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Shaping a Sustainable Future in the Era of Big Data

Book of Abstracts

AIRO ASSOCIAZIONE ITALIANA DI RICERCA OPERATIVA

AIRO YOUNG

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About AIROYoung

AIROYoung is the youth chapter of the Italian Operations Research Society (AIRO), founded in 2016 to foster collaboration among Ph.D. students and young researchers in operations research, mathematical optimization, and decision science. It also aims to facilitate their integration into Italian and international companies operating in these fields.

AIROYoung organizes workshops and scientific seminars focused on optimization and decision science, providing participants with opportunities to present their research, attend talks by renowned international speakers, and connect with companies developing or using advanced operational research techniques. Over the past eight years, these events have become key networking and professional growth opportunities, attracting hundreds of young researchers and Ph.D. students worldwide.

Shaping a Sustainable Future in the Era of Big Data

Optimization and Data Science have emerged as hot topics in recent years, as businesses and researchers seek to maximize efficiency and extract valuable insights from vast amounts of data. These fields are at the forefront of technological advancements, driving innovation and shaping the future of various industries. Additionally, these disciplines are vital in addressing the complex challenges of the future. From optimizing resource allocation and supply chain management to tackling climate change and healthcare optimization, these fields offer powerful tools and methodologies to tackle the multifaceted problems of the future.

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Contents

Plenary Speaker Abstracts

Bayesian optimization for mixed feature spaces using tree kernels and graph kernels

Toby Boyne[1] Alexander Thebelt[1] Yilin Xie[1] Shiqiang Zhang[1] Jixiang Qing[1]
Jose Folch[1] Robert Lee[2] Nathan Sudermann-Merx[2] David Walz[2]
Behrang Shafei[2] Calvin Tsay[1] Ruth Misener[*,1]

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Abstract. We investigate Bayesian optimization for mixed-feature spaces using both tree kernels and graph kernels for Gaussian processes. With respect to trees kernels, our Bayesian Additive Regression Trees Kernel (BARK) uses tree agreement to define a posterior over sum-of-tree functions. With respect to graph kernels, our acquisition function with shortest paths encoded allows us to optimize over graphs, for instance to find the best graph structure and/or node features. We formulate both acquisition functions using mixed-integer optimization and show applications to a variety of challenges in molecular design, engineering and machine learning.

AI in industry and academia: war or alliance?

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Abstract. After many years in academia and business, I would like to share my thoughts on the role of academia and industry in the field of artificial intelligence today. There are trends to consider and opportunities to evaluate in order to understand what the future looks like in this area. War or alliance? ... I say (this will be revealed during my talk).

Machine Learning Augmented Branch and Bound for Mixed Integer Linear Programming

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Abstract. Mixed Integer Linear Programming (MILP) is a pillar of mathematical optimisation that offers a powerful modelling language for a wide range of applications. The main engine for solving MILPs is the branch-and-bound algorithm. Adding to the enormous algorithmic progress in MILP solving of the past decades, in more recent years there has been an explosive development in the use of machine learning for enhancing the main tasks involved in the branch-and-bound algorithm. These include primal heuristics, branching, cutting planes, node selection and solver configuration decisions. This talk gives a taste of such approaches, addressing the vision of integration of machine learning and mathematical optimisation as complementary technologies, and how this integration can benefit MILP solving. We give detailed attention to machine learning algorithms that automatically optimise some metric of branch-and-bound efficiency. We also address appropriate MILP representations, and mention benchmarks and software tools used in the context of applying learning algorithms.

Acknowledgements. This work appears in *Mathematical Programming* ([1]). The authors were partially supported by OPTIMAL, a project funded by the Dutch Research Council (NWO) under grant OCENW.GROOT.2019.015; and by TAILOR, a project funded by EU Horizon 2020 research and innovation programme under grant 952215.

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Industry Abstracts

Solving MINLPs with gurobipy

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Abstract. The release of Gurobi 12.0 introduces significant advancements in solving Mixed-Integer Nonlinear Programs (MINLPs), providing users with enhanced capabilities to model and solve complex optimization problems involving both integer and nonlinear constraints. In this presentation, we will focus on the new modeling components in gurobipy, Gurobi's Python interface, and how they simplify the process of defining and solving MINLPs. Whether you're new to MINLPs or an experienced user, this session will provide valuable tools for tackling complex optimization problems with ease.

Save for Fleet: a stop and refueling routing optimization for transportation companies

Vittoria Crotti[*,1]

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[*]Presenting author

Abstract. Multiprotexion is a company specializing in the surveillance of international transport vehicles. The company provides multiple services, including a 24/7 operational center to manage alarms received from drivers and assisted fleet route guidance for fuel savings.

Since fuel savings are very important to customers, an Operations Research algorithm has been developed in collaboration with the University of Brescia. We will illustrate the algorithm and its future developments. It is capable of solving the Vehicle Routing Problem (VRP) while minimizing refueling costs. Moreover, it is able to consider and optimize the mandatory rest times of drivers.

The algorithm is part of a business plan and has already been implemented on the Multiprotexion website.

Solving global optimization problems with FICO Xpress

Pietro Belotti[*,1,2] Tristan Gally[3] Imre Pólik[4]

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[2]Fair Isaac Italy
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Abstract. The FICO® Xpress Solver is a leading solver of mathematical optimization problems. It solves linear, convex quadratic, and second-order conic optimization, and their mixed integer counterparts. Also, it features a local solver for nonlinear optimization problems and other useful tools: a module for multi-objective optimization and one for finding Irreducible Infeasible Subsystems (IISs), among others.

The FICO® Xpress Solver has been the first among all leading commercial solvers to provide, with version 9.0 released in 2022, an exact solver for mixed integer *nonlinear* optimization (MINLO) problems, among the most difficult class of problems but with a plethora of interesting applications such as Chemical Engineering, the management of power grids, and many others.

This talk will present the Solver's salient features. We will provide an overview of its solution techniques and present a sample application to showcase the modeling and solving features.

Machine Learning in the Cloud: It's Not Just a GPU with WiFi!

Matteo Goretti[*,1]

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Abstract. Using the cloud for Machine Learning projects doesn't just mean "getting a bigger server"!

The cloud is an ecosystem with its own rules, tools, and best practices. Without a clear strategy, your data-driven project can quickly turn into a nightmare of costs and inefficiency.

In this talk, through a practical case study, we'll explore why the cloud is not just an infrastructure but a whole new paradigm for working with data and models–and how to leverage it effectively to achieve scalability, flexibility, and efficiency.

Halide auto-scheduling: an open problem in combinatorial optimization

Gabriele Lombardi*,1 Michele Antolini[2]

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*Presenting author

Abstract. Efficient implementation of Image-Processing algorithms is a hard task: it requires deep knowledge of processing architectures, expertise vectorization and parallelization, experience in selection of trade-offs such as inlining versus buffering. Moreover, the same algorithm may require multiple implementations to mange differences between processing hardware, eventually including accelerators such as GPUs.

The Halide domain-specific language [3] has been designed to separate the algorithm description from the implementation details, called scheduling. This makes it simpler to write efficient code, but unfortunately the identification of the optimal scheduling recipes remains a tough problem. For this reason, various auto-scheduling algorithms [2, 1] have been proposed, none seems the definitive one.

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Automated Extraction, Visual Recognition, Resource Allocation, and Intelligent Chatbots in Data Science

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Abstract. The Data Science area of DaisyLabs is engaged in several research and development projects, both in collaboration with industrial partners and within internal R&D activities. Our research focuses on automated techniques for extracting information from unstructured documents, such as orders, technical sheets, and delivery notes, transforming them into structured and relational models. To this end, we explore the use of Optical Character Recognition (OCR) and Natural Language Processing (NLP) techniques to improve understanding and processing of textual content. Another research area involves the analysis of product images for the automatic identification of product components according to predefined taxonomies, through the implementation and optimization of advanced visual recognition models. We also study tools and algorithms to optimize resource allocation, with the goal of improving personnel utilization efficiency and ensuring more effective management of operational constraints. Finally, an additional research area focuses on the implementation of a chatbot that assists users in navigating the documentation of a software. By integrating advanced NLP models, the chatbot can respond to specific queries, provide contextual suggestions, and enhance the accessibility and usability of the available informations.

Accelerating Intelligent Document Access for Industry 5.0 through AI-Powered Agents

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Abstract. Fedegari is working at a project that focuses on implementing a Large Language Model (LLM)-based solution to enable intelligent, fast, and optimized consultation of the extensive documentation currently available within the company.

