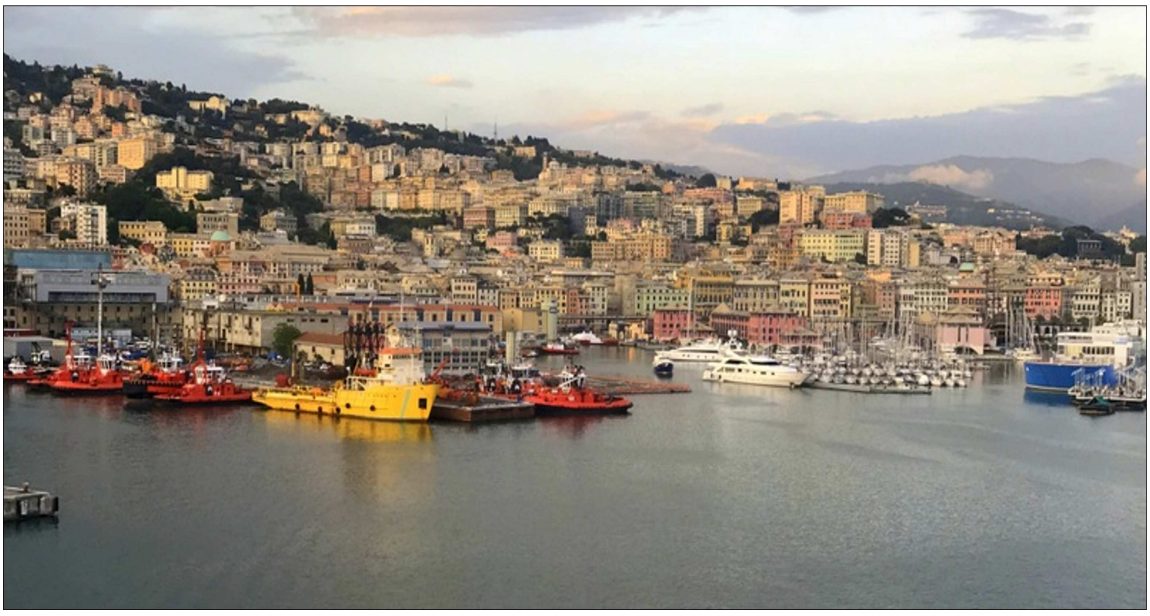
ODS 2019



International Conference on

Optimization and Decision Science

XLIX Annual Meeting of AIRO - Italian Operations Research Society

AIRO

ASSOCIAZIONE ITALIANA DI RICERCA OPERATIVA

Genova, 4-7 September, 2019
Department of Economics and Business Studies
Via Vivaldi, 5 (Darsena)

Book of Abstracts

Preface

Operations Research (OR) is known as the discipline of optimization applied to real-world problems and to complex decision making fields. The focus is on mathematical and quantitative methods aimed at determining optimal or near-optimal solutions. OR has a wide range of applications proving the inter-disciplinarity of its solving approaches, methodologies and tools. Referring to the present book, we find both applications and theoretical results in the following different fields and areas: Smart Port Terminal Operations; Data Exploitation: Methods and Applications; Financial Modeling; Optimization in Public Transport; Optimization in Machine Learning; Support to Industry 4.0 and Smart Manufacturing; Health Care Management and Planning; Data Analytics and Optimization; Technology Transfer: From Data to Actionable Knowledge; Scheduling; Equilibrium Problems, Variational Models, and Applications; Mixed Integer Programming; OR Teaching; Transportation Networks Performance and Reliability; Nonlinear Optimization and Applications; VRP and Related Problems; Stochastic Programming: Optimization Under Uncertainty and Applications; Drone Applications; Optimization in Eco-Sustainable Transportation; Rail Port Operations; New Last-Mile Transportation Paradigms Under Clever Resource Usage and Prominent Technologies; Combinatorial Optimization; OR Applications in Routing; Inventory; Graphs; Travelling Salesman and Arc Routing Problems; Optimization in Telecommunication Networks and Queueing Systems; Optimization for Sustainable Energy Systems; Logistics; Game Theory.

ODS2019, International Conference on Optimization and Decision Science, is the XLIX annual meeting organized by the Italian Operations Research Society (AIRO) in Genova, Italy, September 4th – 7th, 2019, in cooperation with the Department of Economics and Business Studies (DIEC) and the Department of Informatics, Bioengineering, Robotics, and Systems Engineering (DIBRIS) of the University of Genova. The conference is held at **DIEC**, Via F. Vivaldi, 5 – Darsena – 16126 Genova, Italy. ODS2019 has attracted academics and practitioners from private and public companies and industries thus highlighting the strict relationship between OR and its applications. The Conference participants are more than 200 researchers from 26 different countries, representing Europe, North and South America, and Asia, witnessing the international character of the conference.

The book contains the abstracts of the scientific contributions accepted for presentation. The order of the abstracts in the book corresponds to the order of presentation in the conference programme. The short papers corresponding to the abstracts marked with a star in the title have been accepted for the publication in the ODS2019 Special Volume of the AIRO Springer Series "Advances in Optimization and Decision Science for Society, Services and Enterprises". All the contributions were accepted for presentation at the conference after a peer-review process by experts in OR and related fields belonging to the Program Committee. Despite the fact that this book is a list of abstracts and does not contain the core results of the single researches, it provides a realistic and current picture of the state-of-the-art of modern research in the field of OR.

This book has been edited by the Organizing Committee of the conference.

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Programme at Glance

Wednesday - September $4^{th}, 2019$

11:00-13:30	**Registration**			
Room	**Embriaco**			
13:45-14:30	**Opening Session**			
Room	**Embriaco**	**Caffaro**	**Doria**	**Boccanegra**
14:30-16:30	W1 Smart Port Terminal Operations - 1	W2 Data Exploitation: Methods and Applications	W3 Financial Modeling	W4 Optimization in Public Transport (AIRO-OPTSM Chapter)
16:30-17:00	**Coffee break**			
Room	**Embriaco**			
17:00-18:00	**Plenary Lecture - Paolo Signorini**			
18:00-18:30	**Walking transfer to Palazzo San Giorgio**			
	Palazzo San Giorgio - Sala dei Capitani			
18:30-20:00	**Round Table** **Resilience and Management of Emergencies in Logistic Networks**			
	Palazzo San Giorgio - Portico			
20:00-22:00	**Welcome Cocktail**			

Thursday - September 5^{th}, 2019

Room	Embriaco	Caffaro	Doria	Boccanegra	Fieschi
8:30-10:30	T1 Optimization in Machine Learning - 1	T2 OR Support to Industry 4.0 and Smart Manufacturing - 1	T3 Health Care Management and Planning - 1	T4 Data Analytics and Optimization	Software Demo
10:30-11:00	**Coffee break**				
Room	**Embriaco**	**Caffaro**	**Doria**	**Boccanegra**	**Fieschi**
11:00-13:00	T5 Optimization in Machine Learning - 2	T6 OR Support to Industry 4.0 and Smart Manufacturing - 2	T7 Health Care Management and Planning - 2	T8 WORKSHOP OR Towards Technology Transfer: From Data to Actionable Knowledge	Software Demo
13:00-14:00	**Lunch**				
Room	**Embriaco**				
14.00-15.00	**Plenary Lecture - Nello Cristianini**				
Room	**Embriaco**	**Caffaro**	**Doria**	**Boccanegra**	**Fieschi**
15:00-16:30	T9 (AIRO)Young Reserchers in Machine Learning and Operations Research	T10 Scheduling	T11 Equilibrium Problems, Variational Models, and Applications - 1	T12 WORKSHOP OR Towards Technology Transfer: From Data to Actionable Knowledge	Software Demo
16:30-17:00	**Coffee break**				
Room	**Embriaco**	**Caffaro**	**Doria**	**Boccanegra**	**Fieschi**
17:00-18:30	T13 Mixed Integer Programming	T14 OR Applications - 1	T15 Equilibrium Problems, Variational Models, and Applications - 2	T16 (AIRO)Young Tutorial Session: Young OR Specialists in the Industry - Experiences, Tips, and Panel Discussion	Roundtable: Comparing the Contents of the OR Courses in Italian Universities
19:30-23:00	**Social Event: ODS Sport - Beach Volley Tournament**				

Friday - September 6^{th}, 2019

Room	Embriaco	Caffaro	Doria	Boccanegra
8:30-10:30	F1 Smart Port Terminal Operations - 2	F2 Transportation Networks Performance and Reliability	F3 Nonlinear Optimization and Applications - 1	F4 VRP and Related Problems
10:30-11:00	**Coffee break**			
Room	**Embriaco**	**Caffaro**	**Doria**	**Boccanegra**
11:00 -13:00	F5 Sochastic Programming: Optimization Under Uncertainty and Applications	F6 OR for Drone Applications	F7 Nonlinear Optimization and Applications - 2	F8 Optimization in Eco-Sustainable Transportation
13:00-14:00	**Lunch**			
Room	**Embriaco**			
14:00-15:00	**Plenary Lecture: Bruce Golden**			
Room	**Embriaco**	**Caffaro**	**Doria**	**Boccanegra**
15:00-16:30	F9 Rail Port Operations	F10 New Last-mile Transportation Paradigms Under Clever Resource Usage and Prominent Technologies	F11 Combinatorial Optimization	F12 OR Applications in Routing
16:30-17:00	**Coffee break**			
17:00-18:30	**AIRO Meeting**			
From 18:00	**Visit to Genova Cathedral (two rounds)** **Social Dinner at "Chiostro di San Lorenzo"**			

Saturday - September 7^{th}, 2019

Room	Embriaco	Caffaro	Doria	Boccanegra
8:30-10:30	S1 OR Applications - 2	S2 Inventory	S3 Graphs	S4 Travelling Salesman and Arc Routing Problems
10:30-11:00	**Coffee break**			
11:00-12:30	S5 Optimization in Telecommunication Networks and Queueing Systems	S6 Optimization for Sustainable Energy Systems	S7 Logistics	S8 Game Theory
12:30-13:00	**Closing Session**			
15:00-19:00	**Social Event: Boat Trip to Paradiso and Tigullio Gulfs**			

Contents

Wednesday - September 4^{th}, 2019 Embriaco Room 17:00 - 18:00

Plenary Lecture 1: The Role of Port Authorities in the Management of Complex Maritime Clusters: The Ports of Genoa Case Study

Paolo Emilio Signorini
President of Ports of Genova, info@portsofgenoa.com

Chair: **Anna Sciomachen**

Thursday - September 5^{th}, 2019 Embriaco Room 14:00 - 15:00

Plenary Lecture 2: Things to Keep in Mind when Designing Intelligent Agents

Nello Cristianini
University of Bristol, nello.cristianini@bristol.ac.uk

Chair: **Marcello Sanguineti**

Friday - September 6^{th}, 2019 Embriaco Room 14:00 - 15:00

Plenary Lecture 3: The Power of Linear Programming: Some Surprising and Unexpected LPs

Bruce Golden
University of Maryland, bgolden@rhsmith.umd.edu

Chair: **Daniele Vigo**

W1: Smart Port Terminal Operations - 1

Chair: **Walter Ukovich**

New ILP Formulation for the Multi-Day Container Drayage Problem

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Abstract: We present a new Integer Linear Programming (ILP) formulation for a general Multi-Day Container Drayage Problem (MDCDP) that consists in assigning trucks to container transportation tasks during several days. The model describes real-world problems taking their particular issues into account: different types of tasks, different types of containers, a heterogeneous fleet of trucks, the rest periods of drivers and so on. This new formulation is an improvement of a previously published formulation: it considers a more realistic objective function and fixed rest periods of drivers. As a consequence, the number of variables is quite reduced and so the new model can be more easily solved with standard solvers. Finally, computational tests on randomly generated instances are presented in order to illustrate the benefits of the new ILP formulation. In particular, it turns out that computational times for the new model are an order of magnitude lower than the previous formulation.

Keywords: Container Drayage Problem, Integer Linear Programming Formulation, Multi-Day Planning Horizon

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A Receding Horizon Approach for Berth Allocation Based on Random Search Optimization*

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Abstract: An approach to address the berth allocation problem is presented that is based on the receding horizon paradigm. In more detail, berthing decisions are computed by solving an optimization problem at each time step aimed at minimizing the waiting times of vessels exploiting predictions on the ship arrivals and berth occupancy over a moving window starting from the current time instant. A discrete time dynamic model is devised to forecast the state of the terminal in the forward window, and a computationally-efficient approximate solution method based on random search is proposed. The considered framework can be used either for real time planning or scheduling in advance. Simulation results are reported to show the effectiveness of the method indifferent terminal configurations, forward horizons, and traffic intensities, in comparison with state-of-the-art approaches.

Keywords: Berth Allocation, Receding Horizon, Random Search Optimization

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Integrating Ship Movement Scheduling and Tug Assignment within a Canal Harbor*

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Abstract: In this paper we address the in-port ship scheduling and tug assignment problem. This problem aims to determine a schedule of ship movements, and their escorting tugs, within a canal harbor. We formulate the problem as a Boolean satisfiability problem. In particular, we deal with canal-harbors, as this kind of harbors present strict constraints, e.g., on safety distance. We consider the Port of Venice, a medium size Italian harbor, as a case study.

Keywords: Ship Scheduling, Tug Assignment, Locomotive Scheduling Problem, Boolean Satisfiability

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Optimization Requirements in Intermodal Transportation: Business Cases Emerging from the Market

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Abstract: Transportation and logistics sectors are complex systems fundamental for the economic development but, at the same time, source of negative externalities such as pollution, congestion, etc. In these sectors, the operators are requiring even more ICT solutions enabling supply chain data visibility and optimization in order to maximize traffic volumes, profits, efficiency. Among the most common optimization problems there are the booking acceptance management, the definition of transport services (multimodal transport for both import and export containers) and the assignment of a transport service to each booking. This work aims to briefly present a state of the art of intermodal transportation optimization requirements currently emerging from the market.

Keywords: ICT Solutions, Intermodal Transportation, Optimization Requirements

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Three Approaches for a Multiperiod Drayage Problem

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Abstract: We investigate a routing problem arising in the domain of drayage operations, i.e., the distribution of containers around ports. Each customer demands the pick-up and/or delivery of a given number of containers, possibly providing some flexibility about the time at which they have to occur. Two types of trucks are available to perform these drayage operations: one-container and two-container ones, with different costs. The objective is to determine vehicle routes for each period such that the overall routing costs are minimized. We contribute to the problem in several ways. First, we adapt a set covering model proposed in the case of single period planning horizon, which is solved either with all feasible routes by an off-the-shelf MIP solver, or by and a Price-and-Branch algorithm in which the pricing problem is a formulated as a collection of shortest path problems in tailor-made auxiliary acyclic networks. Next, we propose a new arc-flow formulation based on the previous auxiliary networks, and we show that solving it by a MIP solver is usually preferable (besides being simpler) to all previous approaches. Finally, the remarkable effectiveness of the last formulation allows us a broad set of experiments which characterize how possible changes in flexibility levels affect routing costs, possibly allowing carriers to fine-tune flexibility incentives for their customers.

Keywords: drayage, modeling, reformulations

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W2: Data Exploitation: Methods and Applications

Chair: **Giuseppe Stecca**

The Maximum Nearby Flow Problem*

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Abstract: We present a new Linear Programming model that formulates the problem of computing the Kantorovich-Wasserstein distance associated with a truncated ground distance. The key idea of our model is to consider only the quantity of mass that is transported to near by point sand to ignore the quantity of mass that should be transported between faraway pairs of locations. The proposed model has a number of variables that depends on the threshold value used in the definition of the set of nearby points. Using a small threshold value, we can obtain a significant speedup. We use our model to numerically evaluate the percentage gap between the true Wasserstein distance and the truncated Wasserstein distance, using a set of standard grey scale images.

