minimax and Applications, Minimax Theory and its Applications 06 (2021), No. 2, 353–364

A variational inequality approach to a class of network games with local complementarities and global congestion

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We investigate a class of network games with strategic complements and congestion effects, by using the variational inequality approach. Our contribution is twofold. We first express the boundary components of the Nash equilibrium by means of the Katz-Bonacich centrality measure. Then, we propose a new ranking of the network nodes based on the social welfare at equilibrium and compare this solution-based ranking with some classical topological ranking methods.

A two-stage Variational Inequality formulation for a Game Theory Network Model for hospitalization in critic scenarios

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We propose the theoretical structure of a stocastic Generalized Nash Equilibirum model describing the competition among hospitals with first aid departments for the hospitalization in a disaster scenario. Each hospital with a first aid department has to solve a two-stage stochastic optimization problem, one before the declaration of the disaster scenario and one after the disaster advent, to determine the equilibrium hospitalization flows to dispatch to the other hospitals with first aid and/or to hospitals without emergency rooms in the network. We define the Generalized Nash Equilibria of the model and, particularly, we consider the Variational Equilibria which is obtained as the solution to a variational inequality problem.

Closed-Loop Supply Chain Network Equilibrium with online second-hand trading

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This paper studies a closed-loop supply chain network equilibrium problem with online second-hand trading of high-uniqueness products. The closed-loop supply chain network consists of manufacturers, retailers, demand markets, and one online second-hand platform engaging in both horizontal and vertical competition. The optimal behaviors of all the decision-makers are modeled as variational inequality problems, and the governing closed-loop supply chain network equilibrium conditions are given.

Session: Supply Chain and Service Systems C11

Giovanni Righini, Design and optimization of a regional buffalo milk supply chain: a case study

Beatrice Bolsi, Optimizing a Dynamic Outpatient Facility System with Multiple Servers

Roberto Zanotti, A Dynamic Home Healthcare problem with Consistency Constraints

Luigi Raritá, A genetic algorithm to optimize dynamics of supply chains

Design and optimization of a regional buffalo milk supply chain: a case study

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A feasibility study was carried out to assess the economic viability of a regional supply chain of buffalo milk mozzarella in Lombardy, Italy. The design and optimization of the supply chain required the solution of several combinatorial optimization problems at a strategic and tactical level: location, generalized assignment, transportation and inventory/routing. Some of them could be easily solved with a spreadsheet add-in, while others required mixed-integer programming solvers like glpsol and ILOG CPLEX.

Optimizing a Dynamic Outpatient Facility System with Multiple Servers

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The management of queues is a complex problem, and it requires special attention in dynamic environments where information changes over time. This work focuses on an outpatient facility system where patients are attended by identical parallel servers offering different services. Each patient requires service and expects to receive it within a given target time; after which, a tardiness is created. The objective of the problem is to minimize the total tardiness while defining which services each server will offer during the working hours. The arrival of patients is dynamic, and the server's configurations of services can be updated from time to time. To solve the problem, we propose a local search-based heuristic that locally assigns a configuration to each server based on the improvement reached in terms of total tardiness. The heuristic is tested on realistic instances, considering different settings, showing its superiority over the solution currently implemented on the facility system.

A Dynamic Home Healthcare problem with Consistency Constraints

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In recent years, the healthcare sector has begun to change the way certain services are delivered to patients. One of the most challenging aspect is the organization of an outpatient system where patients are able to recover in the comfort of their own home. Differently from the traditional system where patients must stay at the medical facility to receive care (inpatient system), an outpatient solution avoids unnecessary overnight hospitalization. In this work, we consider the problem of a home healthcare agency that employs medical professionals (nurses) to provide short-and long-term services to patients. When planning nurses activity over a predefined time horizon, the agency has to decide which patients to serve directly and which ones to assign to external providers (with whom they have an agreement). The focus is on the patients and the goal is to provide the highest possible level of service. To this aim, we introduce consistency constraints, i.e., constraints that impose consistency on the nurse that visits a patient. When a patient is accepted, a nurse is assigned to him/her for the entire duration of the time horizon. This increases both trust in the agency and the perceived quality by the patient. We consider a dynamic version of the problem, in which new patients requests are collected along the time horizon and, at the end of each day, a decision on which requests to accept is made. Consequently, nurses routes are computed. We propose several scenario-based algorithms to solve it and evaluate their performance on a new set of benchmark instances.