In the long term, the solution will also integrate AI-powered agents, providing enhanced access to heterogeneous data sources and facilitating the processing of their content.

The initiative aligns with the principles of Industry 5.0 by promoting greater efficiency through data and AI while emphasizing human-centric decision-making. By leveraging this solution, operators can avoid time-consuming and complex searches within logs and documentation. Instead, they can focus on higher-value critical thinking and decision-making processes, fully supported by data-driven insights.

Contributed Abstracts – Talks

Developing a vehicle re-routing algorithm based on VMS integration for traffic congestion mitigation

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Abstract. Urban traffic management is a critical issue, due to its notable environmental and health impact. Therefore, we propose a re-routing algorithm based on Variable Message Signs (VMS) integration in order to optimize traffic flows and reduce congestion. The core idea is to create a system which integrates real-time optimization with predictive scenario simulation, addressing e.g. traffic disruptions or road closures. First of all, the proposed methodology includes traffic data analysis to identify network links prone to congestion or inefficiency. In addition, model driver behavior is took into account through User Equilibrium (UE) framework. The algorithm then evaluates possible interventions, considering VMS nodes as critical points where traffic can be efficiently redirect. Results show that this adaptive traffic management strategy ensures efficiency and effectively supports planned interventions through scenarios evaluation. This work has been partially supported by CN MOST program (PNRR Sustainable Mobility Center, grant n. CN00000023, CUP B43C22000440001).

Design of e-bike recharging infrastructure solving min-max MIPs via binary search

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Abstract. In recent years, electric bicycles have taken on a central role in the cycling landscape, finding applications in various fields such as cycle logistics, urban commuting, and cycle tourism. The latter, in particular, has seen a growing adoption of e-bikes for travel and tourism-related activities. Within this context, our study addresses the problem of optimally locating charging stations for electric bicycles in the cycle tourism sector. Given the variety of e-bike models available, each with different battery ranges, it becomes essential to position charging stations to minimize the maximum distance between two consecutive chargers. In the era of Big Data and growing concerns for sustainability, optimizing such infrastructure is crucial for fostering eco-friendly tourism and sustainable mobility. This problem can be formalized as a min-max location problem with a budget constraint, considering multiple origins, destinations, and routes, and is addressed using advanced optimization techniques that leverage data-driven modeling. The proposed procedure begins with the definition of an augmented graph for each route, where an initial node (α) and a terminal node (ω) are introduced. On this structure, a mixed-integer programming (MIP) model can be applied to find the optimal solution. However, our approach presents an alternative method based on a binary search process, simplifying computational complexity. At each iteration, the method identifies the maximum distance between two chargers and verifies compliance with the budget constraint, progressively refining the solution. The results, obtained on both randomly generated networks and real-world case studies, such as the VenTo cycle route and the cycling network of the Asiago Plateau's Seven Municipalities, demonstrate that our approach outperforms commercial solvers regarding efficiency and solution quality. By optimizing resource allocation and promoting sustainable tourism, this study exemplifies the role of optimization and data-driven strategies in shaping a more sustainable future.

A Welfare Maximization-based Methodology for on-line Orchestration of Grid-connected Electric Buses

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Abstract. The energy storage systems of grid-connected electric buses (eBuses) equipped with Vehicle-To-Grid technology are a valuable source of flexibility that the power system operator can manage to mitigate the impacts of grid contingencies and the randomness of renewable power generators [3, 2]. In this context, many market schemes have been recently deployed to enable these flexibility sources to offer ancillary grid services in the electricity markets, and a large number of optimization methods have been proposed for flexibility resource allocation, and for defining strategic bidding strategies. However, after the ancillary service market settlement, the eBuses owner is compelled to adapt the charging/discharging profiles of all the grid-connected eBuses according to the system operator's request [1, 4]. This scheduling problem can be formalized by a multi-temporal mixed-integer programming problem, which aims at maximizing the welfare of all the grid-connected eBuses. The insight is to define proper utility functions describing the cost/benefit of the charge/discharge power profiles in function of the eBus parameters and its state of charge and to propose proper linearization techniques enabling the prompt solution of the welfare maximization problem by conventional mixed integer linear programming solvers.

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Exact Algorithms for the Two-Stage Robust Location Routing Problem

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Abstract. The Location Routing Problem arises in many logistic settings where strategic and operational decisions are combined. We study a two-stage Robust Location Routing Problem (2SRLRP), where, in the first stage, the decision-maker determines the set of depots to open, and, in the second stage, a Team Orienteering Problem is solved, managing uncertain demands in a Robust Optimization (RO) fashion. To the best of our knowledge, the most recent work where a variant similar to this problem is solved is [1], where a column-and-constraint-generation-based approach was used. In our work, we study the characteristics of the 2SRLRP in depth through extensive experimentation, implementing different RO methods inspired by the literature, considering different uncertainty sets, and varying problem parameters.

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Real-time rerouting of traffic flows to prevent disruptions

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Abstract. In this paper a real-time system aimed at minimizing the risk of damage or breakdown, due to incoming traffic, of a road structure, for example a bridge, is studied. The information on the current level of risk and on the amount of traffic in the area surrounding the structure are assumed to be available. The vehicles that are directed towards the structure and may increase the risk are assumed to be detected in real-time. We contribute to the design of the system with an optimization model that runs in real-time and assigns paths to vehicles with the goal of minimizing the risk of disruptions. In case the vehicles are diverted from their original path to protect the structure, the paths assigned by the model are chosen to minimize the impact of traffic on the surrounding area. Computational experiments, run on data taken from a real case, show that the proposed approach is able to strongly reduce and, possibly, to eliminate the risk of dangerous situations.

Optimization of solid organ transplantation management through simulation-based approaches

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Abstract. Organ transplantation significantly improves both life quality and longevity by replacing damaged organs. However, timely management of donors is crucial to prevent organ degradation. This work introduces a comprehensive approach to address this challenge. Initially, using real-world data from several successful solid organ donation cases in the Lazio Region of Italy, we develop probability models to analyze the duration of each activity. Moreover, we use a UML activity diagram to represent the entire process, and employ a Monte Carlo simulation to assess the overall duration and identify the most critical activities. Subsequently, we conduct multiple simulations to evaluate alternative procedures, focusing on optimizing cost-performance trade-offs. Specifically, we investigate process perturbations, such as rearranging test sequences, to achieve significant time reductions while considering potential cost implications if consent is not obtained. Our findings highlight ways to improve process efficiency while balancing associated costs, and provide a Decision Support System to assist decision-makers in selecting the best management strategies.

Post-triage patient reallocation in emergency department networks

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Abstract. The timely provision of emergency care has become a pressing challenge, driven by a consistent annual increase in visits to emergency departments (EDs), particularly for non-urgent cases. In this study, we focus on the reduction of waiting times before medical treatment, post-triage, by proposing a reallocation scheme for non-urgent patients. This scheme leverages inter-temporal demand-supply imbalances across EDs within a multi-hospital network.

To implement this approach, we first analytically demonstrate, within a simplified context, that reallocation effectively reduces waiting times when there is a congestion imbalance between EDs operating under steady-state conditions. Building on this foundation, we aim to better capture the complex dynamics of real-world EDs by proposing a novel strategic-operational optimization model for managing patient flow. This model leads to the formulation of 2 optimization-based solution methods that incorporate the logistics of patient reallocation and addresses the non-stationary, highly time-varying arrival and service rates. In this model, arriving patients can either be admitted at the arriving hospital or reallocated to another hospital within the same centralized system based on system capacity and congestion levels, while considering consistent vehicle routing and availability. Additionally, the model is extended to integrate patient pooling, enabling more flexibility and efficiency in the use of vehicles, and patient equity, prioritizing individual outcomes alongside system-wide efficiency. Ultimately, we implement the model in a real-world case study involving a 4-hospital network in northern Italy and quantify a realistic bound on the potential benefits of the reallocation scheme.