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Extending the Potential-Based Measure of Efficiency to Multiperiod Data

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Abstract: Data Envelopment Analysis (DEA) is a well-known non-parametric methodology for assessing the relative efficiency of organizational units. Recently, a potential-based measure of efficiency (PBM) has been proposed based on the minimization of an efficiency potential function that assigns to each operating point a scalar value that reflects its potential for efficiency improvement. In this research, PBM is extended to the case of multiperiod data using a contemporaneous approach. An efficiency score for each period and a global PBM score for the whole period can be computed. Both can be decomposed as the product of the partial efficiency scores of each input and output dimension in each period and in the whole period, respectively.

Keywords: Data Envelopment Analysis, Multiperiod Data, Efficiency Potential

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A New Methodological Perspective for Classification Model Selection

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Abstract: The aim of this work is to propose a new performance measure for classification problems. ROC Curves and related measures, as the Area Under the ROC Curve, are typically adopted to select the best model in classification predictive analytics. It is recognized that when ROC Curves cross, the selection of the best model is an open point of research. In fact, the weakness of the AUC index is that it should not be applied when ROC curves intersect, because in these cases the AUC index can lead to conclusions that misrepresent the performance of the model. Furthermore these situations are really common in real world applications. In this contribution a new idea for model selection is proposed inside the threshold-indipendent framework. More precisely our idea considers to relate the probability estimated by each model and the observed class in a functional perspective. This function, opportunely defined, is compared with the one representing the perfect classification through a functional distance. This leads to the definition of an index that quantifies the distance from the optimal model. Furthermore this distance is weighted in an appropriate way, i.e. considering the dispersion of the errors with respect to the estimated probabilities. The approach proposed in this contribution works for binary and multiclass ordinal target variable. Empirical evidence are provided on simulated and real data sets.

Keywords: Ranking Models, Functional Distance, Machine Learning

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A Data Analytics Approach for 4D Trajectories in ATFM

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Abstract: 4D trajectories is a key concept of the future Air Traffic System as highlighted in relevant R&D programme both in Europe and in the US., i.e., SESAR and NEXTGen. The scope is to guarantee flexibility to Airspace Users (AUs) and, at the same time, to improve system predictability. The ambition is to allow AUs to fly their preferred route whenever possible. From the system perspective, this calls for a new class of Air Traffic Flow Management (ATFM) models that explicitly consider AUs' preferences. This is a quite challenging task because AUs' preferences, which depend on many factors, e.g., costs, duration, geometry etc., are not always fully known. We present a data analytics approach for 4D trajectory optimization. The approach is composed of a predictive component that learns AUs' preferences and reduces the set of possible 4D trajectories accordingly; and of a prescriptive component that assigns 4D trajectories to flights by solving a path-based integer programming formulation. Using trajectories queried from Eurocontrol DDR2 data repositories, the learning phase is mainly based on tree classifiers, support vector machines and multiple regression. As a result, a set of trajectories and information on related AUs' preferences are computed for each flight, and feed the optimization model.

Keywords: Air Traffic Management, Machine Learning, Integer Programming

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Learning Context for Multi Armed Bandits

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Abstract: In the last years, contextual bandit algorithms became increasingly popular for solving complex sequential decision problems. Indeed, they proved to be effective and flexible for news recommendation, on-line advertising and clinical trial design. However, in many applications non labeled data about potential context are available before the sequential decision making problem start to be solved. In such a case it is possible to exploit the available data to off-line learn different embeddings to be further optimized when the on-line decision problem starts to be solved. We focus on the Bernoulli bandit with binary reward and assume the expected reward is a linear function of the context. In this setting, we apply the Thompson Sampling procedure, and following (Agrawal and Goyal, 2013) we assume the reward for choosing arm i at time t follows a parametric likelihood function which results into a multivariate gaussian as the posterior distribution at time t+1. We present results of numerical experiments on different datasets.

Keywords: Contextual Multi Armed Bandit, Off-Line Embedding

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W3: Financial Modeling

Chair: **Pierpaolo Uberti**

Risk Parity with Expectiles

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Abstract: A recent popular approach to portfolio selection aims at diversifying risk by looking for the so called Risk Parity portfolios. These are defined by the condition that the risk contributions of all assets to the global risk of the portfolio are equal. The Risk Parity approach has been originally introduced for the volatility risk measure. Here we show how to define Risk Parity portfolios when the expectiles are used as (coherent) risk measures, and we investigate some of their properties. Furthermore, we propose several methods for practically finding Risk Parity portfolios with respect to expectiles and we compare their accuracy and efficiency on real-world data. Expectiles are also used as risk measures in the classical risk-return approach to portfolio selection, where we present a new linear programming formulation.

Keywords: Risk Diversification, Portfolio Selection, Equal Risk Contribution

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The Optimal Number of Allowances in an ETS: A Bilevel Stochastic Programming Approach

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Abstract: The fourth phase of the European Union Emissions Trading System, EU-ETS, will begin in 2021, and the authorities have already adopted some crucial modifications of its rules. In particular, the overall number of EU-ETS allowances will decrease by 2.2% per year from 2021 onwards, against a current annual reduction rate of 1.74%. The key variable of the present model is the optimal number of emission allowances to be issued by the regulatory authority to electricity producers. We assume that the price of emission allowances is linked to the probability that total emissions of electricity producers will exceed the cap fixed by the regulatory authority. The problem for the regulatory authority originates from a trade-off between economic growth and environmental targets. Indeed, restricting the number of allowances issued should force electricity producers to switch their generating technologies to greener ones, but, at the same time, increases the price of such allowances, raising, consequently, production costs and lowering the competitiveness of an economic system. On the contrary, a large number of allowances can lower their price so close to zero to vanish their impact. A bilevel stochastic programming model is advanced, where the decisions, the number of allowances issued by the regulatory authority and the energy mix taken by electricity producers, influence each other. The generation of scenarios mixes qualitative and probabilistic methods. In particular, Markov chain bootstrapping methods are used to jointly simulate gas and coal prices and electricity demand.

Keywords: EU-ETS, Electricity Markets, Bilevel Stochastic Programming

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Linear Models for Portfolio Selection with Real Features*

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Abstract: An efficient investment portfolio would have maximum return or minimum risk. Several approaches based on the "expected returns - variance of returns" rule, seek for a good balance between yield and risk. These approaches may differ in either how to measure risk or how to estimate expected yields. In this work we consider linear programming models found in the literature to estimate risks, like mean absolute deviation and Gini's mean difference. Thus, two mixed integer programming models are investigated in a portfolio optimization problem for a given expected return. For such, we add real features, including transaction lots, cardinality, and investment threshold. Experiments using data from the Dow Jones stock market demonstrate the superiority of the investigated models in the presence of these real features when compared with a market average indicator of return.

Keywords: Portfolio Optimization, Mean-Risk Models, Mean Absolute Deviation, Gini's Mean Difference, Real Features

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*The short paper related to this contribution will be published in the ODS2019 Special Volume of the AIRO Springer Series: "Advances in Optimization and Decision Science for Society, Services and Enterprises".

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Portfolio Leverage in Asset Allocation Problems*

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Abstract: In the classical portfolio optimization framework, the leverage of a portfolio is not taken into account and, by assumption, the risk of a portfolio is totally described by the volatility of its returns. As a consequence, the portfolios on the classical mean variance efficient frontier are not indifferent in terms of leverage. The introduction of leverage measurement in portfolio theory permits to consider other kinds of risk, like margin calls, forced liquidations at undesired prices and losses beyond the total capital. The literature on this topic is very limited while portfolio leverage is of central importance, in particular to set up operative investment strategies. In this paper we propose a simple definition of leverage and we try to introduce it in the classical portfolio selection scheme. We define the concept of leverage free equivalent portfolios in order to compare different investment alternatives for given levels of leverage. The central result of the paper is that the leverage free equivalent of the classical mean-variance efficient portfolios do not preserve the original mean-variance dominance structure. This permits to discriminate if an increase in the expected return of a portfolio totally depends on the leverage effect or is a consequence of a more efficient allocation.

Keywords: Portfolio Optimization, Portfolio Leverage

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Superiority Conditions for the 1/N Investment Strategy: A Theoretical Approach

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Abstract: The uniform investment strategy, that is the strategy of allocating 1/N to each of the N available assets, has been very often applied by financial agents and extensively studied by lots of researchers in the field. Many empirical contributions offered inspiring comparative results which showed that the out of sample performance of the 1/N strategy outperforms most of the portfolios built with different investment models. The rationale of this phenomenon has been appropriately ascribed to the presence of some fundamental uncertainty in the decision model, which leads to potentially large estimation errors, making the 1/N strategy a reasonable investment to choose. Within the mean-variance framework, we more deeply investigate the theoretical reasons of the success of the 1/N strategy shown in the aforementioned empirical studies.

Keywords: Portfolio Optimization, Naive Diversification, Out-of-Sample Performance

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W4: Optimization in Public Transport (AIRO-OPTSM chapter)

Chair: **Valentina Cacchiani**

Robust Capacitated Train Rescheduling with Passenger Reassignment Under Stochastic Disruptions

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Abstract: This talk deals with a train rescheduling problem in a railway system with ticket-reserved mechanism during large disruptions, such as a rolling stock breakdown leading to some cancelled services, where passenger reassignment strategies have also to be considered. A novel mixed-integer linear programming formulation is established with consideration of train retiming, reordering, rerouting and reservicing. Based on a time-space modeling framework, a big-M approach is adopted to formulate the track occupancy and extra train stops. The formulation aims to maximize the transported passengers subject to cancelled services and to minimize a total delay time for all trains at their destinations. The proposed mathematical formulation also considers planning extra stops for non-cancelled trains in order to transport the disrupted passengers, which were supposed to travel on the cancelled services, to their pre-planned destinations. Other constraints deal with seat capacity limitation, track and station capacity, and some robustness measures under uncertainty of disruption durations. We propose different approaches to compute advanced train dispatching decisions under a dynamic and stochastic optimization environment. A series of numerical experiments based on a part of "Beijing-Shanghai" high-speed railway line is carried out to verify the effectiveness of the proposed model and methods.

Keywords: Train Rescheduling, Passenger Reassignment, Disruption Management, Mixed-Integer Linear Programming

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Effective Pruning Strategies for Heuristic and Exact Train Scheduling Algorithms

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Abstract: This talk deals with the development of speed-up procedures or pruning strategies to efficiently solve huge job shop scheduling instances with additional constraints required to model large-scale train scheduling problems, in which a block section or track circuit corresponds to a nostore (blocking) machine and a train corresponds to a job. Specific characteristics of the studied railway problems are related to the formulation of deadline (hard) constraints and are studied to design such speed-up procedures. The key idea of these procedures is to prove that no improvement to the current best-known solution is possible if a specific train sequencing and/or timing decision is taken for a given partial or empty train scheduling solution. This idea can be applied to improve the solution process of heuristic and exact methods, both before starting the solution process (static speed-up) and during the solution process (dynamic speed-up). In a branch and bound algorithm, a partial train sequencing solution can be extended by dynamic speed-up procedures without any need of a new branching, while greedy heuristics can perform significantly faster and get a higher number of feasible solutions by means of speed-up procedures. If the problem is viewed as a mixed-integer linear program (MILP), the proposed idea helps to strongly reduce the problem size in a preprocessing phase via static speed-ups. A set of computational experiments on practical train scheduling instances show the potential improvements that can be achieved when incorporating static and/or dynamic speed-up procedures in heuristic/exact algorithms and when using these procedures combined with a MILP solver.

Keywords: Railway Optimization, Train Scheduling, Branch and Bound, MILP

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Energy-Efficient Train Control*

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Abstract: This research presents a practical application of the Energy Efficient Train Control (EETC) problem, which involves a collaboration between the Operations Research group of the University of Bologna and ALSTOM Ferroviaria SpA. The work is carried out within the framework of project Swift, funded by the Emilia Romagna regional authority. Given a train running on a certain line, the problem requires to determine a speed profile that minimizes the traction energy consumption. In particular, we consider the setting of a real-time application, in which the speed profile has to be recomputed due to changes in the schedule caused by unpredictable events. We introduce three solution methods: a constructive heuristic, a multi-start randomized constructive heuristic, and a Genetic Algorithm. Numerical experiments are performed on real-life instances. The results show that high quality solutions are produced and that the computing time is suitable for real-time applications.

Keywords: Heuristic, Railway Optimization, Energy, Train Control, Real-Time

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Comparing Yield Management Models Performances Through Live Testing at Trenitalia

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Abstract: A joint working group by Trenitalia and IBM developed a Yield Management System (YMS), able to forecast demand and optimize seat allocation per fare category and segment. From 2005, it has been implemented gradually to most of 'Le Frecce' trains at Trenitalia, main Italian and 3rd European railway undertaking. Continuous improvements have been designed, tested and deployed over time, in particular (i) the development of a methodological framework for assessing performances, and (ii) the design, run and analysis of a live test comparing a new prototype to the incumbent algorithm. The methodological framework is aimed to assess YMS performance and determine corrective actions, such as models calibration, user parameters improvements, algorithmic changes. It relies on a defined set of 39 Key Performance Indicators and a Monitoring tool developed from post-departure computation of Revenue Opportunity (studied by Temath, 2010). In addition, the Experimental Design (DoE) approach was considered for planning, running and evaluating tests on algorithmic changes, with a focus on the external factors like demand fluctuations, trends and shocks). This well-rounded approach has been applied to a pilot live test on a major models change in 2018. Here, following the 'sandbox' methodology developed by Talluri (2010), the new prototype was directly compared to the incumbent algorithm on alternate dates. Key operational challenges included: choice of the test perimeter, impact of user parameters, presence of outliers, analysis of 'closures' (decisions that led to any unavailability) operated either by the YMS or the analysts. The statistical analysis of pre and post departure indicators (Vinod, 2006) evidenced satisfactory results. The confidence in the methodology, together with the encouraging results of initial tests, led to the extensive implementation of the new prototype after only 61% of test completion, allowing for cost savings and anticipated revenue gain.

Keywords: Live Test, Revenue Opportunity, Yield Management

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Light Robustness in Train Stop Planning and Timetabling with Uncertain Demand

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Abstract: We study the problem of determining the schedule and stop pattern for a set of trains in a railway line, when passenger demand is uncertain. Passenger demand fluctuation can lead to overcrowded trains or even unsatisfied demand, causing passenger discomfort. Our goal is to determine, at the planning stage, a stop plan and a train schedule that can cope with different demand scenarios occurring during operations. We propose Mixed Integer Linear Programming (MILP) models, based on the technique of Light Robustness, in which uncertainty is handled by inserting a desired protection level against increased demand, and efficiency is guaranteed by limiting the travel time and the number of train stops. The proposed models have different ways of inserting protection, and require different information about passenger demand. We test these models on real-life data of the Wuhan-Guangzhou high-speed railway line under different demand scenarios.

Keywords: Robustness, Passenger Demand, Timetabling and Stop Planning

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T1: Optimization in Machine Learning

Chair: **Manlio Gaudioso**

Adaptive Random Projections for Efficient Second/First/Zeroth-Order Optimization

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Abstract: Linear solvers are a fundamental tool in machine learning. However, the complexity of optimizing a linear function quickly grows with the number of samples n and parameters d. To improve the scalability of these methods we propose to embed the optimization problem in a smaller linear space using carefully constructed random projections. This is equivalent to replacing the original model with one with fewer parameters that can be optimized more efficiently. The embedding space is continuously updated during the optimization to guarantee that the embedding remains accurate, and that the approximate optimization process converges to the optimum as quickly as the one in the original space. We also prove with a rigorous worst-case analysis that by carefully choosing the projections using adaptive sampling the size of the embedding never exceeds the effective degrees of freedom of the problem, which are usually much less than the original number of parameters. Important applications of this approach are the first provably accurate and efficient second and zeroth-order algorithms for sequential optimization in machine learning.