A genetic algorithm to optimize dynamics of supply chains

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This paper focuses on a model for supply chains, based on partial and ordinary differential equations, that model, respectively, densities of parts on suppliers and queues between consecutive arcs. An optimization approach is discussed via a cost functional that, in consideration of a wished outflow, weights queues of materials by variations of processing velocities for suppliers. The minimization of the cost functional is achieved via a genetic algorithm that, as for the processing velocities, considers mechanisms of selection, crossover and mutation. A simulation example is discussed for the optimization procedure.

Invited Session: Networks Performance and Reliability D11

Yuval Hadas, Braess paradox via Shapley value

Mauro Gaggero, Strategic and tactical optimization of distribution networks for perishable products

Rodolfo Metulini, A functional approach for traffic flows large data reduction

Mauro Passacantando, A network centrality measure based on the equilibrium social welfare in network games

Braess paradox via Shapley value

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The well known Braess paradox shows that adding one link to a network may sometimes reduce the overall network performance. In this talk, we analyze the Braess paradox from a transferable-utility cooperative game-theoretical point of view. We in- vestigate a family of transportation network cooperative games, where the set of players is defined as a given subset of links and the utility functions are defined in terms of a measure of congestion on the subgraphs associated with the corresponding coalitions. For each subgraph, the measure is computed by solving an instance of the user (Wardrop) equilibrium problem. The Shapley value of each link is used to establish the importance of that link in the considered network. Negative Shapley values of some links show the occurrence of the Braess paradox. Finally, taking into account the link failures probabilities, we extend our cooperative game-theoretical framework to investigate the network resilience.

Strategic and tactical optimization of distribution networks for perishable products

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This work investigates strategic and tactical optimization of distribution networks for perishable products. This kind of products is characterized by a given remaining lifetime that progressively reduces until a minimum value is reached (typically, the zero level). In other words, perishable products are characterized by a certain utility that remains more or less constant until the expiration date is reached. After expiration, the utility goes to zero (Nahmias, 1982). Optimization of the delivery of such products poses important problems such as reduction of wastes and efficient exploitation of available resources within the distribution network. First, a discrete-time dynamic model of the network is constructed: the model is made up of a directed graph, where nodes and arcs represent warehouses and transportation links, respectively. Second, strategic goals consisting in the selection of optimal values of stock replenishment cycles, safety stocks, and amounts of products to transfer are pursued via optimization techniques taking into account uncertainties in the demands of customers. Third, strategic decisions are tuned according to a rolling-horizon optimization approach implementing a tactical decision viewpoint, where no uncertainties on the demands of customers exist. This framework, originally proposed by Gaggero and Tonelli (2020), is extended by considering new optimization models in the strategic step to better account for uncertainties in the requests of customers. Simulation results in different demand scenarios confirm the effectiveness of the proposed framework as compared to a traditional lot-for-lot approach.

[1] S. Nahmias. Perishable inventory theory: a review, Operations Research, 30(4):680-708, 1982.

[2] M. Gaggero and F. Tonelli. A two-step optimization model for the distribution of perishable products. Networks, pages 1-19, 2020, in press, DOI:10.1002/net.22008.