Uncovering the Impact of COVID-19 on Clinical Pathways for Pulmonary Patients: A Process Mining Approach

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Abstract. Pulmonary diseases are major causes of morbidity and mortality globally, significantly impacting healthcare systems due to their chronic nature. In Canada, respiratory diseases such as chronic obstructive pulmonary disease, pneumonia, and lung cancer continue to pose substantial challenges to healthcare management. The COVID-19 pandemic further exacerbated these challenges, severely disrupting care for pulmonary patients. This study examines the impact of COVID-19 on the clinical pathways of patients with pulmonary diseases at the Cardiology and Respiratory University Hospital in Quebec. Using process mining, we analyze clinical data from the pre-pandemic (2018-2019) and pandemic (2020-2022) periods to assess changes in patient care, focusing on hospitalization and Emergency Room episodes. Key findings indicate a reduction in the number and duration of episodes, with a general streamlining of activities. Notably, patient transitions were expedited during the COVID-19 era, likely due to the need to manage increased patient loads and minimize infection risks. However, variability in the time between request and completion of exams and procedures suggests that the impact on care quality remains unclear. While healthcare systems adapted to the immediate pressures of the pandemic, further research is needed to evaluate the long-term effects on patient outcomes and care quality. The study concludes with recommendations for optimizing clinical pathways in future public health crises, emphasizing the need for comprehensive data analysis and integrating additional techniques such as machine learning.

Scheduling Blood Components Production: a Real-Life Case Study

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Abstract. The production echelon of the blood donation supply chain is responsible for manufacturing blood components such as red blood cells, plasma and platelets [1]. Donated whole blood units are processed in dedicated blood centres for separation into the different components. Key decisions involve the timing of separation operations and the use of resources. In this work, we propose a scheduler for this production system. It includes two models, one for each production period within the day, differentiated according to the specific operations performed. The proposed scheduler was applied to real instances provided by the Department of Immunohematology and Transfusion Medicine of the Niguarda Hospital, Milan, Italy, which is one of the largest blood centres in Italy. We first validated the scheduler by evaluating its ability to reproduce the real production environment and provide optimized schedules. Next, we performed a scenario analysis to identify the best setting for other realistic production configurations.

References.

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Robust operating rooms advance scheduling with probabilistic regression

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Abstract. Effective resource management is crucial in the healthcare sector to ensure quality service delivery while controlling costs. Operating room (OR) management presents several specific challenges, among which it is worth mentioning elective surgery advance scheduling, which determines the assignment of surgeries to dates and ORs [3]. Properly managed advance scheduling can enhance both hospital staff working conditions and patient satisfaction. A significant challenge in achieving efficient schedules comes from the uncertainty surrounding operating times. These uncertainties can lead to either overtime or under-utilization of operating rooms, both of which make the hospital incur into unexpected costs.

This paper seeks to address the robust surgery advance scheduling problem in the presence of uncertain operating times using a data-driven approach. We devise a method to generate robust solutions, capable of adapting to data variability. Our proposed approach adopts the implementor-adversary (I-A) framework [2]: an *implementor* devises a solution based on a subset of known parameters, while an *adversary* iteratively introduces solution-violating parameter realizations, that are then passed to the implementor in the form of new constraints. Within this framework, our proposed adversary step leverages on historical data to generate realistic parameter realizations sampling by using probabilistic regression techniques to define the distributions of surgical times, offering complete flexibility in defining the uncertainty set [5].

Computational tests on realistic data have been conducted to validate the methodology, demonstrating satisfactory outcomes both in terms of solution quality and computational efficiency. The proposed approach has also been compared to other methods commonly used to deal with uncertainty, namely budget set [1] and chance constrained programming [4].

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Online Facility Location with Recurring Maximum Demand

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Abstract. We study an *online facility location problem* in which the demand points arrive at discrete times. There is a fixed cost for locating a facility, and there is a variable cost at each time for serving points that have arrived up to that time. The considered variable cost reflects *recurring maximum demand* and is defined as the maximum distance between the points and their nearest facilities. The existing online location/clustering studies on *one-time* demand (i.e., each point is served only at the time it arrives) demonstrate that constant-factor competitive guarantees are not attainable unless facilities/centers can be relocated/updated (or other simplifying assumptions hold). While centers can often be updated in clustering applications, facilities typically cannot be relocated in many practically relevant settings. In this work we introduce and study the *Cumulative Variable Cost Thresholding* (CCT) algorithm. CCT irrevocably locates facilities at points that are farthest from an existing facility when the cumulative variable cost exceeds a specified threshold. As our main contribution, we show that CCT is constant-factor competitive for online facility location with recurring maximum demand [1].

References.

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A hybrid genetic algorithm with an exact decoding procedure for the fair and static balancing of electric vehicles

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Abstract. As electric-sharing transport systems spread and fleets grow, operational needs, such as electric vehicle relocation, along with social issues, including equitable access to services in urban areas, become increasingly important, presenting new scientific and computational challenges. In [2], an Integer Linear Programming (ILP) model is proposed to describe the static and fair rebalancing of electric vehicles sharing systems (SFR-EVSS), which involves operations that characterize free-floating networks, such as battery swaps and the replacement of low-charged vehicles, as well as an integration with the equity indicator described in [1]. In particular, the objective function minimizes a weighted sum of the cost related to the rebalancing tour, the missed customers' demand and the imbalance with respect to demand-independent fairness factors. We present an implementation of the ILP in [2] by a solver and a hybrid genetic algorithm to obtain near-optimal solutions. The algorithm starts from an initial population generated by a greedy randomized approach and evolves it through a tailored crossover operator. Solutions are encoded as a permutation of fixed locations to visit (rebalancing tour), with a decoding procedure that determines optimal batteries and vehicle operations by solving the ILP after fixing the tour-related variables. Experiments conducted using real-world data from the city of Bari, Italy, demonstrate the validity of the evolutionary approach in efficiently finding near-optimal solutions and exploring different trade-offs that balance operational costs, customer demand satisfaction and service fairness.

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Waste collection and sensor information: a data-driven approach to compute its value

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Abstract. Waste collection is an important part of waste management that can be eased by installing volumetric sensors inside the dumpsters [1]. While these sensors generate a maintenance cost, they provide additional information, useful to decide which dumpsters to empty in a setting where a daily visit to all dumpsters is too costly. Sometimes, for example when a dumpster is close to a set of other dumpsters often visited, the maintenance cost may be greater than the value of the information provided by the sensor. This leads to the problem of finding the sensor location that minimizes the sum of the cost of routing, the penalty for the waste overflow and the maintenance costs of the sensors. In this paper, we tackle this problem using a heuristic based on Adaptive Large Neighborhood Search and a one-step lookahead policy, in order to compute the number and location of sensors to install aiming to minimize the total cost. We apply the proposed approach to a realistic setting with 50 dumpsters in Torino. The results show that by placing sensors in 21 dumpsters, it is possible to save 17000€ yearly and to reduce the vehicle's time on the road by 15.5%.

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A rolling horizon heuristic approach for a multi-stage stochastic waste collection problem

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Abstract. In this work [1] we present a multi-stage stochastic optimization model to solve an inventory routing problem for the collection of recyclable municipal waste. The objective is the maximization of the total expected profit of the waste collection company. The decisions are related to the selection of the bins to be visited and the corresponding routing plan in a predefined time horizon. Stochasticity in waste accumulation is modeled through scenario trees generated via conditional density estimation and dynamic stochastic approximation techniques. The proposed formulation is solved through a rolling horizon approach, providing a rigorous worst-case analysis on its performance. Extensive computational experiments are carried out on small- and large-sized instances based on real data provided by a large Portuguese waste collection company. The impact of stochasticity on waste generation is examined through stochastic measures, showing the importance of adopting a stochastic model over a deterministic formulation when addressing a waste collection problem. The performance of the rolling horizon approach is evaluated, demonstrating that this heuristic provides cost-effective solutions in short computational time. Managerial insights related to different geographical configurations of the instances and varying levels of uncertainty are finally discussed.

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Autonomous Vehicles for precision agriculture operations

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Abstract. Precision agriculture plays an increasingly central role in the sustainable management of agricultural resources [3, 4]. This innovative approach relies on advanced technologies to optimize agricultural operations, ensuring more efficient crop management and reducing waste. Among emerging technologies, autonomous vehicles, such as drones (UAVs) [1] and ground robots (UGVs) [2], revolutionize monitoring and surveillance practices. The integration of UAVs and UGVs addresses the challenges of managing complex and vast environments effectively, improving precision in crop monitoring, reducing environmental impact, and containing operational costs. We focus on the problem of collaborative farmland monitoring through an integrated UAV-UGV system. The problem involves optimizing the UGV's path, which follows the indications provided by the UAV to visit a specific set of sensors and monitor designated sub-areas. The objective is to guarantee complete coverage of the areas of interest while meeting operational constraints such as memory capacity, energy autonomy, time limits for the validity of sensor data and the time the UGV can travel. A particularly significant aspect of the proposed model is the integration of recharging stations distributed across the farmland. These stations allow the UGV to recharge its battery and transfer collected data. The problem is formulated as a mixed-integer linear programming problem and is validated by adopting an exact solver. A computational analysis evaluates the behaviour of the proposed system, exploring the characteristics of feasible solutions. The results provide a comprehensive overview of the factors that influence system performance, with the aim to promote progress in precision farming systems and establishing the foundations for future developments and applications.