Keywords: Machine Learning, Random Projection, Linear Function, Convex Optimization, Quasi-Newton Methods, Zero-Order Optimization

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Support Vector Machine Based Bayesian Optimization Under Unknown Constraints

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Abstract: This paper addresses the topic of Bayesian Optimization (BO) under unknown constraints. More precisely, we consider optimization problems characterized by an objective function that is a black-box, multi-extremal and expensive to evaluate, subject to a set of constraints unknown a priori. This is a typical setting in simulation-optimization: in many cases, the simulation model/software is not able to compute the value of the objective function, for some configurations of the decision/control variables, due to the violation of some constraint. Our idea is to use a Support Vector Machine (SVM) classifier to approximate the boundary of the unknown feasible region (black-box feasibility determination problem), while a Gaussian Process is used as probabilistic surrogate model of the objective function, used to perform BO constrained on the estimated feasible region. Thus, the overall sequential optimization approach consists of two consecutive phases. In the first phase (black-box feasibility determination), the next point where to evaluate feasibility is selected with the aim to improve the estimate of the feasible region. In the second phase, the next point is selected to optimize the objective function: we adopted the Lower Confidence Bound acquisition function, constrained on the estimate of the feasible region. Results on a set of test functions and real-life problems are presented.

Keywords: Constrained Bayesian Optimization, Feasibility Determination, Simulation-Optimization

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On the Optimal Trade-Off Between Sample Size and Precision of Supervision

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Abstract: We consider a variation of the classical linear regression model, in which one is additionally given the possibility of controlling the conditional variance of the output given the input, by varying the computational time dedicated to supervise each training example, while fixing an upper bound on the total available computational time. Using this model and a large-sample approximation, we minimize the generalization error as a function of the computational time per example. Two main cases are considered in the analysis: in one case, the precision of the supervision increases less than proportionally when increasing the computational time per example; in the other one, it increases more than proportionally. The results of the analysis highlight, from a theoretical point of view, that increasing the number of data is not always beneficial, if it is feasible to collect a smaller number of more reliable data. Hence, not only their number, but also their quality matters. This looks particularly relevant in the current era of Big Data, and should not be overlooked when designing data collection procedures. We conclude presenting several numerical results validating the theory, and discussing extensions of the proposed framework to other optimization problems modeling the trade-off between sample size and precision of supervision.

Keywords: Optimal Supervision Time, Linear Regression, Variance Control

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Gradient Boosting with Extreme Learning Machines for the Optimization of Non Linear Functionals*

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Abstract: In this paper we investigate the use of the Extreme Learning Machine (ELM) paradigm for the approximate minimization of a general class of functionals which arise routinely in operations research, optimal control and statistics problems. The ELM and, in general, neural networks with random hidden weights, have proved to be very efficient tools for the optimization of costs typical of machine learning problems, due to the possibility of computing the optimal outer weights in closed form. Yet, this feature is possible only when the cost is a sum of squared terms, as in regression, while more general cost functionals must be addressed with other methods. Here we focus on the gradient boosting technique combined with the ELM to address important instances of optimization problems such as optimal control of a complex system, multistage optimization and maximum likelihood estimation. Through the application of a simple gradient boosting descent algorithm, we show how it is possible to take advantage of the accuracy and efficiency of the ELM for the approximate solution of this wide family of optimization problems.

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Enhancing the Performance of Randomized Decision Trees

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Abstract: Decision trees (DTs) are widely used Machine Learning techniques for classification. Their appeal is due to the good trade-off between interpretability and classification performance. Designing optimal DTs is known to be NP-hard [1] and a lot of attention has been devoted to heuristic algorithms based on sequential greedy procedures (see e.g. CART [2]). These heuristic methods lead to suboptimal models which may suffer from poor accuracy. In the last decades, alternative approaches have been devised to determine optimal DTs, mainly based on integer programming formulations (see e.g. [3]). Compared to the heuristic algorithms, the optimal approaches achieve better accuracy but in larger computational times, which may be prohibitive for datasets of moderate size. An interesting extension of DTs, recently proposed in [4] and referred to as Optimal Randomized Classification Trees (ORCTs), are based on random decisions at each node. ORCTs, whose training amounts to solving continuous nonlinear optimization problems, seem to achieve better accuracy compared to both heuristic and optimal methods, in much shorter computational time with respect to the latter. In order to get simpler predictive models, in [5] a sparsification strategy has been added to the ORCTs training optimization problem. In this work we investigate ways to improve the training and generalization performance of ORCTs, including a more effective sparsification technique.

Keywords: Optimal Randomized Decision Trees, Sparsity, Classification

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T2: OR Support to Industry 4.0 and Smart Manufacturing – 1

Chair: **Massimo Paolucci**

Industry 4.0: The New Scenario and Challenges for Cyber Physical Manufacturing Systems Decisional Processes

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Abstract: Industry 4.0 and Smart Manufacturing are currently characterizing what is commonly considered the fourth industrial revolution. The third industrial revolution was associated with automation based on the introduction of computer numerical control (CNC), supervisory control and data acquisition (SCADA), enterprise resource planning (ERP), and manufacturing execution system (MES). Now, Industry 4.0 is focused on connection and integration of people, items and machines in the manufacturing processes considering three pillars, i.e., digitalization, sensorization and optimization according to the cyber physical manufacturing systems (CPMS) concept. Digital twins in CPMS systems allow to provide a real time visibility on all process; sensorization, mainly through IoT, allows interconnectivity among machines, materials and enterprise systems. This new and continuously changing scenario leads to new challenges and opportunities. The aim of this talk is to provide an overview of the new decisional capabilities offered by digital twins and operational research techniques in next generation manufacturing systems.

Keywords: Cyber Physical Manufacturing Systems, Digital Twin, Advanced Analytics

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Industrial Clusters Optimization

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Abstract: Symbioptima is a EU project proposing a new paradigm for industrial clusters: the human-mimetic symbiosis. Drawing inspiration from one of the most complex biological organism, namely the human body, it promotes the mutual interaction of diverse industries, also among different sectors, for beneficial reuse of flows (e.g. water, waste, by-products, energy, recycled materials) that could result in a more resource-efficient production at network level, and in fewer adverse environmental impacts. Synergy and optimization of the flows of a cluster are obtained thanks to the hierarchical decentralization of operations management tasks to multiple collaborating Production Units, integrating at inter-plants and cross-sectorial level the monitoring, supervision and shared optimization of their activities. A main topic in such a context is however to be able to guarantee an even distri-bution among the participating production units of the extra profit generated through the flow reuse process. In this work, we model the system through mathematical programming and we propose a solution, based on a series of linear programs, which optimizes the profit and balances it among the production units participating in the symbiosis.

Keywords: Industrial Symbiosis, Linear Programming, Algorithms

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Decision Support System for Augmented Maintenance in a Cyber Physical Production System

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Abstract: The evolution of planning and control processes, and the necessity of enhanced personnel skills, requires newly conceived tools and systems. This presentation describes the architecture and functionalities of a Decision Support System (DSS) prototype capable of supporting the augmented maintenance of all assets constituting a Cyber Physical Production System (CPPS), i.e. integrating both physical and digital or virtual assets. The objectives are to grant the CPPS functional continuity thanks to self-maintenance and repairing activities and to the real-time monitoring of the process, the clear identification of the cause-effect chain of the malfunction, with certain identification of responsibilities, the progressive standardization, automation and orchestration of the corrective procedures on the process, the definition of effective KPIs supporting the decision-making process. To achieve these objectives, the following methodologies are used: Machine Learning: to process even a priori unknown data so to autonomously adapt to the evolution of the CPPS; Process Intelligence: to process information coming from the CPPS components, and to provide analysis, comparison and evaluation techniques, so to detect cause-effect relationships; Internet of Things: to allow interaction among production equipment, machines and business systems used for production planning, security and maintenance. The main expected benefits of the new process / service can therefore be summarized as: predictive rather than reactive approach to CPPS maintenance; improved effectiveness and control of the decision-making process, thanks to the ability to make autonomous decisions for routine control activities, or by involving and supporting expert personnel in a timely and contextual manner; exploitation of interactions and synergies between processes and CPPS components by orchestrating users and activities; better evidence of the correlations between the causes and effects of detected critical issues.

Keywords: Cyber Physical Production Systems, Internet of Things, Machine Learning

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Smart Thermal Calibration – Machine Learning in ABB Circuit Breaker Manufacturing

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Abstract: Industry 4.0 is a new approach of applying advanced information systems and digital technologies to traditional manufacturing processes. At the heart of Industry 4.0 is the smart factory, where data flows steadily between well-connected operations and production stages. Within the fourth industrial revolution paradigm, there is a significant evolution of many methodologies of continuous improvement, such as Lean Six Sigma. Several Six Sigma targets are achieved by the application of smart and autonomous systems. These systems are fueled by data and supported by analysis techniques such as machine learning. The ABB circuit breaker Smart Thermal Calibration project arises in this Industry 4.0 scenario. In circuit breakers, thermal protection is carried out using a bimetallic contact that bends in response to the heat released when conducting overcurrent. This expanding switch is calibrated to trip once it has absorbed a certain amount of heat, de facto after a certain time lapse which must not exceed ranges specified by IEC and UL standards. Thermal calibration is therefore a stage of circuit breakers manufacturing and the thermal behavior after calibration must be tested for essential safety reasons. The purpose of the Smart Thermal Calibration project is to develop a Six Sigma oriented version of the actual calibration process. This dissertation deals with engineering and machine learning approaches applied to ABB circuit breaker manufacturing in order to improve the reliability level of finished products while reducing cycle time, rework rate and the waste of human and material resources.

Keywords: Machine Learning, Industry 4.0, Lean Six Sigma

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Machine Learning Application in Optimization: Job-Shop Scheduling in Industry 4.0

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Abstract: The world is facing the fourth industrial revolution. In this context, we study new production scheduling opportunities by exploiting the synergies between Optimization, Internet of Things, Data Science, and Artificial Intelligence techniques. The use case is represented by a Job-Shop Scheduling problem with sequence-dependent setup times and limited resources in which we want to minimize the make-span (Costa et al., 2013). However, due to the high stochasticity affecting the production processes, sometimes rescheduling decisions must be taken over a schedule that was supposed to be optimal (Pinto et al., 1998). We propose a methodology based on periodic estimation of the improvement produced by rescheduling with means of machine learning classifiers. To develop the classifier, we first create a simulator for generating data simulating the historical status of the plant. The data include, for each time step, the processing time variations, the common plant features and the rescheduling decision. The goodness of a rescheduling is calculated through heuristics optimization based on tabu-search algorithm. The rescheduling decisions are then treated as classification label values (e.g., 1 if rescheduling at a certain time improves the performance, and 0 otherwise). Then, we use feature extraction to transform the raw data into features suitable for modeling. With the extracted values, we divide data into training set (70%) and test set (30%). Furthermore, with the training set, we build different classification models by trying various classification algorithms (Support Vector Machines, Random Forest, and Neural Networks). Finally, we compare the performance of different models by validating the classification correctness on the test set and we select the one with highest classification accuracy. By using the proposed approach, the decision maker is able have a fast way to decide if a rescheduling action will improve or not the scheduling performance.

Keywords: Industry 4.0, Rescheduling, Machine Learning

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T3: Health Care Management and Planning - 1

Chair: **Elena Tánfani**

Nurse-to-Patient Assignment in Home Care Services with Uncertain and Temporally Correlated Patient Demand

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Abstract: Assisting patients at home, rather than in hospital, offers many advantages, from the decrease in hospitalization costs to the improvement in the quality of life of patients. Home care services will, therefore, become more and more common in the next future, especially for dealing with the elderly population, who, most of all, benefits from home care treatment. However, home care services are expensive and must be carefully managed in order to make them efficient. A key problem in planning home care services is the assignment of patients to nurses. It is a medium term decision which heavily affects the workload of nurses for a long time horizon. However, when assigning patients to nurses, their demand, namely the number of weekly visits, is not fully known. Indeed, it depends on the patients' conditions, and they may change along time. We consider the problem of assigning patients to nurses over a planning horizon of several weeks. Patients may require different kinds of continuity of care: they may require to be cared after by only one nurse, or they may accept to be assigned to different nurses in different weeks, but this should be discouraged, or they may be cared after by different nurses even in the same week. To deal with the uncertain temporal evolution of the patients' demands a robust solution is generated through an implementor-adversarial-like approach. Two levels of flexibility are considered and compared: in the less flexible case the assignment of patients with no continuity requirement is independent from the demand realization, while in the more flexible one it is re-optimized based on the current patients' conditions.

Keywords: Home Care, Nurse-to-Patient Assignments, Time Related Uncertain Demand

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The Price of Flexibility in Surgery Pre-Admission Appointment Scheduling

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Abstract: We consider an appointment scheduling problem arising at a medical center that provides surgery pre-admission exams. The daily problem can be restated in the machine scheduling framework as a proportionate open shop with constrained parallelism. We propose two alternative scheduling policies in order to investigate the trade off between quality of service in terms of patient waiting time versus patient degree of freedom in booking the appointment. Specifically, the former policy is a first come first served policy evaluated by simulation. It allows for the maximum degree of freedom since the patient can go to the center without prior notice and can be served with no guarantee about maximum waiting time or may be turned down in case of overflow. The latter policy instead, is based on a deterministic MILP optimization model. It minimizes patient waiting time and it fixes scheduling decisions, thus corresponding to the minimum degree of freedom. The two policies are compared experimentally on a wide set of realistic data comprising different mixes of patients.

Keywords: Appointment Scheduling, Proportionate Open Shop, Patient-Centered Policy

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A MILP Model for Biological Sample Transportation in Health Care*

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Abstract: In this paper, a real-world transportation problem is addressed, concerning the collection and the transportation of blood and biological sample tubes from draw centers to a main hospital. Blood and other biological samples are collected in different centers during morning hours and have to be transported to the main hospital by a fleet of vehicles. Each sample has a given lifetime, i.e., a deadline. If a sample can not arrive to the hospital before the deadline either is discarded or a stabilization process must be carried out in dedicated centers. After stabilization, a sample can be delivered to the main hospital by a new deadline. A time-indexed Mixed Integer Linear Programming formulation of the problem is provided and tested on different instances generated from real-life data.

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OPT3COR: Citizen Centered Integrated Digital Services for Optimized Access Management to Medical Support Services for Maternity Care

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Abstract: In this talk we introduce the OPT3COR (Optimization Citizen Centered Care Oriented) research project. The objective of the project is to design and develop a digital service, in the "Citizen Centered Care" perspective, based on decision support systems able to provide accurate timing, scheduling and costs of services for the well-being of pregnant women and their fetuses (from the beginning of pregnancy up to childbirth). As well known, the paradigm currently adopted in the provision and delivery of health services is usually "hospital-centered". This paradigm can be changed towards a "citizen-centered" model, which would allow a patient to be directly and actively involved in prevention and care activities. In particular, the patient centrality plays a fundamental role in medical support services for pregnant women. The approach we propose is based on simulation-based optimization. We first develop a discrete event simulation model reproducing the pathways of pregnant women, taking into account the resources and the services delivered by the points of birth. Then the model is combined with "black box" optimization algorithms, providing the back-end of the digital services. The service front-end is provided by applications for different devices. The e-communities represent a concrete tool for citizens and providers to carry out this "patient-centered" system. The project is developed to support the services for maternity care of Lazio Region.

Keywords: Citizen Centered Care, Simulation-Based Optimization, Maternity Care

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Master Oncologists Planning in a Cancer Outpatient Center

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Abstract: This work deals with the problem of assigning oncologists to available ambulatory time slots in a cancer outpatient center over a given planning horizon. This research began with a collaboration with the San Martino Hospital located in the city of Genova (Italy) recently involved in setting up a new cancer outpatient. The center delivers chemotherapy treatments to patients treated by seven oncology and hematology specialties. Preliminarily, simulation has been used to determine, at a strategic decision level, the availability of the main common resources involved in the care process, i.e. number of seats and beds for the chemotherapy infusions and number of ambulatories dedicated to the oncologist visits. The still open problems are twofold. At a tactical level, assigning oncologists to the available ambulatory time slots, based on the clinicians availability and on the clinical characteristics of patients. At an operational level, determining the appointment planning and scheduling of patients in each day. In this work, we focus on the first problem, proposing MIP optimization models aimed at meeting the treatment demand of the pathologies to be treated. Preliminary results on the real case study and on a set of randomly generated instances are reported.