A functional approach for traffic flows large data reduction

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The analysis of origin-destination traffic flows may be useful in many contexts of application (e.g., urban planning, tourism economics) and have been commonly studied through gravity models (Tinbergen, 1962). By means of a gravity approach, we aim at characterize and modelling the dynamic of such flows over the time in the strongly urbanized and flood-prone area of the Mandolossa (western outskirts of Brescia, northern Italy). However, as long as up-to-date technologies allow scholars to obtain large dataset (in terms of both individual and time index - length N and T, respectively) the statistical estimation of the gravity model may incurs into computational issues. Our data, provided by FasterNet in the context of MoSoRe project on the flow of mobile phone SIM among different aree di censimento and recorded hourly basis for several months, configure as a panel with large time series. Panel data econometrics (Baltagi, 2008) allow to account for individual and time heterogeneity in the dependent variable (i.e., the traffic flow). Time heterogeneity is generally captured, using the fixed effects two-way error component model, by time dummies, which coefficients' estimation may be infeasible when T is large compared to N. In this regard, we propose a strategy to reduce the time dimension by preserving time heterogeneity as much as possible. We do so by a data reduction technique based on clustering similar days - similarly to what has been done in Metulini & Carpita (2020) - where traffic flow from (to) the four cardinal points to (from) the Mandolossa, recorded hourly basis in a day, configures as a functional curve (Wang et al., 2016).

A network centrality measure based on the equilibrium social welfare in network games

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A network game is a noncooperative game modeling the social and economic interactions among players through a graph. Each node represents a player which can interact only with its neighbors in the graph, while possible congestion effects are due to all the network players. In this talk, we consider a class of network games with bounded strategy sets and quadratic utility functions describing local complementarities and possible global congestion. First, we provide a representation formula, based on the Katz-Bonacich centrality measure, for the Nash equilibrium in the case where some of its components lie on the boundary. Moreover, we propose a new network centrality measure to analyze the importance of a player by measuring the percentage variation of the social welfare computed at the Nash equilibrium when the player is removed from the network. Notice that the proposed centrality measure can takes on negative values if the social welfare of the network increases after removing a player (similar situation to the well known Braess paradox). Finally, we compare the proposed measure with well known topological centrality measures and some recent Nash equilibrium-based centrality measures.

AIROYoung Special Sessions

Stefano Bortolomiol

Davide Crapis

Veronica Dal Sasso

Martina Fischetti

Serena Fugaro

Alice Raffaele

Marco Ferraro

Fabrizio Grandoni

"OR IN... FIVE MINUTES" - A pitch-talk session

Stefano Bortolomiol
École Polytechnique Fédérale de Lausanne
Davide Crapis
Research Science, Lyft Inc.;
Veronica Dal Sasso
Optrail s.r.l.;
Martina Fischetti
Vattenfall BA Wind;
Serena Fugaro
Institute for Applied Mathematics of the Italian National Research Council;
Alice Raffaele
University of Verona;

This session aims at the promotion and divulgation of Operations Research. Each participant will have a five-minute slot to present their work in a clear and understandable way, even for people unfamiliar with the subject. The topic of each pitch talk can be both practical and theoretical, with references to applications. Besides knowing and discovering several fields of application of OR, this session offers the opportunity to discuss the relevance of scientific communication, as well as the main issues to take into account when trying to spread our research. At the end of the session, a brief refreshment will be offered to those who would have contributed.

THE ESSENTIAL THINGS TO KNOW ABOUT EUROPEAN FUNDS

Marco Ferraro
Agenzia per la Promozione della Ricerca Europea APRE;
Fabrizio Grandoni
IDSIA USI-SUPSI Istituto Dalle Molle di Studi sull'Intelligenza Artificiale;

This session introduces the main European funds, such as ERC Starting Grants and Marie Sklodowska-Curie Actions, to young researchers. What should a good application contain? When and how to apply? All the main relevant information will be presented and discussed, in order to know what to take into account.

Plenary Speakers

Pitu Mirchandani, Issues, Problems, Challenges and Solutions in Transforming Integrated Road/Power Infrastructures for Electric/Alternate-fueled Vehicles

Matthias Ehrgott, Data Envelopment Analysis: From Linear Optimisation to Multiobjective Linear Optimisation

Dolores Romero Morales, Latest Advances in Transparent Machine Learning: A Mathematical Optimization Perspective

Teodor Gabriel Crainic, Planning Many-to-One-to-Many Freight Transportation Systems with Shared Resources

Issues, Problems, Challenges and Solutions in Transforming Integrated Road/Power Infrastructures for Electric/Alternate-fueled Vehicles