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Crop Rotation Problems with Sustainability Constraints

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Abstract. This work addresses the planning of crop allocations over a finite time horizon, considering crop rotation principles and diversification strategies aligned with EU PAC sustainability directives. The problem involves determining crop sequences on farmland plots, factoring in: (1) yield and profit dependencies on prior crops; (2) sustainability requirements to mitigate soil degradation and pest proliferation.

Building on [1], we present an improved arc-flow model incorporating additional constraints from the updated CAP 2024-2027. For large instances, a column generation approach with dynamic programming for pricing ensures scalability. Computational results validate the applicability of these methods for real-world and simulated scenarios.

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Efficient computation of betweenness centrality in temporal graphs

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Abstract. Buß et al [1] recently proved that the problem of computing the betweenness of all nodes of a temporal graph is computationally hard in the case of foremost and fastest paths, while it is solvable in time $O(n^3T^2)$ in the case of shortest and shortest foremost paths, where n is the number of nodes and T is the number of distinct time steps. We proposed a new algorithm for temporal betweenness computation. In the case of shortest and shortest foremost paths, it requires $O(n+M)$ space and runs in time $O(nM) = O(n^3T)$, where M is the number of temporal edges, thus significantly improving the algorithm of Buß et al in terms of time complexity. Experimental evidence is provided that our algorithm performs between twice and almost 250 times better than the algorithm of Buß et al. Maybe more importantly, our algorithm extends to the case of *restless* walks (that is, walks with waiting constraints in each node), thus providing a polynomial-time algorithm (with complexity $O(nM)$) for computing the temporal betweenness in the case of several different optimality criteria. Such restless computation was known only for the shortest criterion (Rymar et al [2]), with complexity $O(n^2MT^2)$. We performed an extensive experimental validation by comparing different waiting constraints and different optimisation criteria. Moreover, as a case study, we investigate six public transit networks including Berlin, Rome, and Paris. Overall we find a general consistency between the different variants of betweenness centrality. However, we do measure a sensible influence of waiting constraints.

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A Lagrangian relaxation approach for the Cluster Deletion Problem

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Abstract. The rapid spread of fake news through dense clusters in networks jeopardizes trust and stability. Traditional approaches targeting harmful content often overlook the structural network dynamics that drive disinformation. The Cluster Deletion Problem addresses this by removing edges that bridge communities, disrupting disinformation flow while preserving intra-group communication. Indeed, given a graph representing the considered network, the Cluster Deletion Problem aims to transform it into a cluster graph via minimal edge deletions. This transformation ensures that communication within distinct groups remains intact while isolating those that connect separate communities, thereby mitigating the spread of disinformation.

In this work, we address this problem with a tailored Lagrangian heuristic based on a dual descent algorithm, incorporating both a subgradient method and an ad-hoc repair heuristic. The proposed approach is tested on existing instances, in most cases providing better lower bounds with respect to the ones existing in the literature.

How to pack goods efficiently? The usage of the Production Scheduling Model based on the Food Industry example

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Abstract. The use of Big Data technology across supply chain stages, such as planning, logistics, investments, production, and maintenance, opens new opportunities for optimization and increased efficiency. A key focus is the packaging process for finished goods, particularly in the food industry, where packaging must occur immediately after production, imposing high organizational demands. This article analyzes the packaging process, highlighting common issues related to its inefficient organization. Optimizing the packaging process begins with analyzing the current state by mapping workflows, identifying parameters, and defining variables. A critical requirement is establishing the minimum machine cycle time to avoid excess inventory. A production scheduling model was developed using historical data such as production tonnage, changeover matrices, and bottleneck performance, which determines overall line efficiency. The results obtained through this approach provided insights into optimal batch sizes, planned changeovers, and reduced machine micro-downtime, addressing common inefficiencies in packaging operations.

Daily Planning of Acquisitions and Scheduling of Dynamic Downlinks for the PLATiNO Satellite

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Abstract. PLATiNO is a small Synthetic Aperture Radar Earth observation satellite launched in 2022. The operational life of the satellite is controlled by an activity plan, generated on a routine basis, which includes acquisitions, maneuvers, and downlinks. The plan aims to satisfy as many requests as possible, thus maximizing the satellite exploitation, without violating operational constraints. We develop a genetic algorithm, which is enhanced with repair procedures to fix infeasible solutions and local search operators, to quickly identify high-quality local optima. In addition, we model the problem using exact and relaxed Mixed Integer Linear Programming formulations that allow to compute a tight estimation of the optimal solution value. The proposed heuristic algorithm is tested on several realistic benchmark instances derived from real-world data. The computational results show that our approach is able to compute near-optimal solutions within computing times that are fully compatible with real-world applications.

A Bi-Objective Model for Multimodal Container Transportation Considering Waiting Time as a Key Decision Variable

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Abstract. Port logistics and container flow optimization have been widely studied to minimize waiting times and reduce congestion [1, 2]. This paper introduces a novel approach by quantifying waiting time as a measurable cost variable rather than treating it as an abstract concept. Using a bi-objective optimization model combined with simulation. This study focuses on balancing two key objectives: minimizing port traffic congestion and reducing freight costs in Multimodal transport systems. A linear optimization model is applied alongside the epsilon constraint method to identify trade-offs between the objectives. Although trains are more cost-effective than trucks, their limited daily availability contributes to port congestion and shipment delays. By incorporating waiting time as a cost factor, this study provides decision makers with a practical tool to optimize vehicle assignments, reduce overall transportation costs, and alleviate congestion in port operations.

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Evaluating Optimization Performance for Container Terminals: A Simulation-Based Study with Witness Horizon

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Abstract. Container terminals are crucial nodes in global supply chains, where efficiency in resource allocation and operational decisions has a significant impact on logistics performance. As highlighted by [3] and [1], optimization techniques improve decision-making in container terminals, leading to reductions in energy consumption and increased efficiency. Addressing these challenges often requires the integration of simulation and optimization (see, e.g.,[4]). This study explores the application and performance evaluation of optimization algorithms implemented in the Witness Horizon Experimenter. These methods include Adaptive Thermostatistical Simulated Annealing and Hill Climb. Research presented in [2] has already demonstrated the versatility of Witness Horizon in the modelling and optimization of port logistics systems, emphasizing its ability to simulate real-world scenarios and improve decision-making through the integration of queuing theory and discrete-event simulation. The aim of this study is to evaluate and compare the efficiency of these optimization algorithms through simulations of different scenarios at a container terminal in Genoa, highlighting the potential of simulation-optimization methodologies for strategic decisions evaluating which optimization procedure is the most effective for solving real operational problems.

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Quantum Integer Programming for the Capacitated Vehicle Routing Problem

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Abstract. Quantum computing offers new opportunities for tackling combinatorial optimization problems like the Capacitated Vehicle Routing Problem (CVRP) [2], a challenging NP-hard problem in logistics. This study explores quantum optimization techniques [1] for the CVRP using a two-phase heuristic approach (*Clustering* + *Routing*) to minimize qubit usage. The clustering phase leverages *Modularity Maximization*-based algorithms, while the routing phase, formulated as a *Travelling salesman problem*, utilizes adaptive subtour elimination strategies. We evaluate quantum algorithms, including *Adiabatic Quantum Computation, Quantum GAMA, Quantum Approximate Optimization Algorithm*, and *Variational Quantum Eigensolver*, benchmarking them against classical methods like Gurobi. Despite current hardware limitations, results on small instances show the potential of quantum approaches for solving complex CVRP scenarios. Future advancements in quantum hardware may unlock practical solutions for real-world logistics optimization.

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A Parallel Metaheuristic Framework for Very Large Instances of the Capacitated Vehicle Routing Problem

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Abstract. We propose a parallel metaheuristic framework for the Capacitated Vehicle Routing Problem (CVRP) based on the master-slave parallel programming paradigm. The framework is designed to work with any CVRP solution method without requiring synchronization among slave processes. The proposed approach consists of an iterative scheme in which the master process repeatedly assigns a subset of routes to each slave process, each of which runs a predefined metaheuristic for a certain number of iterations. Each time a slave process terminates, it sends back the optimized routes to the master in exchange for a new subset of routes. The core component of our parallel scheme is the routes' selection procedure. Despite the simplicity of this approach, preliminary results on very large-scale instances show that by properly selecting the routes to send to the slave processes, it is possible to obtain state-of-the-art results with roughly linear speed-up.