Keywords: Chemotherapy Treatment, Oncologists Planning, MIP Models

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T4: Data Analytics and Optimization

Chair: **Enza Messina**

Efficient Kernel-Based Subsequence Search in Data Streams

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Abstract: This paper presents an efficient approach for subsequence search in data streams. The problem consists in identifying coherent repetitions of a given reference time-series, eventually multivariate, within a longer data stream. Although Dynamic Time Warping (DTW) is the metric most widely used for subsequence search solutions, its computational cost is a well-known issue. Our approach overcomes this issue by approximating DTW through a kernel in order to significantly reduce the burden of computation. Contrary to kernel, DTW allows for comparing time series with different length. Thus, to use a kernel, a feature embedding is used to represent a time-series as a fixed length vector. Each vector component is the DTW between the given time-series and a set of "basis" series, usually randomly chosen. The vector size is the number of basis series used for the feature embedding. Searching for the portion of the data stream minimizing the DTW with the reference subsequence leads to a global optimization problem. The objective function is black-box and expensive: we investigated Bayesian Optimization to optimize solve this inner problem. The value of the proposed approach is independent on the application field, but it is especially relevant for implementing innovative Internet-of-Things services. Monitoring walking activity and supporting self-rehabilitation in elderly subjects are the two case studies considered. The kernel-based approach was compared to a traditional DTW implementation, both in terms of effectiveness and computational efficiency.

Keywords: Subsequence Search on Streaming Data, Dynamic Time Warping, Kernel

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Constrained Named Entity Recognition

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Abstract: Information Extraction (IE) is a process focused on automatic extraction of structured information from unstructured text sources. A critical task of IE is the Named Entity Recognition (NER), which consists in identifying and associating atomic elements in a given text to a predefined label such as names of persons, organizations, locations and so on. A powerful tool to perform NER task is Conditional Random Fields (CRFs), that can be used to learn the dependencies between hidden variables (semantic labels) and observed variables (textual cues). Indeed, the labeling problem can be formalized as the assignment of a finite sequence of semantic labels to a set of interdependent variables associated with textual cues. Using CRFs, the problem can be represented on an a cyclic graph and it is equivalent to solve the Maximum Path Problem, that can be easily tackled with the Viterbi algorithm. In order to improve the performances of the inference procedure we extend the CRF model by introducing logic rules, representing domain knowledge, in the decision process. Such rules can be either extracted from data or defined by domain experts. These rules can be used to describe general patterns of the domain, but not all training sentences or data must necessarily satisfy them. For this reason, the rules are introduced as soft-constraints, and the resulting problem can be modeled with a Soft-Constrained Maximum Path Problem, that cannot be solved with the efficient Viterbi algorithm. In order to address this problem, we propose both a metaheuristic algorithm and a Lagrangian relaxation.

Keywords: Name Entity Recognition, Heuristics, Lagrangian Relaxation

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Active Scenario-Generation for Stochastic Programming

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Abstract: In this work, we address Multi-Stage Stochastic Programming (MSSP) through a hybridization between Mathematical Programming and Machine Learning. More precisely, Machine Learning is used to infer different decision policies from the approximated solutions of MSSP on different scenario-trees. Our main contribution is an active scenario-tree generation mechanism which builds a scenario-tree by adding, iteratively, a new scenario. This scenario is selected by minimizing the Sample Average Approximation (SAA) on an out-of-sample validation set of scenarios, which are generated according to the distribution of the stochastic parameters, if known, or historical data, otherwise. Since the minimization of SAA is a time-consuming and blackbox global optimization problem, we propose to solve it through Bayesian Optimization. The approach has been validated on (i) a benchmark production-inventory problem and (ii) Pump Scheduling Optimization in Water Distribution Networks. In both cases, uncertainty is on demand, respectively, on products and water. Numerical results that will be discussed, show the validity of the proposed approach.

Keywords: Multi-Stage Stochastic Programming, Active Learning, Bayesian Optimization

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Constrained Deep Attributed Graph Embedding Model

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Abstract: In this paper we deal with complex attributed graphs which can exhibit rich connectivity patterns and whose nodes are often associated with attributes, such as text or images. In order to analyze these graphs, the primary challenge is to find an effective way to represent them by preserving both structural properties and node attributes. To create low-dimensional and meaningful embedded representations of these complex graphs, several Graph Representation Learning approaches have been proposed. Nevertheless, these approaches mainly follow a neighborhood aggregation procedure while disregarding information enclosed in node attributes. In order to overcome this limitation, we introduce a fully unsupervised Attributed Graph Embedding based on Deep Learning architectures. The proposed model generates a dense vector representation of nodes in an attributed graph by solving two different optimization problems during the training phase. First, the structural optimization model is solved to obtain the embedded representation considering both the local and global graph structural information. Then, the attribute optimization problem aims to obtain the embedded representation of the node attributes while enforcing this representation to be coherent also with the previously obtained structural node embeddings. The model has been validated on a node classification task showing significant performance on benchmark datasets.

Keywords: Graph Embeddings, Constrained Deep Learning, Representation Learning

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Deep Learning Models for Predicting Extreme Stock Movements Integrating News Sentiment

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Abstract: In recent years, Deep Learning models have been increasingly applied for stock prediction thanks to their ability to model the highly nonlinear and non-stationary nature of financial time series. In recent works, models based on a specific type of Recurrent Neural Network (RNN), the Long Short-Term Memory (LSTM), have been shown to be effective in providing a base for a profitable trading strategy on the S&P500. Moreover, news sentiment has been proven to increase the performance of machine learning models for stock prediction. However, much less work has been devoted to forecasting extreme changes in stock prices, which would be of great importance from a risk management perspective. In this study, different LSTM models are investigated and deployed for the task of extreme market movements prediction on the S&P500 index constituents from 2005 to 2018. The proposed models are able to leverage a combination of financial time series returns, technical indicators and sentiment impact score derived from news headlines. The experimental classification results of such models are then compared, demonstrating the positive impact of the sentiment indicator. Additionally, the prediction output is used as a warning signal for two different asset allocation strategies. The first considers the stocks with higher probabilities of having a positive or negative return for the day ahead and takes long and short positions accordingly. The second one is based on Second Order Stochastic Dominance.

Keywords: Deep Learning, Stock Prediction, News Sentiment

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T5: Optimization in Machine Learning - 2

Chair: **Marcello Sanguineti**

Infinite Kernel Extreme Learning Machine*

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Abstract: This paper addresses the analysis of the problem of combining Infinite Kernel Learning (IKL) approach and Extreme Learning Machine (ELM) structure. ELM represents a novel and promising alternative to Neural Networks, for its simplicity in implementation and high efficiency, especially concerning convergence and generalization performance. A currently under developed topic concerning ELM implementation is given by the optimization process of base kernels: choosing different kernel combinations may lead to very dissimilar performance results. An innovative ELM approach using a combination of multiple kernels has been proposed in Liuet al. As a change of paradigm, we are interested in using an infinite set of base kernels, defining in this way an original ELM based algorithm called Infinite Kernel Extreme Learning Machine (IK-ELM). About that, a novel 3-step algorithm combining IKL and ELM is proposed. Finally, a brief analysis about further possible directions is discussed.

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Least Action Principles and Well-Posed Learning Problems*

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Abstract: Machine Learning algorithms are typically regarded as appropriate optimization schemes for minimizing risk functions that are constructed on the training set, which conveys statistical flavor to the corresponding learning problem. When the focus is shifted on perception, which is inherently inter wound with time, recent alternative formulations of learning have been proposed that rely on the principle of Least Cognitive Action, which very much reminds us of the Least Action Principle in mechanics. In this paper, we discuss different forms of the cognitive action and show the well-posedness of learning. In particular, unlike the special case of the action in mechanics, where the stationarity is typically gained on saddle points, we prove the existence of the minimum of a special form of cognitive action, which yields forth-order differential equations of learning. We also briefly discuss the dissipative behavior of the se equations that turns out to characterize the process of learning.

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Probabilistic Tools for Optimization of Classifiers on Large Data Sets

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Abstract: The number of classification tasks on a finite domain (representing a set of vectors of features, measurements, or observations) grows exponentially with its size. However, for a given application area relevance of many such tasks might be very low or negligible. A probabilistic framework is introduced, modeling prior knowledge about probabilities that a presence of some features implies a property described by one of the classes. Impact of increasing sizes of domains on correlations between input-output mappings of computational models and randomly-chosen classifiers is analyzed. It is proven that for large domains the correlations are sharply concentrated around their mean values. Probabilistic bounds are derived via implications of the Azuma-Hoeffding Inequality, holding also without the "naive Bayes assumption". It is shown that the performance of random classifiers is almost deterministic, in the sense that either a given class of computational models can approximate well almost all tasks or none of them. Consequences for the choice of optimal computational models are derived.

Keywords: Classification, Optimization of Computational Models, Concentration of Measures, Azuma-Hoeffding Inequality

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Optimization Problems in Machine Learning

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Abstract: Leveraging data in business decision making is nowadays mainstream as any business in today's economy is instrumented for data collection and analysis. While the aim of machine learning is to generate reliable predictions, management science problems deal with optimal decision making. Thus methodological developments that can leverage data predictions for optimal decision making is an area of research that is critical for future business value. The widespread adoption of machine learning is in parts attributed to the development of efficient solution approaches for the optimization problem of training machine learning models. This work surveys the machine learning literature and presents machine learning as optimization models. Such models can benefit from the advancement of numerical optimization techniques which have already played a distinctive role in several machine learning settings. Particularly, mathematical optimization models are presented for commonly used machine learning approaches for regression [1], classification [2], clustering [3], and deep neural networks [4] as well as new emerging applications in machine teaching and empirical model learning. The strengths and the shortcomings of these models are discussed and potential research directions and open problems are highlighted.

Keywords: Analytics, Machine Learning, Mathematical Programming

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A Multi-Objective Reinforcement Learning Based Hyper-Heuristic

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Abstract: The efficacy of Hyper-Heuristics in tackling NP-hard Combinatorial Optimization problems has been widely shown by the extensive literature on the topic [1] [2]. Moreover, the recent successful results in Deep Reinforcement Learning research (see [3] for a thorough overview) lead to the idea of applying such methodologies in an online optimization setting. In this work, an optimization problem arising in a Cloud Computing setting is presented and discussed. Then, a selection Hyper-Heuristic using different conflicting policies to select among low-level heuristics is detailed. Such heuristics are selected according to one of the conflicting policy according to a distribution defined by a Multi-Objective Simulated Annealing [4] procedure, which explores the Pareto-Front by varying the parameters of the distribution, thus obtaining a well-sampled Pareto-Front. In other words, the hyper-heuristic learns to optimize while optimizing the learning. In order to test the effectiveness of the method, an experimental campaign on a case of practical interest is presented and discussed.

Keywords: Reinforcement Learning, Hyper-Heuristics, Multi-Objective Optimization

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T6: OR Support to Industry 4.0 and Smart Manufacturing – 2 (Contributions from AD-COM Project)

Chair: **Giovanni Righini**

Single Machine on-Time-in-Full Scheduling

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Abstract: A relevant feature in many production contexts is flexibility. This becomes a key issue, for instance, in the case of third-party cosmetics manufacturing. There, the core business is the production of high quality, fully custom orders in limited batches. Companies often apply a so called on-time-in-full policy (never split a job, always satisfy the customer within its delivery date with a single batch), that however yields problems which are not only hard to solve by human experts, but often infeasible. We consider a minimal relaxation of such a policy: in case scheduling all batches is infeasible, we leave the option of splitting some of them in two fragments (at a price), postponing the delivery date of the second fragment. We focus on the combinatorial investigation of the fundamental case in which a single machine is available, with the target of using our findings in a column generation based algorithm for the general multi-machine multi-time-slot case. We formalize our main modeling assumptions, observe a few fundamental properties, and introduce an exact dynamic programming algorithm.

Keywords: Machine Scheduling, Job Fragmentation, Dynamic Programming

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Heuristic Data-Driven Feasibility on Integrated Planning and Scheduling*

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Abstract: We study the merging of data-driven approaches and mathematical programming formulations to solve an integrated planning and scheduling problem where jobs can be split in two separate tasks, one of them allowed to exceed its deadline at a price. Our study is driven by the increasing structural complexity of industrial scheduling problems that in some cases become too hard to be modeled as mathematical programs even by domain experts. We experiment on how to ensure the feasibility at a scheduling level by training a data-driven model, subsequently encoding it with a mathematical programming formulation, to be finally embedded in a planning model. Our experiments prove that our framework provides an effective heuristic approach, competing to exact formulations in terms of both accuracy and quality of the solutions, and it could be extended to those kind of problems where it is too hard to model the schedule feasibility.

Keywords: Integrated Planning Scheduling, Data-Driven, Decision Tree, On Time in Full

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Evaluating Automated Storage and Retrieval System Policies with Simulation and Optimization*

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Abstract: In this paper we present a methodology to evaluate policies for automated storage and retrieval system (AS/RS) in warehouses. It is composed by four steps: (i) formal definition of the physical AS/RS and descriptive modeling on a simulation framework; (ii) model validation and finding of potential bottlenecks by the statistical analysis of datalogs; (iii) definition of operational optimization policies to mitigate such bottlenecks; (iv) evaluation of the policies using the simulation tool through key performance indicators (KPI). In particular, we take into consideration a unit-load AS/RS, we present a new simulation model combining discrete events and agent based paradigms. We consider an industrial test case, focusing on scheduling policies that exploit mathematical optimization, and we evaluate the effects of our approach on real world data. Experiments prove the effectiveness of our methodology.

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*The short paper related to this contribution will be published in the ODS2019 Special Volume of the AIRO Springer Series: "Advances in Optimization and Decision Science for Society, Services and Enterprises".

Rolling-Horizon Heuristics for Capacitated Stochastic Inventory Problems with Forecast Updates*

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Abstract: In this paper we propose a practical optimization approach based on the rolling-horizon paradigm to address general single-product periodic-review inventory control problems. Our framework supports many constraints and requirements that are found in real inventory problems and does not rely on any assumption on the statistical distribution of random variables. Ambiguous demand and costs, forecast updates, constant lead time, lost sales, flexible inventory capacity and product availability can all be taken into account. Three, increasingly sophisticated, solution methods are proposed and implemented within our optimization framework: a myopic policy, a linear programming model with risk penalization and a scenario-based stochastic programming model. The effectiveness of our approach is proved using a data set of realistic instances.

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Paths and Matchings in an Automated Warehouse*

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Abstract: We analyze a number of variations of a combinatorial optimization problem arising from the optimization of an automated warehouse. We classify these variations according to four relevant parameters and we analyze which combinations are polynomially solvable, owing to dynamic programming recursions or to reductions to known graph optimization problems such as the shortest path problem and the minimum cost perfect matching problem.

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T7: Health Care Management and Planning - 2

Chair: **Paola Cappanera**

A Simulation Approach to Support Internal Medicine Wards Reorganization

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Abstract: In this work we focus on patient flows inside Internal Medicine wards with the aim of evaluating new organizational models that should take into account the patient relevant characteristics, e.g. complexity and frailty. A Discrete Event Simulation (DES) model is developed to describe the pathways of complex patients through hospital medical wards. The model has been applied to a case study of an Italian middle size hospital. The first objective is quantifying the impact in terms of resource use, cost and outcome of introducing new organizational models for internal medicine wards. The re-organization is focused on varying the available beds assignment among the wards to better address the care complexity of patients. Patients are clustered considering the main clinical status and other relevant characteristics, such as comorbidities and ward of admission. Preliminary results on the case study application are analyzed and discussed.