Pitu Mirchandani
Arizona State University

There are many reasons to believe, not the least of which is climate change issues, that vehicles of many individuals and organizations will be changed to vehicles that utilize alternative fuels which are more sustainable. The electric vehicle (EV) is a major candidate for this transformation, especially which "refuels" by charging its batteries or swapping its spent batteries with charged ones. Unfortunately, although there is much research gone into technologies of EVs and alternative-fueled vehicles, little effort have gone into designing the "refueling" infrastructures. This presentation discusses the design and operational issues that must be addressed, principally the issues related to the **limited driving range** of each EV's battery and the possible detouring for battery charging or swapping. In particular, the talk will address the optimization and analysis of infrastructure design alternatives dealing with (1) the routing and detouring of vehicles on trips from origins to destinations, (2) the optimum locations of battery charging/swapping stations, and (3) the recharging capacity and operations management of battery charging/swapping system. Some related interesting design and optimization models are based on network optimization, stochastic dynamic programs, reinforced learning, and other approaches, that the presenter and his two recent PhD students, Adler and Song, have addressed. The talk will also discuss some important relevant challenges that lie ahead.

Data Envelopment Analysis: From Linear Optimisation to Multiobjective Linear Optimisation

Matthias Ehrgott
Lancaster University Management School

Data envelopment analysis is a nonparametric operations research technique for performance measurement of decision-making units (DMUs). Given the input and output data of all DMUs, a linear optimisation problem is solved for the DMU under investigation to determine whether its performance of tarnsforming inputs to outputs is efficient among the peer group of DMUs. The subset of efficient DMUs defines an efficient frontier in the input-output space. In this talk, I will discuss the computation of this efficient frontier. To this end, I will investigate data envelopment analysis from a multiobjective point of view to compute both the efficient extreme points and the efficient facets of the technology set simultaneously. I will introduce a dual multiobjective linear optimisation formulation of data envelopment analysis in terms of input and output prices and propose a procedure based on objective space algorithms for multiobjective linear otimisation problems to compute the efficient frontier. I will show that using this algorithm, the efficient extreme points and facets of the technology set can be computed without solving any optimisation problems. I demonstrate via computational experiments to demonstrate that the algorithm can compute the efficient frontier within seconds to a few minutes of computation time for real-world data envelopment analysis instances. For large-scale artificial data sets, the algorithm is faster than computing the efficiency scores of all decision-making units via linear optimisation. Finally, I will discuss the computational complexity of the proposed method, taking into account the fact that there are polytopes that have a number of facets that is exponential in the number of vertices

Latest Advances in Transparent Machine Learning: A Mathematical Optimization Perspective

Dolores Romero Morales
Copenhagen Business School Denmark

There is a pressing need to make Data Science tools more transparent. Despite excellent accuracy, state-of-the-art Data Science models effectively work as black boxes, which hinders model validation and may hide unfair outcomes for risk groups. Transparency is of particular importance for high stakes decisions, is required by regulators for models aiding, for instance, credit scoring, and since 2018 the EU has extended this requirement by imposing the so-called right-to-explanation in algorithmic decision-making. From the Mathematical Optimization perspective, this means that we need to strike a balance between two objectives, namely accuracy and transparency. In this presentation, we will navigate through some novel techniques embedded in the construction of Data Science models to enhance their transparency. This includes the ability to provide global, local and counterfactual explanations, as well as model cost-sensitivity and fairness requirements. We will show the versatility of our methodology when applied to more complex data types such as functional data.

Planning Many-to-One-to-Many Freight Transportation Systems with Shared Resources

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We address the planning of Many-to-One-to-Many (M1M) freight transportation systems, e.g., synchromodal, physical internet, and city logistics, in which an intelligent decision support platform (IDSP) accepts/rejects time-dependent shipper requests and carrier service offers, and decides shipment-to-service assignments and shipment itineraries. The goal is to provide profitable decisions that satisfy both categories of stakeholders, through consolidation in time and space of multi-shipper requests into shared multi-carrier resources. We first discuss M1M systems, the associated planning and management issues and challenges, and the role of Operations Research in addressing them. We then focus on the operations and decision-process dynamics, present the modeling approach with and without look-ahead capabilities, and discuss comparative performances. We then turn to the tactical-planning level and present the model and experimental results. We conclude with future research directions and perspectives.