Multi-Objective VRP Considering Product Quality and Environmental Impact Using Air-Conditioning System

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Abstract. Perishable products are those whose quality is susceptible to degradation when exposed to fluctuating storage conditions. Consequently, effective monitoring during transportation is crucial to prevent such deterioration. In this study, the focus is on the transportation of a specific type of perishable product using refrigerated vehicles. The utilization of these vehicles enables precise regulation of the internal temperature, adjusting it with the ambient temperature at the customer's location. This approach is adopted to mitigate substantial quality loss. Since quality degrades not only at high temperatures, but also at very low temperatures, the air-conditioning system used not only can cool but can also heat the transported product. Notably, the utilization of conditioners requires a greater fuel consumption, leading to higher emission levels. The objective of the proposed model is therefore not only to maximize the quality level of the product delivered to the customer, but also to minimize the environmental impact of the route execution, as well as the cost of routing activities. The problem is formulated as a multi-objective vehicle routing problem, with compatibility constraints and additional restrictions on activating heating or cooling systems. To assess the validity of the proposed model, a series of tests is carried out on both Solomon benchmark instances and test problems derived from a real case study.

Effects of Block Decomposition on Deep Neural Network Training Efficiency

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Abstract. Training deep neural networks is computationally expensive, especially in Big Data settings, driving attention towards the development of more efficient large-scale optimization strategies. Decomposition methods have been proven to be a promising strategy to address this challenge. For this reason, we introduce a decomposed version of CMA Light [1], a watchdog-controlled minibatch algorithm that allows for convergence under mild assumptions while having strong numerical performance. The proposed approach leverages block decomposition over variables to enhance computational efficiency. At each iteration, blocks of variables to be updated are dynamically selected based on heuristics that consider their contribution to optimization process. Preliminary numerical results on Residual Neural Networks (ResNets) on CIFAR-10 and CIFAR-100 datasets demonstrate that this strategy achieves a favorable trade-off between reducing computational cost and maintaining sufficient accuracy.

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A decomposition algorithm for sparse and fair soft regression trees

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Abstract. In supervised Machine Learning (ML) models, sparsity in input features is essential for feature selection, improving interpretability, and possibly enhancing testing accuracy, while fairness measures ensure comparable performance for sensitive groups. We consider decision trees for regression tasks, which are widely used interpretable ML models. In [2] we recently proposed a new variant for Soft Regression Trees (SRTs), which are decision trees with probabilistic decision rules at each branch node and a linear regression at each leaf node. Unlike in the previous SRTs approaches ([3, 1]), in our variant each leaf node provides a prediction with its associated probability but, for any input vector, the output of the SRT is given by the regression associated with a single leaf node. Our SRT variant exhibits the "conditional computation" property (a small portion of the tree architecture is activated when generating a prediction for a given data point) and is well-suited for decomposition. The convergent decomposition training algorithm we proposed in [2] turned out to yield accurate soft trees in short cpu time. In this work we extend the SRT variant and the decomposition training algorithm to take into account model sparsity and fairness measures. Experiments on benchmark datasets indicate that our approach effectively induces sparsity. Computational results show that the decomposition algorithm, adapted to take into account fairness constraints, yield accurate SRTs which guarantee comparable performance between sensitive groups, without significantly affecting the computational load.

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Learning Primal Heuristics for 0–1 Knapsack Interdiction Problems

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Abstract. Knapsack Interdiction Problems (KIP) are NP hard problems of great interest since they model situations where two antagonist forces play against each other by interacting in a leader-follower dynamic. The leader plays first by selecting items to restrict the choices of the follower, while the follower selects those that maximize her profit from the remaining items. In the last decades, several algorithms that can solve these problems have been presented, but they cannot handle large instances in reasonable time. With this work, we build a heuristic that breaks the interdiction constraint and solves two separate linear problems, balancing a low resolution timing with good levels of approximation. We train a Machine Learning model with an InferOpt layer [1], that integrates Combinatorial Optimization problems into ML pipelines with a perturbation approach. We use the output of the pipeline as the cost vector for one of the two linear problems, which are solved exactly and return the approximated solution for the KIP. Through different experiments, we show that the heuristic guarantees low computational time together with small optimality gap.

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Exploring the Potential of Bilevel Optimization for Calibrating Neural Networks

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Abstract. Handling uncertainty is critical for ensuring reliable decision-making in intelligent systems. Modern neural networks are known to be poorly calibrated, resulting in predicted confidence scores that are difficult to use [1]. This article explores improving confidence estimation and calibration through the application of bilevel optimization, a framework designed to solve hierarchical problems with interdependent optimization levels. A self-calibrating bilevel neural-network training approach is introduced to improve a model's predicted confidence scores. The effectiveness of the proposed framework is analyzed using toy datasets, such as Blobs and Spirals, as well as more practical simulated datasets, such as Blood Alcohol Concentration (BAC). It is compared with a well-known and widely used calibration strategy, isotonic regression [2]. The reported experimental results reveal that the proposed bilevel optimization approach reduces the calibration error while preserving accuracy.

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Reinforcement Learning for Dynamic Stochastic Scheduling

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Abstract. The job scheduling problem is one of the most practically relevant scheduling problems and its static version has been the subject of a significant amount of literature in the operations research field: however, this approach is unrealistic in real-world contexts,where the developed schedule is significantly affected by unforeseen events. Therefore, the study of scheduling in the presence of real-time disruption (dynamic scheduling) is attracting increasing attention [1].

This work focuses on dynamic scheduling problem in job shops with new job arrivals at stochastic times, aiming at minimizing the penalties for earliness, tardiness and flowtime, according to the just-in-time policy, based on the idea that early as well as late delivery must be discouraged: a Reinforcement Learning agent-based method for developing a predictive-reactive scheduling strategy is investigated. Specifically, the proposed method involves implementing an event-driven rescheduling policy, wherein the arrival of a new job prompts a rescheduling of the entire timeline from the arrival time onward.

The developed method was tested on a wide range of instances and compared to a simple heuristic, a FIFO agent, and was able to exceed its performance on most instances.

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Q-Learning-Based Iterated Greedy Algorithms for the Dynamic Job Shop Scheduling Problem

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Abstract. This study addresses the dynamic job shop scheduling problem (DJSP) with new job insertions and machine breakdowns. We develop the Q-learning-based iterated greedy (QIG) algorithms to solve the DJSP problem. At first, we apply the QIG algorithm to produce a centralized schedule and then execute this schedule until a dynamic event occurs. Later, the QIG algorithm continuously monitors the current state of the production system and selects actions in response to dynamic events. Since the problem parameters may change depending on dynamic events, we solve a series of new static scheduling problems using the QIG algorithm. We extend the job shop scheduling benchmark instances to the DJSP problem to test the performance of the QIG algorithm. We evaluate the effectiveness of the QIG algorithm in terms of regular criteria, i.e., the total weighted tardiness and the makespan. The computational results indicate that the QIG algorithm provides high-quality applicable solutions to the DJSP problem instead of finding the best solution to the problem as in conventional scheduling problems.

A Mixed-Integer Nonlinear Problem for Voltage Regulation

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Abstract. A very important topic in the energy market is the voltage regulation, which is a particular instance of the alternate current optimal power flow (ACOPF). Since the 1960s, several different approaches have been proposed, but so far we still lack solid and robust solution methods.

In real-time operations, some simplifications are made and the Direct Current OPF is the problem solved. Anyway, the obtained results are not valid for the ACOPF, due to the oversimplifications, so a post-optimization is applied in order to generate suboptimal feasible solutions.

In this work we present the MINLP model for a real-world instance of the ACOPF problem, the peculiarities of our model lie in the objective function and in the handling of discrete setting variables.

Unlike most of the literature instances, we aim to minimize the quadratic deviation from the nominal voltage values. This choice increases the nonconvexities of the problem, making it even harder to be solved. Moreover, we also consider the presence of some nodes with voltage values fixed within a small set of discrete values. We propose two methods to model this and we compare the behavior of commercial solvers in their solution. Since we add integer or discrete variables to our model, the difficulty of the problem further increases.

We also briefly study how different, but equivalent, formulations of the nonlinear constraints modify the performance of the solvers, proposing the most efficient ones.