Keywords: Discrete Event Simulation, Health Care, System Re-Organization

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Priority-Based Scheduling of Operating Rooms Using Artificial Intelligence

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Abstract: According to a study carried on by the National Health Service (NHS) England, NHS hospitals could carry out 280,000 more non-emergency operations a year by organizing operating room schedules better. The operating room scheduling (ORS) problem can be broken down into two segments: production of an initial schedule for a given time unit (e.g. day, week, or month) and generation of altered schedules based on complications or conflicts that require changes in the initial schedule. Complex combinatorial problems, possibly involving optimizations, such as the ORS problem, are usually the target applications of knowledge representation and reasoning formalisms such as Answer Set Programming (ASP). In this work we first present a solution schedule based on ASP for solving the ORS problem. Then, we also present techniques for re-scheduling. Our solution produces a schedule taking into account the different specialties, lengths and priority scores of each planned surgery and the availability of beds for the entire length of stay (LOS) both in the Intensive Care Unit and in the wards. The length of surgery and the LOS are two necessary parameters that can be predicted by two auxiliary modules, based on deep learning technology.

Keywords: Operating Room Scheduling, Artificial Intelligence, Bed Management

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A Simulation-Optimization Approach to Reduce Overcrowding in an Hospital Emergency Department Through the Improvement of Low-Complexity Patient Flow

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Abstract: People arriving to an Emergency Department need to receive medical care in a short time according to their urgency. This task is endangered by the well-studied and increasing problem of the overcrowding, which tends to enlarge the waiting times. Since the majority of the waiting patients are low-complexity, using minor injuries units for discharging these patients earlier allows to reduce the ED overcrowding, improving the service quality for all patients. In this work a Simulation-Optimization approach is adopted for determining the resource allocation and the settings of the ED minor injuries unit in order to minimize the patient waiting time with acceptable costs. To this aim, first we build a Simulation model reproducing the patient flow within the ED. As a second step, we determine the optimal settings combining the DES model with a Derivative-Free Optimization method. We used the model for the Emergency Department of Policlinico Umberto I in Rome.

Keywords: Simulation-Optimization, Patient Flow, Derivative-Free Optimization

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A Flexible Generalized Simulation Model to Describe Hospital Departments and Care Systems

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Abstract: Hospital departments and care systems present a complex organization: they need to be properly dimensioned (structures, technical equipment and human resources) and properly managed (operating rules), aiming at supplying a service which shall be satisfactory to users, sustainable by operators and economically acceptable. Simulation is frequently employed for this scope: it can generally supply detailed information and then constitutes a remarkable help, but it generally implies a long exercise to model the interested real system in order to solve the presented problems; moreover, every real system has peculiar characteristics, so that its developed model is hardly reusable for a different system. To avoid such difficulties a general flexible model, simple and easy to use, has been developed, based on all common characters of hospital departments and care systems, and on some adjusted coding rules. The model includes a "configuration database" and an assistance manager; the first one is a database which collects information about patients (arrival rules, requested treatments and related resources, priority rules) and about resources to be used for each treatment (availability time table and turns of duties), it is easily dimensioned by the model user by answering to simple questions; the second one has a generation block which generates patients and treatments needed for each of them, and a treatment block which rules waiting queues, and seizes and releases all resources requested by every patient for the related time; the two blocks are activated by data supplied by the database. The model can be quickly adapted to the current system under study; it has been employed with success to represent widely different realities, like emergency departments, inspection cycles preceding surgical operations, newborn metabolic screening and diagnosis, assistance cycles to brain injured patients, palliative care cycles, rare pathologies care cycles.

Keywords: Care, Simulation, Generalized Model

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Coordinating the Emergency Response of Ambulances to Multiple Mass Casualty Incidents using an Optimization-based Approach*

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Abstract: During the emergency response to multiple mass casualty incidents (MCIs), a number of coordination (allocation) decisions need to be made in a timely manner. This paper reports on an optimization-based approach that has been developed to solve the ambulance-to-casualty and casualty-to-hospital allocation problems. A number of constraints are taken into consideration such as the number of ambulances and hospitals, along with the capacity of hospitals. Within the approach, the road network of the geographical area under consideration is modeled realistically. Further, the day of the week and the time of day at which multiple MCIs occur are considered as factors influencing the speed of the ambulances. The approach includes a Neighborhood Search Algorithm that has been developed and used to obtain solutions to a multiple MCI case study involving a number of scenarios.

Keywords: Coordination, Multiple Mass Casualty Incidents, Emergency Response, Ambulance-to-Casualty Allocation, Casualty-to-Hospital Allocation

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T8: Workshop - OR Towards Technology Transfer: From Data to Actionable Knowledge

Chair: **Enza Messina**

Mathematics for Optimization

Matteo Longoni

MOXOFF

Stochastic Optimization Model and ML Methods for Merchandising Planning

Ruggiero Scommegna

ORS

Optimization Based Approaches to Digital Marketing and Utilities

Ilaria Giordani, Attilio Redivo

OAKS

Some Lessons Learnt in Building Product-Oriented OR Startup

Fabio Schoen

Intuendi, University of Firenze

T9: (AIRO)Young Reserchers in Machine Learning and OR

Chair: **Martina Fischetti**

Traveling Salesman Problem and Machine Learning

Umberto Junior Mele[1], Xiaochen Chou[1], Luca Maria Gambardella[1], Roberto Montemanni[2]

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Abstract: An extensive literature on symmetric and asymmetric Traveling Salesman Problem (TSP) is available, and this problem has become a valuable benchmark to test new heuristics methods for combinatorial optimisation problems. Here we introduce a machine learning algorithm that is adapted to solve this problem. The framework uses the city coordinates as inputs, and it is trained using reinforcement learning (RL) to predict a distribution over the TSP feasible solutions. Our Deep Learning structure differs from the previous work [Deudon et al., Kool et al., Bello et al.] since we introduce the distances information, and we modified the decoder using the distance between the state and action encodings. To reduce the gradient variance during the RL training a critic network is trained, using the Concorde exact solver for TSP [Applegate et al.], which provides a good baseline for the REINFORCE [Ronald] estimation of the gradient. We compare our method with previous works in terms of times and optimality gaps. The target of this work is to evaluate whether coupling problem-specific combinatorial concepts with machine learning can lead to better results.

Keywords: Traveling Salesman Problem, Geometric Deep Learning, Reinforcement Learning

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A New Polarization Measure for Decision Tree Models

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Abstract: In this work a novel measure of multidimensional polarization is introduced and then applied into classification tree models as measure of splitting goodness. Polarization measures, introduced by Esteban and Ray (1991), are typically adopted in the socio-economic context to measure inequality in income distribution, identifying the presence of endogenously defined groups. Different extensions of these measures are then proposed in literature for the multivariate case, but few extensions have been made for the multidimensional case, i.e. when groups are defined exogenously. In this work a new polarization measure is proposed for the multidimensional case, extending the existing polarization measures to work in different settings and providing a generalization of their axiomatic definition. The new developed measure is applied in this work inside decision tree models. Decision trees divide the variables space in rectangles using a splitting rule, i.e. the observations set is divided into two subsets maximizing a specific measure of goodness. When facing a classification problem, information gain and Gini index are the most used measures to evaluate the impurity of a node, the splitting is then performed if an improvement in nodes pureness is obtained when splitting the observations set. The new measure introduced in this paper tackles weaknesses of the classical ones, because it does not only measure the impurity of a node but, using the concept of polarization, it reflects the distribution of each covariate in the node. In order to show how our proposal works, a simulation exercise has been carried out. The cross validation results obtained on simulated and real datasets underline that polarization classification trees perform better with respect to classification trees derived using classical split measures (i.e. the Gini index, Information gain).

Keywords: Polarization Index, Decision Trees, Classification

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A New Ensemble Tree Model Based on Bayesian Bootstrap

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Abstract: A new methodological approach in ensemble tree modeling using informative Bayesian bootstrap is proposed. In ensemble methods based on bagging, each data resample is generated through Efron's bootstrap. This procedure is equivalent to consider the multinomial distribution as the prior for the data generating process which assigns to each observation equal probability of being sampled. Under the Bayesian framework the natural extension is the bootstrap technique proposed by Rubin which considers the Dirichlet distribution as prior for the data generating process. It is well known that Efron's and Rubin's bootstraps are strongly dependent on the observed values and do not take into consideration any prior opinions. In this contribution a new idea of Bayesian bootstrap is implemented to propose a new ensemble tree model, deriving a class of algorithms called by the author Generalized Bayesian Ensemble Trees (GBET). We compare GBET with respect to other approaches of ensemble derived using Efron's and Rubin's bootstraps. We observe that the introduction of a prior can improve results in terms of prediction stability especially in case of datasets characterized by low sample size. We illustrate the benefits of our methodology through simulation examples and a real case study.

Keywords: Ensemble Tree Model, Bayesian Bootstrap, Bagging

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A Computational Comparison of New Techniques for Reoptimizing Shortest Paths

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Abstract: A wide variety of applications in logistics and transportation often requires to solve a sequence of shortest path problems in which two subsequent instances solely differ by a slight change in the graph structure. At this purpose, the reoptimizing techniques aim to solve each modified instance reusing valuable information gathered in the solution of the previous one of the sequence. Since in scientific literature, in-depth investigations have already been published concerning changes of source node or in cost of a single arc (e.g. [2], [3]), we study more general scenarios, in which multiple cost changes for any subset of arcs are allowed. We exploit the reoptimization purpose implementing the primal-dual approach described by Pallottino and Scutellá [1]. In this work, we compare our proposal with Dijkstra's label setting procedure in order to trace out the border which separates in terms of costs, topology and dimensions the instances for which the reoptimization approach is efficient from those which are better to be solved from scratch.

Keywords: Computational Comparison, Shortest Path, Reoptimization

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T10: Scheduling

Chair: **Alessandro Agnetis**

GPU Scheduling for Deep Learning

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Abstract: Deep learning (DL) methods have recently gained popularity and are used in applications that have become commonplace, like voice and face recognition. Convolutional and recurrent neural networks (CNNs, RNNs) are the most relevant classes of methods in the field. CNNs and RNNs are able to achieve state-of-the-art accuracy by also reducing the number of tensor operations required; however, DL training is still very computing intensive and usually supported by GPUs, which provide parallelization, frequently obtaining a 5 to 40x performance gain compared to CPUs. Despite the growing popularity of DL and the associated hardware acceleration techniques, GPU-based systems still have prohibitive costs that limit their adoption. Top-of-the-line servers like NVIDIA DGX-2 cost up to 500k USD, whereas in public clouds, GPU-powered virtual machines (VMs) time unit cost is 5-8x higher than CPU-only VMs. While the cloud remains the most cost-effective and flexible solution, in large settings operations costs can be lowered by flexibly managing and fostering resource sharing among multiple users. This work addresses the online joint capacity planning of VMs and DL job scheduling by proposing a local search heuristic and a Mixed Integer Linear Programming (MILP) formulation. In particular, DL jobs are assumed to feature a deadline, while multiple VMs are available from the provider catalog, and each VM has, possibly, multiple GPUs. Our solution optimizes the operations costs by (i) right-sizing the VM capacities, (ii) partitioning the set of GPUs among multiple concurrent jobs, and (iii) determining a deadline-aware job schedule. Several objectives are evaluated through a ad-hoc simulator and compared with first principle approaches.

Keywords: GPU Scheduling, MILP, Cloud Computing

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Price-and-Branch for Minimizing Total Completion Time on Parallel Batching Machines

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Abstract: In manufacturing of integrated circuits, burn in operations are key operations to improve quality by detecting early failures. Such operations are performed in the socalled batch ovens, able to process several circuits at the same time. In this paper, the problem of deciding in which sequence to process a given number of circuit boards in a batch oven is addressed. This problem can be modeled as a scheduling problem in a single machine with parallel batch job processing, where jobs 1,2,...,n have both a processing time p_i and a size s_i and the processing machine has a batch capacity C. Batches must be formed and scheduled so that the total size of jobs in each batch does not exceeed C while minimizing the total completion time. The processing time of each batch is determined by the processing time of the longest job in it. Few results on this total completion time problem seem to be available in literature, with the ant-colony algorithm of (Rafiee Parsa et al.) being the state of the art. We develop a heuristic algorithm based on column generation for this single machine problem that is also easily generalized to the parallel machines case. Results show the efficiency and effectiveness of the proposed procedure, which is able to solve instances up to 100 jobs and 5 machines, with very small optimality gaps.

Keywords: Dynamic Programming, Column Generation, Parallel Batching

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Scheduling Orders for a Last-Mile Meal Delivery Food Company

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Abstract: We consider a problem motivated by the pick-up and delivery of meals for the customers of a food company. Clients place a number of meal orders: A delivery location and a feasible delivery-time window are associated to each order and an equal amount of time is allotted for each time window. Food is prepared in a single facility (restaurant) and delivered by a single courier who may dispatch at most two different orders in a single trip. An order is "on time" when it is delivered within its given time window: The company is clearly interested in scheduling orders so that the number of those on time is maximized—as late deliveries correspond to an economic loss. The decision problem arising in this setting is modeled as a special single machine scheduling problem (which also finds obvious applications in manufacturing and logistics). We prove its hardness and propose an exact algorithm based on a branch and bound and different lower bounds. The performance of the enumeration scheme is assessed through a computational study on a set of test instances derived by our real-world application.

Keywords: Scheduling, Branch and Bound, Food Delivery

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A Bi-Objective Heuristic for Green Identical Parallel Machine Scheduling

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Abstract: In recent years sustainability in manufacturing has become a fundamental topic in the scientific literature. Several authors highlighted the preeminent role of manufacturing industry in total world energy consumption and carbon emission (Garetti and Taisch, 2012; Liu et al., 2014), which in turn is the primary cause for triggering the greenhouse effect. In this connection, this work tackles the multi-objective combinatorial optimization problem of scheduling jobs on multiple parallel machines, while minimizing both the makespan and the total energy consumption. The electricity prices vary according to a time-of-use (TOU) policy, as in many cases of practical interest. In order to face this problem, an ad-hoc heuristic has been developed. The first part of the method, called Split-Greedy heuristic, consists in an improved and refined version of the constructive heuristic (CH) proposed in (Wang et al., 2018). The second part, called Exchange-Search, is a novel local search procedure aimed at improving the quality of the Pareto-efficient solutions. The experimental results prove the efficacy of the proposed method with respect to two challenging competitors, i.e., the CH heuristic itself, and the NSGA-II algorithm.

Keywords: Green Scheduling in Manufacturing, Parallel Machines, Bi-Objective Heuristics

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T11: Equilibrium Problems, Variational Models, and Applications - 1

Chair: **Massimo Pappalardo**

Quasi-Variational Equilibrium Models for Network Flow Problems

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Abstract: We consider a formulation of a network equilibrium problem given by a suitable quasivariational inequality where the feasible flows are supposed to be dependent on the equilibrium solution of the model. The Karush-Kuhn-Tucker optimality conditions for this quasi-variational inequality allow us to consider dual variables, associated with the constraints of the feasible set, which may receive interesting interpretations in terms of the network, extending the classic ones existing in the literature.

Keywords: Quasi-Variational Inequalities, Equilibrium Models, Network Flows

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A Game Theory Model of Online Content Competition*

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Abstract: This paper develops a game theory model consisting of online content providers and viewers, where providers compete for the diffusion of their contents on a user-generated content platform. Each provider seeks to maximize the profit by determining the optimal views and quality levels of their digital products. The viewers reflect their preferences through the feedback functions, which depend on the amount of views and on the average quality level. The governing equilibrium conditions of this model are formulated as a variational inequality problem. Moreover, we analyze the Lagrange multipliers and discuss their role in the behavior of providers. Finally, our results are applied to a real example of content competition on YouTube.

Keywords: User-Generated Contents, Nash Equilibrium, Variational Inequalities

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General Oligopolistic Market Equilibrium Problem via Tensor Variational Inequalities: Existence and Regularity Results

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Abstract: The aim of the talk is to consider a general oligopolistic market equilibrium problem in which every firm produces several commodities. The equilibrium conditions of the model are given by the a generalization of the Cournot-Nash principle, which is expressed by a generalized tensor variational inequality in which every operator is defined in a tensor Hilbert space. Hence, the general tensor variational inequalities, recently introduced in [1], are fundamental in order to analyze the economic equilibrium model. For this reason, the study of existence and regularity results for such inequalities has an important rule to the light of applications. To this aim, we start to consider some existence and uniqueness theorems for tensor variational inequalities. Then, we investigate on the approximation of solutions to the tensor variational inequality by using suitable perturbed tensor variational inequalities. We establish convergence of solutions to the regularized tensor variational inequalities to a solution of the original tensor variational inequality making use of the set convergence in Kuratowski's sense. After that, we focus our attention on some stability results. Then, we apply the theoretical results to examine a general oligopolistic market equilibrium problem. Finally, a numerical example is provided.

Keywords: Noncooperative Game, Tensor Variational Inequality, Existence and Regularity Results

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A Variational Formulation for a Human Migration Problem*

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Abstract: Many social and economical factors affect the dynamics of human populations, such as poverty, violence, war, dictatorships, persecutions, tsunamis, floods, earthquakes, family reunification as well as economic and educational possibilities or a job. In this paper, we consider a network based model where the aim of each migration class is to maximize the attractiveness of the origin country and we prove that the optimization model can be formulated in terms of a Nash equilibrium problem and a variational inequality. Finally, some numerical results applied to the human migration from Africa to Europe are presented and analyzed.

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T12: Workshop - OR Towards Technology Transfer: From Data to Actionable Knowledge

Chair: **Laura Palagi**

Integrated Approaches to OR Practice, Aiming for Effective Decision Support

Matteo Pozzi

OPTIT

The Impact of Machine Learning on OR Practice: The ACTOR's Experience

Gianni Di Pillo

ACTOR, "La Sapienza" University of Roma

Optrail: Pioneering Optimization in the Railway Industry

Veronica Del Sasso

OPTRAIL

Towards Autonomous Flexible Picking: Recent Advancements and Challenges

Manolo Garabini

Research Center "E. Piaggio", University of Pisa

T13: Mixed Integer Programming

Chair: **Matteo Fischetti**

Flying Safely by Bilevel Programming*

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Abstract: Preventing air craft from getting too close to each other is an essential element of safety of the air transportation industry, which be come sever more important as the air traffic increases. The problem consists in enforcing a minimum distance threshold between flying aircraft, which naturally results in a bilevel formulation with a lower-level sub problem for each pair of aircraft. We propose two single-level reformulations, present a cut generation algorithm which directly solves the bilevel formulation and discuss comparative computational results.

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Computational Evaluation of Data Driven Local Search for MIP Decompositions*

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Abstract: Driven by the perspective use in decomposition based general purpose solvers, we tackle the issue of improving Dantzig-Wolfe decomposition patterns for generic Mixed Integer Programs (MIP). In particular, we consider the scenario in which a MIP instance and its decomposition are given as input and we address the task of manipulating such decomposition by observing only static algebraic components, with the aim of producing better computational performance features (tighter bounds and comparable computing times). We propose a local search algorithm guided by data driven models and evaluate its performance on MIPLIB instances while starting from decompositions given by either static or data driven detectors.

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Chance Constraint Problem with Integer Scenario Variables

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Abstract: The Chance-Constrained Mathematical Program (CCMP) is an optimization problem that states that the probability of meeting a certain constraint, that depends on the realization of a random variable, must be above a given value. A generalization of CCMP is that in which an unsatisfied realization can enter a recovery mode and in this case a cost that depends on the magnitude of the infeasibility has to be paid. Under specific assumptions, this problem can be modelled as a Mixed Integer Not Linear Problem (MINLP) and we propose a Branch-and-Cut algorithm where we generate cutting planes as outer approximation point cuts, when possible. We follow a decomposition approach whereby we define a single master problem and one scenario subproblems for each normal mode scenario and another one for each recovery mode scenario, involving scenario-dependent constraints. This approach generalizes the one proposed by Lodi et al. that only applies to the case in which the scenario variables are continuous. Given an infeasible solution of the master problem, we distinguish between three different cases: a first case in which the method proposed by Lodi et al. can be applied to generate a cutting plane, after the integrality constraint on the scenario variables has been relaxed; a second case that we address by mean of a novel procedure that returns a valid cut, when it exists; a last case in which some kind of branching is required in order to discard the infeasible solution.

Keywords: Chance Constraint Problem, MINLP, Branch-and-Cut

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Intersection Cuts for Quadratic Mixed-Integer Optimization

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Abstract: In this talk we consider the Mixed-Integer Bilinear Programming problem, a widely-used reformulation of the classical mixed-integer quadratic programming problem. For this problem we describe a branch-and-cut algorithm for its exact solution, based on a new family of intersection cuts derived from bilinear-specific disjunctions. We also introduce a new branching rule that is specifically designed for bilinear problems. We computationally analyze the behavior of the proposed algorithm on a large set of mixed-integer quadratic instances from the MINLPlib problem library. Our results show that our method, even without intersection cuts, is competitive with a state-of-the-art mixed-integer nonlinear solver (SCIP). As to intersection cuts, their extensive use at each branching node tends to slow down the solver for most problems in our test bed, but they are extremely effective for some specific instances.

Keywords: Mixed-Integer Quadratic Optimization, Bilinear Programming, Intersection Cuts

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T14: OR Applications - 1

Chair: **Francesco Archetti**

An Integer Programming Formulation for University Course Timetabling*

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Abstract: The university time tabling problem is defined as the process of assigning lessons of university courses to specific time periods throughout the five working days of the week and to specific classrooms suitable for the number of students registered and the needs of each course. A university timetabling problem is modeled, in this paper, as an optimization problem using 0-1 decision variables and other auxiliary variables. The model provides constraints for a large number of different rules and regulations that exist in academic environments, ensuring the absence of collisions between courses, teachers and classrooms. The real case of a Department and some instances from the literature are presented along with its solution as resulted from the presented ILP formulation.

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On the Sizing of Security Personnel Staff While Accounting for Over time Pay*

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Abstract: At many universities today, especially those in developing countries, budget cuts are leading to the reduction of staff for various campus services. One such service is campus security. However, a more holistic view may in fact reveal that, at least when it comes to security, work load reductions may actually increase the overall cost to the University since such reductions result in increased criminal activity which could be detrimental to the university either through direct financial losses, harm to students and staff or through a loss of reputation. For a given workload (i.e., the number of personnel assigned to each post for each shift) one must determine the appropriate staff size to satisfy this workload while minimizing overall cost. The desired workload may vary monthly (e.g., additional staff needed during special events) and, in addition, the number of available staff may vary monthly (e.g., because of increased vacation leave requests during the summer break). Staff must be provided at least 40 hours per week so too many staff is not cost effective while insufficient staff requires excessive over time in order to satisfy the required work load which is also not cost effective. We investigate the optimal trade-off so as to minimize the total financial cost for varying work loads and staff availability. We also take into account the various agreements between management and the employees' Union. We use standard Integer Programming techniques to solve the resulting problem. The additional constraints increase the complexity of the problem but we use a lower bound on the optimal solution to show that the solution obtained is close to optimal.

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Dynamic Tabu Search for Enhancing the Productivity of a Bottle Production Line*

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Abstract: Many industries use linear production lines, with buffers between each pair of machines for absorbing small breakdowns or other irregularities. These buffers have different thresholds for triggering the possible speeds of the machines. The goal of this study is to tune the values of these thresholds in order to enhance the productivity of the line. A simulation-optimization approach is proposed and applied to a case study involving a soft-drink plastic bottle company. We show that the production can be increased by a few pallets per day. Such results are appealing for the company, as updating these thresholds does not imply any cost.

Keywords: Simulation-Optimization, Tabu Search, Linear Production Line

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Swap Minimization in Nearest Neighbour Quantum Circuits: an ILP Formulation*

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Abstract: Quantum computing (QC) represents a great challenge for both academia and private companies and it is currently pursuing the development of quantum algorithms and physical realizations of quantum computers. Quantum algorithms exploit the concept of quantum bit (qubit). They are implemented by designing circuits which consider an ideal quantum computer, where no interaction restriction between qubits is imposed. However, physical realizations of quantum computers are subject to several technological constraints and adjacency between interacting qubits is one of the most common one. To this end, additional gates, referred to as swap, can be added to a quantum circuit to make it nearest neighbour compliant. These additional gates have a cost in terms of reliability of the quantum system, hence their number should be minimized. In this paper we first give some hints about this cutting edge topic. Then we provide a review of the literature solving approaches for the swap minimization problem in quantum circuits and propose an integer linear programming formulation for it. We conclude with some preliminary results on small test instances and future work perspectives.

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T15: Equilibrium Problems, Variational Models, and Applications - 2

Chair: **Mauro Passacantando**

A Traffic Equilibrium Nonlinear Programming Model for Optimizing Road Maintenance Investments*

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Abstract: We consider a traffic network in which some of the roads need maintenance jobs. Due to budget constraints not all of the roads can be maintained and a central authority has to choose which of the mare to be improved. We propose a non linear programming model where this choice is made according to its effects on the relative variation of the total cost, assuming that users behave according to War drop equilibrium principle. To assess the network improvement after maintenance we use the Bureau of Public Road link cost functions.

Keywords: Traffic Network, Wardrop Equilibrium, Investment Optimization, Braess Paradox

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On Dynamical Systems to Solve the GNEP

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Abstract: The generalized Nash equilibrium problem (GNEP) is an N player game, where each player has to solve a non-linear optimization problem whose objective function and constraints depend on the solutions of the other players. A very useful and general tool to deal with optimization problems and related applications is the variational inequality (VI). For instance, this tool has been successfully used to model and analyze the (classical) Nash equilibrium problem. Then, one popular way to find a solution of the VI is to solve differential equations whose stable points are our desired solutions. This approach leads to the projected dynamical system, the differential variational inequality or the replicator dynamics to cite some of the most popular. Some dynamical systems have been used in the literature to find a particular solution of a generalized Nash game with shared constraints, the so-called variational equilibrium. However, not all the solutions of the GNEP can be found this way as this problem is equivalent, under classical assumptions, to the more complex quasi-variational inequality. In this talk, we show that these dynamical system approaches can be extended to the case of the GNEP. We present some families of dynamical system that are useful in this context and discuss the new difficulties induced by this more complex game. We prove the existence of a solution of these systems as well as some asymptotic stability results. These results are constructive and lead to numerical algorithms with low complexity.

Keywords: Generalized Nash Equilibrium Problem, Quasi-Variational Inequality, Dynamical System

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Opinion Dynamics in Multi-Agent Systems Under Proportional Updating and Any-to-Any Influence*

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Abstract: We study an agent-based model to describe the formation of opinions within a group, where agents belong to classes. In the model any agent influences all the other agents at the same time, and the influence is proportional to the difference of opinions through interaction coefficients. We find that the interaction coefficients must lie with in a tetrahedron for the internal consistency of the model. We show that the system of agents reaches a steady state, but not a consensus over a single opinion or a limited set of opinions.The long-term opinion of each agents depends anyway on its initial opinion.

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A Constructive Method for Solving Optimal Control Models Governed by Parabolic Equations

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Abstract: The analysis of an optimal control model governed by parabolic differential equations is usually developed by carrying out the formulation of the so called "optimality system", which consists of partial differential equations with opposite orientations. Even though existence and uniqueness of the solution may be investigated, in most cases the solution itself is not available in closed form. For this reason, our aim consists of evaluating an accurate approximation. Thus, we provide a constructive method based on a scheme of successive approximations which converge in a suitable function space to a fixed-point representing the required solution. As it is expected, convergence gets slower as time horizon length increases. Successive approximations are evaluated by applying Finite Element method for the spatial semi-discretization; then the resulting ODE system is solved by exponential integrators. Some numerical results are provided in order to test the effectiveness of the proposed approach.

Keywords: Optimal Control Models, Fixed-Point Iteration, Exponential Integration

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T16: (AIRO)Young Tutorial Session: Young OR Specialists in the Industry - Experiences, Tips, and Panel Discussion

Chair: **Martina Fischetti**

What will happen after your PhD? How is the transition from Academia to industry? How is it

to apply OR in a company? Two young researchers, with different experiences in industry, are here to share their opinion and answer your questions. Students who decide to keep studying Operations Research at a PhD level and beyond are attracted by its applications in solving real world problems. Although the gap between academic research and the actual use of models and solutions methods at the industry level is still wide, an increasing number of industries are starting to look at Operations Research as a means to optimize their business. But what is the path that leads to working in such industries? And what are the challenges of adapting academic results to real-world applications? AIROYoung is the chapter of AIRO dedicated to young researchers in Operations Research. It has therefore a special focus on PhDs and PostDocs and organizes different activities to create a network between students and foster collaboration with industries. At our 1st AIROYoung school in Rome this year we proposed a new type of tutorials "from young to young", where more experienced PhD/PostDocs from all over the world taught the new PhDs skills and tools that they found relevant during their PhDs. Given the success of the initiative and the positive feedbacks from the participants, AIROYoung has decided to re-propose the framework in the special session of ODS2019 dedicated to young researchers in Operations Research. Young speakers that are nowadays working using OR in the Industry will share their experience and showcase some examples on how they used their OR background in practice. Part of the session will be dedicated to open discussion with the audience and Q&A. The invited speakers, who have different industrial experiences, will give to the attendees a broad picture and offer plenty of inspiration. The talks will be given by:

- Veronica Dal Sasso, Operations Research Scientist at Optrail
- Martina Fischetti, Lead Engineer in Operations Research at Vattenfall

T17: Workshop - Comparing the Contents of the OR Courses in Italian Universities

Chair: **Federico Malucelli**

Activation of a Huge Class: Mission Impossible?

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Teaching Operations Research Before University

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Soft Skills and Problem Solving More and More Required: OR in New Academic Programs

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OR Teaching Before University: Educational Experiences in the Technical Institutes, Logistics & Transport Curriculum. Reflections and New Perspectives

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F1: Smart Port Terminal Operations - 2

Chair: **Anna Sciomachen**

Maritime Container Terminals can Support Investments for Increasing the Rail Transport Modality?

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Abstract: Recent studies underline that the freight transport will have a positive trend in the next years, increasing until 2050 throughout Europe by 80% [1]; the importance of ports as international logistic nodes will increase as well. Thus, higher freight flows among ports and hinterlands must be efficiently managed, and the rail transport, together with intermodal transport, seem to be the best alternatives! Unfortunately, the rail share modality is much lower than the road one. This paper concerns an analysis on the best investments in seaports to improve the rail share modality when transferring goods from ports to final destinations. In [2] the authors show that it is possible to obtain a new rail capacity able to increase the modal split thanks to possible alternative investments. Following the above considerations, in the present paper the increasing of the rail capacity at ports is investigated. The main aims are to understand if the terminal can obtain an adequate return on the investment such to justify the intervention and the amount of rail flow the terminal can profitable manage. The analyses is conduct by assuming i) to have to transport by rail only 20' and 40' standard containers and tanker; ii) to know the actual flows from the terminal and their split among the considered types of containers. The analyses will investigate the maximum cost related to the management of the containers in such a way to have a given return on investments. Preliminary results are presented.

Keywords: Freight Distribution, Rail Investments, ROI

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A Heuristic Approach to Solve the Interval Immune Transportation Problem

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Abstract: We address the problem of finding the range of the optimal cost of a transportation problem when supply and demand vary over intervals and the transportation costs are immune against the transportation paradox. We introduce a theorem that characterizes the structure of the optimal solutions and we propose a heuristic approach, based on this theorem, to solve the problem. The algorithm is tested on a wide set of instances and proved to hugely outperform the solution approaches proposed in the literature.