Capacity and pricing optimization in car rental: a tactical-operative approach

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Abstract. The aim of this work is to support pricing and capacity decisions of a car rental company [1, 3, 2]. We consider the specific scenario of a rental company, with a given number of rental stations. Each rental station is characterized by a given capacity in terms of number of vehicles that compose the fleet. The vehicles can be of different types (e.g. base, medium, and premium). We also consider the rent duration, the rent start and end times, and the booking date. Both tactical and operational issues are addressed. The tactical problem is represented by a mixed integer non-linear programming model (MINLP), whose main aim is to choose, on the basis of the demand occurred in the past and on historical price values, the prices to apply in future periods for each type of request, and the capacity for each class. The possibility to perform relocations of vehicles between stations as well as the possibility of one-way booking is allowed. From the operational point of view, starting from the main findings obtained solving the tactical problem, a policy is developed to satisfy the demand that occurs in real time. Preliminary computational results show the profitability for a car rental business owner of adopting the proposed strategy.

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Optimal gas pipelines operation: sustainability and sector coupling

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Abstract. The study develops comprehensive mathematical approaches to optimize gas pipelines operation and apply the methodology to real-world problems. The objective is to support decision-making of gas Transmission System Operators to minimize the $CO_{2\text{-eq}}$ emissions related to gas compression work. This research improves the level of detail of gas network modelling, incorporating gas transport dynamics, compressors, and control valve operation in a unified framework. We develop a solution strategy combining graph-preprocessing (model reduction), Mixed Integer Linear Programming and Nonlinear Programming with complementarity and smoothing techniques. Additionally, we propose a economic oriented Nonlinear Model Predictive Controller based on stabilizing and cyclic steady-state constraints, which can find a wider application on any periodic process. The methodology is validated with real data, and it is applied to the Italian network, showcasing the potential of the optimization to reduce the $CO_{2\text{-eq}}$ emissions of compression especially when gas operators have less experience. Electro-compressors can leverage periods of low electricity carbon intensity related to high RES production.

A Constraint Disaggregation Method for Structure-Preserving Aggregations in LP Problems: Application to Renewable Energy Grids with Hydrogen Storage

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Abstract. The integration of renewable energy sources into electrical grids has become a critical area of research due to the increasing need for sustainable and resilient energy systems. To address the variability of wind and solar power output over time, electricity grids expansion plans need to account for multiple scenarios over large time horizons, increasing the size of the resulting Linear Programming (LP) problem, making it computationally challenging for large scale grids. To tackle this, we propose an approach that aggregates time-steps to reduce the problem size, followed by an iterative refinement of the aggregation, in order to converge to the optimal solution. Using the previous iteration's solution as a warm start, we introduce and compare methods to select which time intervals to refine at each iteration. The first method selects time-steps based on the proportion of net power production within each interval. We provide a general theoretical justification for its use and sufficient conditions under which an optimal solution of an aggregated linear problem can extend to an optimal solution of the original problem. The second method employs a Rolling Horizon (RH) method to evaluate the feasibility of the aggregated solutions, and selects the time interval on which the validation fails. These selection methods are then compared against a random interval selection approach.

Short-term Adjustment of Train Unit Circulation and Platform Assignment: A Branch-and-Check Method

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Abstract. This paper investigates the integrated adjustment of the Train Unit Circulation Plan (TUCP) and Train Platforming Plan (TPP) in response to short-term passenger demand. Considering a set of mandatory trips and flexible trips that may be either canceled or implemented, the objective is to minimize operating costs while accommodating extra trips, adhering to train unit maintenance constraints, and ensuring that platform assignments deviate as little as possible from the original plan. We propose an Integer Linear Programming model and an exact decomposition algorithm based on the *Branch-and-Check* framework, which extends the classical Benders decomposition method. The algorithm incorporates problem-specific acceleration techniques to reduce the search space and effectively guide the search process. The proposed model and algorithm are tested on instances derived from China's high-speed railway system, demonstrating that the decomposition algorithm significantly outperforms directly solving the problem by using a commercial solver, and showing the effectiveness of the acceleration techniques. Comparisons with the sequential optimization method—which addresses the TUCP and TPP in sequence—highlight the advantages of integrating these two problems while accounting for platform deviation penalties. Finally, the stability of the algorithm is further validated through experiments varying the number of flexible and extra trips in large-scale instances involving approximately 1000 trips and 100 train units.

An Integer Programming Model for the Dynamic Airspace Configuration problem

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Abstract. Given the relevance of aviation as a transportation network and its remarkable economic impact, the air traffic demand is bound to increase. High traffic density in a given airspace region can cause safety issues and difficulties in monitoring tasks that can, in turn, result in flight delays. It is therefore crucial to efficiently organize the airspace structure to avoid under- and overloaded areas of the airspace. We begin by describing the airspace structure, introducing the concept of sector and configuration, and how to quantify the air traffic excess associated to a configuration. We will then introduce the Dynamic Airspace Configuration problem as the problem of determining a sequence of configurations (configuration plan) that optimally meets the air traffic demand; such a sequence must also satisfy some operational restrictions that smooth the configuration dynamics, as to avoid, e.g., too frequent switching between configurations. We propose an Integer Linear Programming model that provides a configuration plan that minimizes the traffic excess for a given time frame and present a polyhedral study that explains its good computational performance. We extend the computational results in [1], obtained by testing the model on five days of historical data over the Madrid Area Control Center. Our results focus on the comparison of different time discretizations and different restrictions on the configurations' transitions, highlighting the advantages of our approach with respect to current practice.

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The Flying Dial-A-Ride Problem for Urban Air Mobility

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Abstract. Recently, the adoption of flying cars for air taxi services has garnered significant attention due to their potential for enhancing urban mobility and sustainability. Efficient routing and scheduling of flying vehicles are needed to enable their implementation. Although existing studies have progressed in tackling basic problems for flying cars ([1, 2]), critical operational challenges, such as temporal synchronization between vehicles performing operations at the same landing pad, are still overlooked.

In this work, we introduce the *The Flying Dial-A-Ride Problem* to address these gaps. First, to capture the problem's complexities, we propose two compact models and a trip-based model. Then, we design an exact algorithm strengthened with decomposition techniques for the latter. Finally, we conduct computational experiments using real-world taxi data to derive managerial insights and offer practical guidance

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A Solution Approach for Optimizing Train Unloading Operations

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Abstract. In maritime container terminals, optimizing train unloading processes is essential for enhancing efficiency and reducing operational costs. The process of unloading a train at a maritime container terminal involves removing containers from the train and transferring them to the terminal for further handling, storage, or preparation for loading onto ships. This operation is carried out using specialized cranes, which unload the containers from the train wagons. The containers are then positioned on handling equipment for transfer within the terminal, where they are either stored or prepared for shipment [1]. This study focuses on unloading a single train and assigning containers to export yard for onward shipping. A Mixed-Integer Linear Programming (MILP) approach is proposed to minimize gantry crane movements, adjustments to its spreader length, and the total movements of reach stackers during container assignments. The model ensures container assignment to yard blocks follows size, weight, and destination constraints while coordinating the operations of cranes and reach stackers. Given the challenges faced in solving small-sized instances, we are considering adding cuts and a heuristic to improve computational efficiency. The resulting decisions can be integrated into a terminal operating system (TOS) as work queues to support unloading operations. Preliminary results will be presented to demonstrate the effectiveness of the proposed approach in achieving these objectives.

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How to Apply the Concept of Fragility in a Tactical Timetabling Process

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Abstract. In a typical timetabling process, route planners are tasked to build a timetable for the next months or year. This process usually involves starting from an existing timetable and manually adjusting it through a time-consuming trial-and-error approach. To cope with increasing traffic demand, railway companies require effective decision support systems to guide practitioners throughout their decision-making process. While several robustness measures have been proposed, many overlook the impact of dispatching decisions on knock-on delays, limiting their real-world applicability. This work introduces a fragility-based approach to timetable design, drawing inspiration from the fragility concept recently proposed by [1] as a way to identify the sections of a timetable where a primary delay is more likely to generate knock-on delays. Our approach focuses on identifying the most critical sections of a timetable and reducing their fragility to build a new and more robust timetable. Considering real-life scenarios from a Norwegian railway line, we are able to improve the fragility of a timetable, even when considering conservative strategies for possible improvements.

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An improved (strongly polynomial) combinatorial algorithm for the nucleolus in Convex Games

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Abstract. Horizontal Collaboration is the cooperation of two or more agents that operate at the same level of the supply chain. This field is gaining attention for its possible economic and environmental impact [3]. Collaborative Game Theory emerges as a natural theory to address it, offering modeling tools and sound solution concepts, such as the nucleolus. However, when a large number of agents is involved, also computational aspects have to be taken into account.