Keywords: Transportation Problem, Interval Linear Programming, Heuristic Approach

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Displacing Containers from Mega-Ships to Dry Ports with Limited Buffer and Network Capacity

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Abstract: Container terminals operations are going to be highly affected by the mega-ships trend. Mega ships allow a clear reduction in transport costs but require investments in handling and short term storing capacity. Thousands of unloaded containers must be displaced from the yard to the required destinations in short time. Moreover, we have to consider several limitations both in the network and in the vehicles capacities and availability (Ambrosino et al., 2018, Di Francesco et al., 2019). As a consequence, a pressure on the surrounding transport network, and port gates is generated. This work investigates the impact of mega-ships into the port surrounding network and propose a model to optimize the displacement of containers toward the dry port destinations. The aim is to give a decision support for operational planning when limited capacity is considered both in the yard for container storage and in the network for quantity of container transferred per time unit. The model considers time dependent costs and traveling time on the network, with the aim to represent / limit the congestion. The congestion can be limited by partially delaying transports, and by exploiting (limited) storage capacities in network nodes. The model is used to study the process of containers displacement in a case study derived from APT-VL (Vado Ligure) (Musso and Sciomachen, 2019) which is going to be the main Italian container terminal equipped to manage mega-ship traffic. The problem is modeled as multi-period network problem where arc costs and traveling time change during specific time frames.

Keywords: Mega-Ships, Multi-Commodity Flow, Port Operations

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A New Formulation of the Single Door Truck Scheduling Problem*

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Abstract: In this paper we propose a new formulation for the truck scheduling problem at a cross-docking terminal with one inbound door and one outbound door. Through the computational experience, we show that the new formulation is more effective than a formulation from the literature.

Keywords: Cross-Docking, Mixed Integer Formulation, Scheduling

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Emerging Digital Technologies in Port-Related Logistics Centres: Business Opportunities and Managerial Implications

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Abstract: Digital technologies are strongly shaping the service sector of multimodal transport and maritime logistics. Innovations embedded in the paradigm of Industry 4.0, indeed, have brought a new wide array of applications in line with the concept of smart transportation and traffic flows optimization. In this perspective, port-related logistics centres represent a fruitful research field to evaluate the impact of digital technologies and related business opportunities, given the complex and multifaceted supply chain network they are involved in. Hence, the study aims to scrutinize how the adoption and the diffusion of emerging digital technologies could offer valuable business opportunities for the managing entities of port-related logistics centres, logistics service providers, carriers and shippers, by performing a systematic literature review and examining over 100 manuscripts published on leading international journals. Thus, the paper identifies major business benefits related to the adoption of new enabling technologies by logistics centres. We emphasize the potential strategic options that emerge from this process and enable logistics operators to create added value for their customers and enhance the competitiveness of the whole supply chain. In particular, we examine which competitive advantages they can obtain, considering both the increase of the overall operational efficiency and the differentiation of logistics services. As a result, the study demonstrates the lack of a comprehensive framework to evaluate the impact of new digital technologies on port-related logistics centres managing entities and logistics service providers' business models as well as on the overall supply chain they are involved in. Furthermore, the outcomes provide valuable insights for both academics and practitioners focused on strategic options addressed to innovate multimodal transport and logistics.

Keywords: Digital Technologies, Business Opportunities, Strategic Decisions, Port-Related Logistics Centres

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F2: Transportation Networks Performance and Reliability

Chair: **Yuval Hadas**

Optimization of Car Traffic in Emergency Conditions*

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Abstract: In this work, the aim is to present a possible methodology to redistribute car traffic, modelled via a fluid dynamic approach, within a part of the Caltanissetta city (Italy), when critical events, such as car accidents, occur. Adopting a decentralized approach, a cost functional, that measures the asymptotic average velocity of emergency vehicles, is maximized with respect to traffic parameters at nodes with two incoming and outgoing roads. Then, the management of high traffic is analyzed through local optimal coefficients at each node of the network. The whole traffic dynamics is studied by simulations, which confirm the correctness of the optimization procedure. It is also shown that optimal parameters allow a fast transit of emergency vehicles on assigned paths on the network.

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Disruption Management in Public Transport Systems

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Abstract: The planned daily service of a public transport company can be disrupted by different events, such as vehicle breakdowns, delays or exceeding capacity limitations on the number of passengers. These disruptions may cause the planned service to become infeasible and thus require the construction of an alternative service. The problems involved, that we are interested in, are timetabling as well as vehicle and driver scheduling. In the planning as well as disruption management literature these problems are mostly solved sequentially or by partially integrated approaches. One approach that considers integrated timetabling and vehicle scheduling during the planning phase is presented by Galli, L., et al (2018). Another example is that of Malucelli, F., Tresoldi, E. (2019), who consider the problem of vehicle and driver scheduling during disruption management. In our approach we try to reduce the solution space by only re-optimizing within a certain time window and afterwards returning to the planned service. Additional benefits are that drivers experience only initial deviation from their scheduled duties and some complicated constraints on driver duties may not apply within the re-optimization time window. M.A.I.O.R., a company that develops software solutions for public transport providers, is currently working on adapting the approach by Galli, L., et al (2018) to disruption management. They as well restrict the re-optimization to be within some time-window.

Keywords: Disruption Management, Timetabling, Scheduling

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Centrality Metrics After the Morandi Bridge Collapse

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Abstract: Network analysis is a research area which obtained much interest at the beginning of the 21st Century, and it is rooted in the discovery that, despite the diversity of complex systems, the structure and the evolution of the networks behind them is driven by a common set of fundamental laws and principles. Thanks to graph theory, algorithms, and current computational power, it is indeed nowadays possible to apply different types of analysis on large size networks in many different domains. Centrality analysis [1] is one example of analysis and it allows for instance to find the most influential nodes in a network, being these nodes extremely well-connected thanks to their degrees or because they lay down on many shortest paths. We applied centrality analysis to the road network of the region Liguria before and after the Morandi bridge collapse[†] to understand how this dramatic event changed the underlying network. Starting from the OpenStreetMap[‡] (OSM) dataset of the Liguria region we considered only public and accessible car roads and computed classical measures, e.g., betweenness and closeness centralities, at the regional (macro), metropolitan (meso), and city (micro) levels. To take into account the physical constraints of the territory, we used the tags in the OSM dataset to tune the time needed to traverse a road segment, at full legal speed, with respect to other road properties. To consider the bridge collapse we deleted from the network all roads closed because unusable after the crash. The results show that the metrics changed, as expected, and that the network became larger in terms of distances. The analysis we performed is based on the static road network topology only, but more interesting results can be obtained if also traffic data are taken into account, and we plan to extend the study to consider also this data source, possibly by accessing to real traffic data available at the Municipality level. Moreover, a second possible extension will compare less classical centrality measures like those introduced in [2] in order to understand the gain that can be obtained with respect to classical metrics.

Keywords: Centrality Measures, OpenStreetMap, Road Network

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[‡]https://www.openstreetmap.org

Resilience of Traffic Networks: Definition and Evaluation Methods

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Abstract: Initially introduced in the study of ecological systems, the concept of resilience, intended as the ability of a system potentially exposed to risk of adapting, resisting or changing, in order to achieve and maintain an acceptable level of operation, has been applied to multiple areas of study, transportation and civil infrastructure included (Zhou, Wang and Yang, 2019). Being the performance of a transportation system the result of the interaction between supply and demand, the purpose of this paper is to implement a discrete-time dynamic model for evaluating the resilience of a traffic network, in order to overcome the limits of the methods for resilience evaluation exclusively based on the network topology. In particular, the interest of this work is on evaluating the resilience of a traffic network in case a criticality, e.g. an accident, happens in one or more links. In order to obtain this result, in the pre-incident phase, the User Equilibrium traffic assignment problem is solved through a suitable optimization procedure and the computed total travel time is used as a benchmark for all the following ones. In case of critical events, such as accidents, the characteristics of the traffic network suddenly change, and consequently the hypothesis of perfect information for all the users, at least in the near future, is most likely wrong (Zhu et al, 2010). For this reason, starting from the critical event, the problems of assignment are considered as Partial User Equilibrium traffic assignment problems, characterized by gradually incorporating information about network conditions over time (He and Liu, 2012). The total travel time needs then to be calculated for each time interval: the resulting optimization problem has a nonlinear nature and is then solved with heuristic techniques. The resilience of the network is evaluated starting from the comparison between the total travel times under normal operating conditions and those calculated after the critical event.

Keywords: Traffic Networks, Resilience, Traffic Assignment

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Reliability Evaluation of Public Transportation Transfers Via a Game-Theoretic Approach

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Abstract: The assessment of network performance can relate to components such as nodes and arcs, in terms of their contributions to the overall network reliability and connectivity. In public transportation, transfer points are nodes that connect different routes and enable network connectivity. Public transportation networks should provide efficient and uninterrupted physical movement of people and freight from place to place. A game-theoretic approach based on cooperative games with transferable utility is proposed. Given a public transportation system, a game is defined which considers the public transportation network, the transfer points, the travel times, the stochastic properties of transfers, and the demand. The nodes of the network represent the players in such a game, and the Shapley values of the nodes are used to identify the centrality of the nodes. A two-level Monte Carlo approximation of the Shapley value is introduced, which is both fast and capable of integrating the stochastic properties of the network. Based on such a game, the relative importance of each transfer point can be identified, considering the reliability of transfers.

Keywords: Public Transportation, Transfers Analysis, Cooperative Games

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F3: Nonlinear Optimization and Applications - 1

Chair: **Massimo Roma**

Efficient Local Search Procedures for Quadratic Fractional Programming

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Abstract: The problem of minimizing the sum of a convex quadratic function with the ratio of two quadratic functions can be reformulated as a Celis-Dennis-Tapia (CDT) problem and, thus, according to some recent results, can be polynomially solved. However, the degree of the known polynomial approaches for these problems is fairly large and that justifies the search for efficient local search procedure. In this paper the CDT reformulation of the problem is exploited to define an approach which, on the theoretical side, is proved to converge to a stationary point, while from the practical side it is shown through different numerical experiments that the main cost of the algorithm is a Singular Value Decomposition to be performed during the initialization phase. The theoretical and practical results for this algorithm are further strengthened in a special case.

Keywords: Quadratic Fractional Programming, Celis-Dennis-Tapia Problem, Tikhonov Regularization

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Some Spherical Separation Variants for Classification Problems

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Abstract: We face the problem of separating two sets of points by means of a sphere, focusing on the case where the center of the sphere is fixed. Such approach reduces to the minimization of a convex and nonsmooth function of just one variable (the radius), revealing very effective in terms of computational time, as shown in [2]. In particular, we analyze the case where the center of the sphere is selected far from both the two sets, embedding the grossone idea [3] and obtaining a kind of linear separation. This approach is suitable for use in connection with kernel transformations and can be easily extended by introducing the margin concept [1] of the type adopted in the support vector machine (SVM) technique. Preliminary numerical results are presented on classical binary datasets drawn from the literature.

Keywords: Spherical Separation, Classification, Grossone

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An Efficient Optimization Approach for Subset Selection, with Application to Linear Regression and Auto-Regressive Time Series

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Abstract: In this talk we present a computational approach devoted to two important problems from statistics: best subset selection in linear regression and automatic model selection and parameter estimation in time series. Although many approaches have been presented for these problems, here we propose an innovative decomposition method based on the solution of MINLP models. Best subset selection in linear regression corresponds to finding a sparse linear model to fit some data, while for auto-regressive (AR) time series models the problem is to find a best regression taking into account model complexity, i.e., the order of the AR fit. Both problems are solved through a twoblocks Gauss-Seidel decomposition framework for which we could prove finiteness and other relevant properties. The proposed approach has been numerically tested on standard benchmarks and the results we could obtain prove that our proposed method is competitive with the best available ones both in terms of quality of the returned solution as well as in terms of CPU time.

Keywords: Model Selection, Linear Regression, Best Subset Selection, Autoregressive Time Series, Gauss-Seidel Decomposition

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Large Scale Global Optimization through an Intelligent Selection of Local Search Starting Points

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Abstract: In this talk we will present an innovative approach for global optimization (GO) problems based on the selection of starting points for local optimization. It is well known that coupling local refinement with global exploration is the key to the success of GO methods. We will present our approach based on an innovative application of clustering methods suitable for large scale optimization. A criterion based on similarity of feasible solution is defined in order to decide whether it is worth to start a local search from the current point. Innovative approaches based on low-dimensional mapping of high dimensional solutions are presented. Moreover we extend this approach to population based methods like, e.g., Differential Evolution and we show how clustering methods can be used within population algorithms to save computational effort while preserving the quality of the methods.

Keywords: Large Scale Global Optimization, Clustering Methods, Low-Dimensional Mapping, Differential Evolution

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Lipschitz Continuity of Perturbed Quadratic Programs and Applications

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Abstract: In [1] it is proved that the solution function of standard and even general quadratic programs are Lipschitz continuous (with best Lipschitz constants) with respect to the parameters in the objective function and in the right hand-side of the constraints. In the case of the metrical projection onto a perturbed polyhedron, again, the best Lipschitz constants are obtained. All these results improve analogue results obtained in [4]. In this talk I present two main applications of the results mentioned just above. First, we find with arbitrary precision the projection with respect to the L2 norm of a function f on a set of polynomial functions linked to f through an integral inequality. Next, we find an explicit Lipschitz modulus of continuity for so called graph convex polyhedral multifunctions with respect to the famous Pompeiu-Hausdorff metric, improving the estimation obtained in [3]. For future research, I will try to improve the Lipschitz constants in [2] obtained for the solution function of monotone affine variational inequalities.

Keywords: Quadratic Program, Lipschitz Continuity, Graph Convex Polyhedral Multifunction

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F4: VRP and Related Problems

Chair: **Paolo Toth**

On a Dynamic Orienteering Problem

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Abstract: We study a real-time decision problem defined on a directed graph where a travel cost is associated with each arc and a prize is associated with each node. The nodes are partitioned in mandatory and optional. Along a certain request-time horizon, mandatory nodes will certainly request a visit that must be satisfied; optional nodes will originate a request with a given time dependent probability, and such a request can be accepted or not. During a following limited travel time horizon, a server will start from a fixed origin, will visit both mandatory nodes and the optional nodes whose request has been accepted, and will end at a fixed destination. The profit of the server is the difference between the total collected prize and the total travel cost. The problem consists in finding a policy for accepting/rejecting optional requests during the request-time horizon in order to maximize the expected server profit while respecting the travel-time horizon limitation. We discuss the relevance of the problem and we derive a recursive formula for the expected profit optimization. Given the intractability of the recursion, we design several heuristic policies, based on combination of simple myopic rules, Monte Carlo simulation, and heuristic solution of the static counterpart of the dynamic problem, i.e., the Probabilistic Orienteering Problem. We set up a simulation framework where instances with up to 100 nodes are considered under different probabilistic assumptions and different widths of the travel-time horizon. The results of extensive computational tests are discussed.

Keywords: Real-Time Decisions, Orienteering Problem, Probabilistic VRPs

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The Cumulative Capacitated Vehicle Routing Problem with Profits under Uncertainty*

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Abstract: In this paper, we introduce the cumulative capacitated vehicle routing problem with profits and uncertain travel times. The aim is to visit a subset of customers maximizing the total collected revenue expressed as a decreasing function of the uncertain arrival times. The selective nature of the problem, the stochasticity of travel times, and the introduction of the capacity of vehicles make the problem quite challenging. We present a risk averse approach leading to a non-linear mixed integer mathematical model. To solve the model, we develop a very fast and efficient metaheuristic designed to address the selective nature of the problem. The performance of the metaheuristic is shown by preliminary results obtained for two sets of benchmark instances.