Convex games are cooperative profit games characterized by supermodular pay-offs [4] that can efficiently model some relevant Horizontal Collaboration settings. Maschler, Peleg, and Shapley [2] investigated the structural properties of the nucleolus in these games, proposing a natural (non polynomial) method to iteratively reduce its computation to a sequence of so-called stage or reduced games. In 1996, Kuipers [1] claimed to have developed a polynomial-time algorithm for a variant of this approach.

We independently developed a similar variant, only later learning about Kuipers' unpublished and challenging-to-access paper. Our approach simplifies the methodology and improves computational efficiency.

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Matheuristic Approaches for a Practical Flow–Shop Scheduling Problem

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Abstract. This study considers a practical *Flow-Shop Scheduling Problem* (FSSP), motivated by a real-world industrial case from Filtrec S.p.A., an Italian filter manufacturer. Even though real-world applications of FSSP frequently involve various complexities such as flexible flow-shop structure with multiple parallel machines per stage, unrelated machines, machines dedicated to multiple stages, machine-job compatibilities, sequence-dependent setup times, and job due dates, combined effects of these complexities are underexplored in the literature. To address this research gap, we first present a *Mixed Integer Linear Programming* (MILP) model capable of representing the aforementioned complex factors with the objective criterion of average tardiness minimization. Then, to mitigate the computational complexity of the problem and to construct schedules for large instances, we develop a matheuristic method in which we use a novel job prioritization approach and solve two variants of the aforementioned MILP model which minimize the average tardiness and the total completion time, respectively. Finally, we evaluate the performance of the proposed matheuristic over various sets of instances derived from actual data. We show that our approach is generally able to obtain small average tardiness values in the resulting schedules.

A Generalized Fast Krasnoselkii–Mann Method with Application to Optimal Transport

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Abstract. We present a novel Fast Krasnoselskii–Mann-type method that maintains the fast $o(k^{-2})$ convergence rate on the fixed-point residual while allowing for twice larger step sizes. This method reveals an intriguing connection between Nesterov and Halpern acceleration mechanisms, and offers a unified algorithmic framework to accelerate a wide range of splitting algorithms. We show that the enhanced parameter flexibility provides an efficient solution to solve Monge–Kantorovich optimal transport problems.

Branch-and-bound Algorithms as Polynomial-time Approximation Schemes

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Abstract. Despite an extensive practical use of branch-and-bound algorithms, our understanding of their theoretical performance still has significant gaps. We intend to expand the knowledge by showcasing an interesting connection between B&B algorithms and the theory of approximability. We will consider two famous family of problems in combinatorial optimization, the Knapsack Problem ([1]) and the Parallel Machine Scheduling Problem ([2]). Building on the work of Finkel'shtein ([3] and [4]), we show that a certain natural branch-and-bound algorithm yields a polynomial-time approximation scheme for the Multiple Knapsack Problem. Using a similar idea, we exhibit a B&B algorithm for the Unrelated Machine Scheduling problem that turns out to be a PTAS as well. Next, we employ common input-rounding techniques to obtain a fully polynomial-time approximation scheme for a relaxed version, the Uniform Machine Scheduling problem. Finally, we add another layer to the theoretical knowledge by showing that the latter algorithm generalizes the standard dynamic programming approach frequently used for machine scheduling problems.

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Branch-and-cut algorithms for colorful components problems

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Abstract. We aim to partition a node-colored graph into *colorful components*, namely, connected subgraphs whose vertices have different colors from others in the same component. We address this problem with three different objectives, according to which we: *(i)* minimize the number of removed edges; *(ii)* minimize the number of connected components; or *(iii)* maximize the number of edges in the transitive closure of the output graph. These problems have applications in community detection, cybersecurity, and bioinformatics. We present integer non-linear formulations, which are then linearized using standard techniques. To solve these formulations, we develop exact branch-and-cut algorithms, embedding valid inequalities, bounds limiting the number of variables, and warm-start and preprocessing techniques. Benchmark instances are tested to computationally demonstrate the effectiveness of the proposed procedures.

The Covering Tour Problem with Path Upgrades

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Abstract. This work introduces the Covering Tour Problem with Path Upgrades (CTPU), where the objective is to find a minimum-cost tour on a graph while ensuring coverage for all non-tour nodes. Unlike the classical Covering Tour Problem [1], the CTPU exploits arc upgrades within a specified budget, enabling multiple paths to share upgraded arcs. This allows several nodes to gain coverage from a single upgrade, extending coverage to previously unreachable nodes. To address the CTPU, we propose several Mixed-Integer Linear Programming formulations with different strategies to prevent subtours. Additionally, we introduce families of valid inequalities to strengthen these formulations and improve computational performance. For formulations with exponentially many constraints, we develop alternative versions of a Branch-and-Cut (B&C) procedure. Computational experiments show the methods' efficiency and the impact of valid inequalities and the B&C procedure on solution quality and computation time.

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Contributed Abstracts – Posters

A solution method for the Train Dispatching Problem

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Abstract. During operations, unexpected events may cause the infeasibility of the original train schedule. In this case, the Train Dispatching Problem (TDP) has to be solved: it consists in rescheduling trains by applying retiming, reordering and rerouting strategies to avoid train conflicts and minimize delays.

TDP has been deeply investigated in the literature and in practice. Recently, the DISPLIB library of benchmark instances [1] has been made available for the DISPLIB competition to allow the comparison of different methods on TDP. In this competition, a set of trains is given and, for each train, a sequence of operations is provided, each one using several resources, having a minimum duration and lower and upper bounds on the time instant at which the operation can start. Due to safety rules, each resource can only be allocated to one train at a time. In addition, a release time is needed after the resource can be used by another train. The goal is to minimize train delays expressed through linear penalties and step functions.

An effective mathematical model for real-time train rescheduling is RECIFE-MILP proposed by [2]. In this work, we investigate how to adapt RECIFE-MILP and combine it with a heuristic algorithm to tackle the TDP as defined in the DISPLIB competition.

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A novel Minibatch Algorithm for large-scale optimization

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Abstract. In this work, we address the problem of developing an optimization algorithm suitable for the training of deep learning models, which involves the minimization of unconstrained objective functions. Specifically, we propose a novel mini-batch-based optimization algorithm that incorporates a linesearch technique to adaptively compute the optimal step size. The linesearch method employs a stochastic version of the objective function, significantly reducing computational costs while maintaining accuracy. Extensive numerical experiments on a variety of deep learning tasks, including classification and regression problems, demonstrate the effectiveness and efficiency of the proposed approach. The results highlight the potential of this method for large-scale optimization in deep learning applications.

Weight-splitting upper bounds on the edge-weighted clique number of a graph

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Abstract. The Edge-Weighted Maximum Clique Problem (EWMCP) is a generalization of the maximum clique problem which seeks to find a clique that maximizes the total weight of its edges. The edge-weight splitting bound is an upper bound to the optimal solution value of the EWMCP, obtained by dividing and assigning the weight of each edge to its endpoints, and then solving the Vertex-Weighted Maximum Clique Problem (VWMCP) on the resulting graph. We propose a bilevel formulation to compute the best possible splitting of the edge weights, and hence the tightest possible upper bound to the optimal solution value, which we refer to as optimal edge-weight splitting bound. We then derive a linear programming reformulation of the bilevel problem, having exponentially many constraints, called Edge-Weight Splitting inequalities (EWS). We solve this reformulation in a cutting plane fashion, separating the EWS inequalities via the solution of a series of VWMCPs. We finally study the theoretical properties of the optimal edge-weight splitting bound, and extensively test it on a set of standard benchmarks used in the literature and simulated instances, examining the gap relative to their actual optimal solutions. Results show that, while from a theoretical point of view the optimal edge-weight splitting bound can be arbitrarily weak, in practice it guarantees good performances and significant gap reductions with respect to the lower bound provided by the linear relaxation of the natural formulation of the problem.

Profitability and sustainability in complex chemical value chains under product-specific carbon footprint constraints

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Abstract. The global effort to combat climate change has led many countries to adopt legally binding net-zero targets for the next 25–30 years. Since indirect emissions are also considered, a key strategy for companies is to require suppliers to produce cleaner products by meeting strict emissions standards per unit or weight. This study introduces the Product-Specific Carbon Footprint Optimization (PSCFO) problem, a deterministic multi-objective value-chain model aimed at minimizing CO_2 emissions while maximizing a company's total contribution margin. The objective is to achieve these goals while ensuring compliance with external customer demands for product-specific carbon footprint limits. To address the PSCFO problem, we propose a bilinear programming model using a "flow-like" formulation based on existing models from [1] and [2].

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Operating room scheduling with fair workload and proper training for residents

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Abstract. This work addresses the challenges of healthcare management in Operation Research. Common scheduling criteria typically aim to maximize the number of scheduled patients while considering their urgency and waiting times, optimize operating room utilization in order to minimize idle periods and overtime, and ultimately reduce costs [2, 3, 4, 5]. However, research on how workload balance can improve patient service quality is relatively limited [1] and even more if we consider trainees hours. In this work a multi-objective Mixed Integer Linear Programming (MILP) model is proposed to handle surgical case assignment and sequencing scheduling from a fairness perspective. It ensures balanced working hours for surgeons and residents while fostering progressive training opportunities for the latter, including diverse procedures and defined objectives for skill advancement.

To address the uncertainty of Real Operating Times (ROTs), various Machine Learning techniques are compared using common metrics such as Mean Absolute Error, Root Mean Squared Error, and R^2, as well as by evaluating the quality of the resulting optimized schedules. Due to the computational complexity of the MILP model, a metaheuristic is introduced to deliver near-optimal solutions significantly faster than general-purpose solvers. Applications in the Vascular Surgery department of the Città della Salute e della Scienza hospital in Turin demonstrate promising results, with operating room utilization rates increasing from 55% to 80%. While specifically tailored for this hospital, the model can be easily adapted to other contexts by adjusting the weights of the objective function or model parameters.

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OR Applications: Optimal Data Hiding in Radiographic Images

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Abstract. Data hiding in digital objects comprises a set of frameworks, methods and algorithms [3] aimed at embedding information into digital audio, images, etc. A large class of image watermarking algorithms operates on the intensity level histogram exploiting the image redundancy modifying pixel intensities to embed information called *payload*.

Histogram shifting represents a family of methods that operate in the spatial domain by modifying pixel intensity levels in appropriate portions of the image histogram to insert payload data. Ideally, the parts to be used are those characterized by a *high peak level* next to a *zero level*; this approach is well-suited for radiographic images where only a subset of gray levels is used, giving the histogram a “comb” structure. In [1], for example, the payload was embedded using a *local* maximization algorithm.

In our most recent work [2] we proposed a combinatorial optimization procedure that considers all the contiguous zero-runs, in order to take into account the *global* characteristics of such “comb” structure. This approach applies to the image histogram an optimal shifting strategy that maximizes the total payload.

Obtained results showed that our approach has a better performance than the known algorithms in the literature. Hence, the presented work became the new reference for data embedding in images having the aforementioned characteristics.

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Design and Prototype of a Smart Sorting System Integrating Image Processing with Deep Learning and Weight-Based Classification

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Abstract. The integration of automated systems in industrial processes offers numerous advantages, such as improved efficiency, precision, and cost reduction. Unlike human labor, automated sorting systems can operate continuously without fatigue, ensuring consistent performance and high repetition accuracy. Machine vision and deep learning technologies have revolutionized sorting applications by enabling non-contact measurement and real-time decision-making. These technologies are widely applied in various industries, including agriculture, logistics, and food processing. This research focuses on developing a dual-section sorting system for industrial fish processing. The system incorporates a vision-based sorting module, which uses a camera to capture images and classify objects using a trained deep learning model, and a weight-based sorting module, which utilizes a load cell and servo mechanism to categorize fish based on their weight. By combining these two complementary methods, the proposed system enhances sorting speed and accuracy, making the packing and sorting process more efficient. This prototype provides a promising solution for industrial automation, with potential applications in diverse fields requiring intelligent sorting systems.

A Multi-Period Hydrogen Refuelling Station Location Problem

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Abstract. Infrastructure location problems arise in various sectors, including transportation, and become particularly complex when introducing new technologies [2]. This study addresses the placement of hydrogen refueling stations (HRS) in railway networks, a critical step for advancing hydrogen propulsion. The problem requires an interdisciplinary approach, incorporating operations research and logistics [1]. While sensitivity analysis assesses input uncertainty, stochastic programming and scenario-based planning better integrate it into decision models. We propose the Multi-Period Hydrogen Refueling Station Location Problem for Railways (MPHRSLPR), modeled as a Mixed-Integer Linear Program (MILP). It optimizes station placement over a 15–30 year horizon, minimizing total investment and operational costs while meeting hydrogen demand. The approach is validated using case studies from the Wielkopolska region in Poland.

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Cost Optimization in Bicycle Networks

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Abstract. The promotion of sustainable transportation modes, such as cycling, has emerged as a crucial aspect of urban planning and design. The design of an efficient bicycle network is a complex optimization problem that requires analysis of different factors including infrastructure layout, connectivity, safety, and accessibility. In addition, the fastest routes are not always the preferred options for cyclists, who consider different criteria when choosing the best routes from their origin to their destination. Therefore, the aim of this study is to propose an optimization strategy to build the most suitable bicycle network for the city of Parma, Italy, given a set of possible interventions (e.g., build a bicycle lane, improve the quality of existing lanes, etc.) that could be applied by the municipality considering a limited budget. In this strategy, firstly, we conduct an analysis to define a set of user profiles, where each profile corresponds to a combination of different criteria used by the cyclist to choose a route, such as shortest time, safety, and practicability. After this analysis, we optimize the overall cost perceived by the users aiming at moving from different origins to different destinations in the city, considering their profiles already determined. To address this problem, we propose branch-and-bound and dynamic programming methods, as well as two heuristic procedures. We validate all proposed methods using randomly generated data, considering graphs to represent the network with up to 1600 vertices, while the collection of real data regarding the city of Parma is being finalized.

A Graph-Based Football League Scheduling Problem

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Abstract. Sports scheduling assigns dates and venues for games, but multiple constraints make it complex [2]. Teams face limits on consecutive home or away matches, and schedules must be set three rounds in advance. Scheduling affects fair play, club operations, security, and broadcasts. A key challenge is matchweek scheduling (Friday–Sunday) with fixed timeslots and a 2-hour-30-minute gap between games. Factors like audience interest, home advantage, and fan relationships optimize scheduling. The Football League Scheduling Problem is NP-hard, requiring heuristics and metaheuristics. This study presents a graph-based scheduling model, representing match pairs as graph nodes, to find a feasible season-long path [1]. The approach is tested on Poland's 1st football league.

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Machine Learning for re-optimization: A pipeline to efficiently tackle Vehicle routing problem with time windows when demand variations occur

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Abstract. In industrial settings, optimization problems like the Vehicle Routing Problem (VRP) frequently recur with similar characteristics, where only a few parameters of solved instances vary while most features remain constant. This research proposes a data-driven approach using Machine Learning (ML) to enhance the efficiency of solving such recurring instances by leveraging historical data patterns. A comprehensive ML pipeline has been developed to capture patterns in recurring VRP instances, encompassing the generation of artificial instances, feature extraction, and training of predictive models to forecast key aspects of optimal solutions. The experimental results demonstrate high accuracy in predicting critical solution features, such as the required number of vehicles, suggesting potential applications in enhancing optimization processes for recurring problem instances. The results of this study demonstrate how machine learning can complement traditional optimization methods by learning from past solutions, opening new perspectives for improving optimization processes in recurring operational contexts.

A Gradient Method with Momentum for Riemannian Manifolds

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[*]Presenting author

Abstract. In this work we consider smooth optimization problems on Riemannian manifolds [1, 3] and we propose gradient methods with momentum. Convergence results are established and computational experiments are performed. The obtained computational results show the validity of the proposed approach that extends that recently presented [2].

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Approximation and exact penalization in simple bilevel variational problems

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Abstract. In this talk we analyse a simple bilevel problem, where the lower-level is a monotone variational inequality and the upper-level is a convex optimization problem. Regularity is gained by adding a given degree of inexactness to the lower-problem and allows us to leverage techniques of exact penalization, bounding the growth of the penalization parameter. The resulting penalized problem relies on the reformulation of the lower-level through the Minty gap function, that we approximate with cutting planes techniques. We devise different algorithms to treat the affine and non-affine cases, we discuss their convergence and provide theoretical bounds on the final degree of inexactness. Numerical results are reported for the non-affine case to test the sensitivity of the problem to several parameters, showing that the true final inexactness is generally meaningfully lower than the theoretical one.

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