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The Team Orienteering Problem with Overlaps

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Abstract: The Team Orienteering Problem (TOP) aims at finding a set of routes subject to maximum route duration constraints that maximize the total collected profit from a set of customers (see Butt and Cavalier (1994), Archetti, Speranza, and Vigo (2014)). Motivated by a real-life Automated Teller Machine (ATM) cash replenishment problem that seeks for routes maximizing the number of bank account holders having access to cash withdrawal, we investigate a generalization of the TOP that we call the Team Orienteering Problem with Overlaps (TOPO), in which the total gathered profit can be strictly lower than the sum of the individual collected profits. We present exact algorithms based on column generation. An extensive computational analysis shows that the designed algorithms can efficiently solve synthetic and real-life TOPO instances. Moreover, the proposed algorithms are competitive with the best exact solution methods from the literature for the TOP. In particular, the algorithms can find the optimal solution for 371 out of the 387 benchmark TOP instances introduced by Chao, Golden, and Wasil (1996), 33 of which are closed for the first time.

Keywords: Routing with Profits, Cash Distribution, Column Generation

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Logic-Based Benders Decomposition for the Heterogeneous Vehicle Routing Problem with Time Windows

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Abstract: We consider an optimal algorithm based on the logic-based Benders decomposition and a variant, called branch-and-check, for the heterogeneous fixed fleet vehicle routing problem with time windows. The objective is to service, at the minimal cost, a set of geographically dispersed customers within their time windows by a limited and capacitated fleet of heterogeneous vehicles. The proposed algorithms decompose the problem into a generalized assignment master problem and independent traveling salesman sub-problems with time windows. Valid optimality and feasibility cuts are devised to guarantee the convergence of the algorithms, which include enhancements to solve the master problem and the sub-problems. Extensive computational experiments on 216 benchmark instances illustrate the effectiveness of the suggested approaches. Instances with up to 100 customers are solved to proven optimality and the results indicate that the best proposed algorithm is competitive with state-of-the-art methods.

Keywords: Vehicle Routing Problem, Time Windows, Heterogeneous Fleet, Logic-Based Benders Decomposition, Branch-and-Check

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A Kernel Search Heuristic for the Multi-Vehicle Inventory Routing Problem

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Abstract: An inventory routing problem is studied in which the goal is to determine an optimal distribution plan to replenish a set of customers, by routing a limited fleet of capacitated vehicles over a discrete planning horizon. Each customer consumes a per period quantity of products and has a maximum inventory capacity. The goal is to minimize the total distribution cost, that comprises the routing and the inventory holding costs. A novel matheuristic is proposed for this problem which is based on the Kernel Search (KS), a heuristic framework that has been shown to find high-quality solutions for a number of Mixed-Integer linear Programming (MIP) problems. The basic idea of the KS is to identify an initial kernel of valuable variables and subsets of the remaining variables from the continuous relaxation of the MIP formulation, and then to solve a sequence of MIP sub-problems, each restricted to the current kernel and a subset of variables. As the relaxation of the MIP formulation of a routing problem is not meaningful, the initial kernel and the subsets of variables are built using information gathered from a tabu search algorithm. Extensive computational experiments are conducted on a large set of benchmark instances. The results show that the matheuristic outperforms state-of-the-art algorithms, finds 51 new best-known solutions out of 640 small-size instances, and 102 new best-known solutions out of 240 large-size instances.

Keywords: Inventory Routing, Matheuristic, Kernel Search

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F5: Stochastic Programming: Optimization Under Uncertainty and Applications

Chair: **Francesca Maggioni**

Dealing with the Stochastic Home Energy Management Problem*

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Abstract: This paper focuses on the home energy management problem faced by a smart prosumer equipped with photovoltaic panels and a storage system. Some of the home appliances (the shiftble ones) can be controlled in that the consumer may specify an operating time window within the load should be turned on. The inherent uncertainty affecting the main model parameters (i.e. loads and production from renewable) is explicitly accounted for by adopting the two-stage stochastic programming modeling paradigm. The solution provides the prosumer with the optimal scheduling of the shiftable loads and the using profile of the storage system that guarantee the minimum expected energy procurement cost, taking into account the prosumers comfort. Preliminary results, collected on three different categories of residential prosumers, have shown the effectiveness of the proposed approach in terms of cost saving and the advantage related to the use of a stochastic programming approach over a deterministic formulation.

Keywords: Home Energy Management, Stochastic Programming, Optimal Scheduling

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A Two-Stage Stochastic Programming Approach for Generation and Transmission Expansion Planning with High Shares of Renewables

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Abstract: Given forecasts of future values of load, fossil fuel prices and investment costs, investments are defined by means of a mixed integer linear model that determines how the capacity mix should evolve in order to meet the demand for electricity and fulfill policy targets, while minimizing the sum of operational, investment and decommissioning costs. A cost minimizing investment schedule is determined for decommissioning of existing thermal plants and construction of new generation capacity, as well as of electrical regional interconnections. Policy goals and environmental targets, such as fossil fuels and CO2 emissions reduction, are explicitly considered in the expansion plan. Since generation and transmission expansion plans are generally made for a long-term planning horizon, the system conditions are generally uncertain at the time the expansion plans are decided. Uncertainties include wind and solar build costs, emission costs and fossil fuel prices. A high level of temporal detail is required to accurately study the integration of large shares of renewable energy sources. In order to obtain high accuracy without dramatically increasing computational cost, we select a set of representative days by performing a clustering analysis on input data. Results obtained with our methodology in the Italian energy system under a 11-year planning horizon show how the proposed model can offer a professional guidance and support in strategic decision to the different actors involved in electricity transmission and generation.

Keywords: Generation and Transmission Expansion, Renewables, Stochastic Programming

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Optimization Methods for the Same-Day Delivery Problem*

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Abstract: In the same-day delivery problem, requests with restricted time windows arrive during a given time horizon and it is necessary to decide which requests to serve and how to plan routes accordingly. We solve the problem with a dynamic stochastic method that invokes a generalized route generation function combined with an adaptive large neighborhood search heuristic. The heuristic is composed of destroying and repairing operators, and the generalized route generation function, taking advantage of sampled-scenarios that are solved with the heuristic, determines which decisions should be taken at any instant. Results on different instances have shown the effectiveness of the proposed method in comparison with a consensus function from the literature, with an average decrease of 10.7%, in terms of solution cost, and 24.5%, in terms of run time.

Keywords: Same-Day Delivery Problem, Pickup and Delivery Problem, Dynamic Stochastic, Adaptive Large Neighborhood Search, Route Generation Function

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A Deterministic Approximation for the Long-Term Capacitated Supplier Selection Problem with Total Quantity Discount and Activation Costs Under Uncertainty

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Abstract: The Capacitated Supplier Selection problem with Total Quantity Discount and Activation Costs (CTQD-AC) is a multi-supplier multi-product procurement problem including supplier selection, total quantity discount policies, restricted availabilities of the products at the suppliers, and business activation costs. To model realistic procurement settings in the long-term period, the CTQD-AC has been studied in its stochastic counterpart by explicitly considering different sources of uncertainty, such as product demand and prices (Manerba et al., 2018). However, due to the computational burden of solving stochastic models, only relatively small instances can be efficiently addressed. For this reason, following Tadei et al. (2012, 2017), we propose a deterministic approximation of the stochastic CTQD-AC problem that works under a mild assumption on the probability distribution of the random variables. The quality of our approximation is tested against the classical two-stage Stochastic Programming approaches existing in the literature.

Keywords: Procurement Logistics, Total Quantity Discount, Deterministic Approximation

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Sampling Methods for Multistage Robust Convex Optimization Problems

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Abstract: In this talk, probabilistic guarantees for constraint sampling [1]-[2] of multistage robust convex optimization problems are derived [3]. The dynamic nature of this difficult class of problems is tackled avoiding the conservative use of explicit parametrizations through decision rules adopted in the literature [4]. An explicit bound on the probability of violation of the randomized solution is provided and a proof of convergence of the randomized approach presented. Exact and sampled-based lower bounds to the original multistage robust optimization program are discussed. Numerical results dealing with a multistage inventory management problem show the efficacy of the proposed approach.

Keywords: Multistage Robust Optimization, Constraint Sampling, Violation Probability

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F6: OR for Drones Applications

Chair: **Claudio Sterle**

Flying Sidekick Traveling Salesman Problem with Multiple Drones

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Abstract: The boom of e-commerce have encouraged companies to find always more effective ways to provide home delivery services. Among the many methods detected, the use of drones is earning more and more interest. Many recent papers have treated drones for parcel deliveries, in particular when vehicles are coupled with drones (see, e.g., Murray and Chu). However, few papers have treated the use of multiple drones: Wang et al. and Poikonen et al. have considered multiple vehicles and multiple drones in a theoretic way. The present work, on the contrary, considers the problem where a set of drones and one vehicle are coupled and drones depart from and return to the vehicle. We propose a MILP formulation, a branch-and-cut algorithm, and we study the effect of multiple drones on the solution, evaluating the results on the benchmark instances for the problem where the vehicle is equipped with only one drone.

Keywords: Drones, Multiple, Routing

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Drone-Based Humanitarian Logistics for Delivery of Perishable Items

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Abstract: Just as emergency public safety systems (i.e., ambulance, fire protection, and police) which are road-network based, we have been developing complementary emergency systems that are airborne, primarily using helicopters, for emergency humanitarian assistance, for example search-andrescue missions, delivery of emergency goods, and emergency medical assistance. The general problem is as follows: after a disaster like a major hurricane and discovery of patient demands, how can we meet the resulting "To-Do" list, where each item may be perishable, may have a deadline for delivery, and may have list of possible substitutions from the available inventories? Item pick-ups by a drone (e.g., blood samples) may also be on the to-do list. Given the large number of possible scenarios for the general problem, this talk addresses in detail only the following specific problem. We have p delivery drones to serve m remote demand points that need delivery of emergency medical supplies such as blood units. These demand points are reachable only by drones constrained by a limited distance range to service a demand point. The drones operate out of mobile platforms which may be moved on usable roads. Each demand point requires a single package of product whose utility decreases with delivery time due to product perishability. Furthermore a customer's demand may have a delivery time deadline. The main problem addressed is to locate p platforms, and their associated drones, so that the total disutility is minimized. We study (1) the one-day case where platforms are moved to the optimal location set to service the discovered demands, and (2) the two-day case where the platforms may be moved to other available locations on the night of the first day.

Keywords: Drones, Humanitarian Logistics, Time-Dependent Formulation

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A Continuous Solution Method for the Multi-Visit Drone Routing Problem

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Abstract: In recent years the usage of drones in Last-Mile Logistics has continued to stir great interest in the OR community. Many papers have considered different hybrid truck-and-drone delivery schemes. Among the different schemes, we focused on the Multi-visit Drone Routing Problem which assumes: a heterogenous set of packages, a drone capable of carrying multiple packages at a time, a flexible launch/retrieval site set, and a user-defined energy depletion function. In this context, we propose a new method based on a general framework, devoted to determine potential interesting launch/retrieval sites along the road network edges. It consists of two phases. In the first one, the road network edges are discretized to obtain launch/retrieval sites, and a first solution is determined. In the second phase, knowing the truck route and the set of customers served by the drone, it is possible to reduce the completion time by carefully synchronizing truck and drone routes. Indeed, we exploit the flexibility of the drone route, which can move forward or backward between launch/retrieval sites in such a way that the truck's waiting times are minimized. This result is obtained solving an original Mixed Integer Second Order Cone Programming model. The proposed method has been tested on several instances and the obtained results show its effectiveness with respect to state of the art approaches.

Keywords: UAVS, Routing, Logistics

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Exact and Heuristic Approaches for the Flying Sidekick TSP

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Abstract: In recent years the usage of unmanned aerial vehicles (UAV) in different fields, such as surveillance, disaster management and transportation, is significantly increasing and new decision problems are arising and are worth to be investigated. In this work we focus on the usage of UAV in the last-mile distribution. The flying sidekick traveling salesman problem (FS-TSP) is a drone assisted parcel delivery problem aimed at defining the distribution plan of a driver-operated truck assisted by an unmanned aerial vehicle. The objective is the minimization of the time required to service all the customers, taking into account UAV payload capacity, battery and distance constraints. The truck and the UAV may must depart and return to a single depot, either in tandem or independently. In this work a new extended MIP formulation for the problem, strengthened by several additional valid inequalities integrated in a branch-and-cut-and-price algorithm is proposed. Moreover, a heuristic approach to deal with larger instances is also presented. The proposed exact and heuristic methods are tested on several instances and compared with other approaches present in literature, showing good results in terms both of the quality of the solution and computation time.

Keywords: Logistics, Integer Programming, Branch and Cut and Price

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An Integrated Location-Covering Model for Hybrid UAV-Based Delivery System

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Abstract: Unmanned aerial vehicles (UAVs), or drones, have been successfully adopted in a number of cases [1]. Applications to delivery systems have recently received considerable attention., e.g., package delivery to remote rural regions, first- and last-mile delivery in urban and suburban areas and express delivery of, for example, medical supplies. In these cases, several advantages in adopting UAVs can be identified as they represent a potentially greener alternative to conventional delivery modes. However, micro, mini, and small drones can spend only a very limited time airborne. On the other side, urban contexts can be characterized by pedestrian areas or narrow alleys. Hence, combining drones with other means of transportation, e.g. trucks, may lead to a significant increase of efficiency and effectiveness in performing package deliveries. Synchronization is required in combined operations of drones and vehicles for package deliveries, and constraints related to UAVs motion and energy have to be considered. In this talk, we present a multiperiod location- covering problem of one truck and a set of UAVs for package delivery in an urban area. We assume that in a given time window T a set of customers C, has to be served by a set of UAVs which pick up the packages from a truck and deliver them to the customers. The truck can be located in different points of the urban area and moved among them between two consecutive missions of the UAVs, where a mission is a set of demands served. Each UAV is characterized by a maximum autonomy expressed in kilometers and has to be recharged on the truck. The problem consists in determining the locations of the truck and the UAV missions over the time window to minimize the total cost related to the truck and UAV operation and energy consumption subject to the constraints: (i) all customers have to be served within the time window, (ii) each UAV has to be recharged before or when it reaches the minimum battery level. Following previous work [2] we present solution method and preliminary computational results.

Keywords: Delivery Systems, Drones, Location, Covering

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F7: Nonlinear Optimization and Applications - 2

Chair: **Stefano Lucidi**

Linesearch Based Algorithms for Continuously Differentiable Multiobjective Optimization Problems

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Abstract: In this work, we propose an algorithm model for multiobjective optimization problems with continuously differentiable objective functions. The proposed method follows a steepest descent approach for multiobjective optimization and its distinguishing feature is that of not scalarizing the objective functions but rather of trying to build an approximation of the Pareto front. The algorithm iteratively improves a temporary list of non dominated solutions. At every iteration, this list is updated by performing suitable new multiobjective linesearch techniques starting from the points of the old list. These linesearch techniques are performed along directions which must satisfy mild descent properties. In fact, unlike the standard steepest descent approach, these directions do not necessarily need to be descent directions respects all the objective functions. The particular features of the proposed multiobjective linesearch techniques and the particular properties required on the search directions are able to guarantee that sequence of lists produced by the algorithm model globally converges towards a set of Pareto stationary points. Finally we report the results of a preliminary numerical experience where we have compared the computational behavior of a particular implementation of the described algorithm model on a set of test problems with the ones of algorithms based on approaches previously proposed in literature.

Keywords: Nonlinear Optimization, Multiobjective Optimization

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An Augmented Lagrangian Method Exploiting Second Order Information

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Abstract: In this talk we are concerned with the minimization of a nonlinear function subject to general nonlinear constraints and bound constraints on the variables. To find KKT points, we propose the use of a projected Newton-type direction which is proved to be locally and superlinearly convergent under standard assumptions on the problem. In order to define a globally convergent algorithm, we embed the Newton-type direction within an augmented Lagrangian framework [Andreani et al. 2007] which explicitly handles the bound constraints. Concerning the solution of the augmented Lagrangian subproblem, we adopt a recently proposed efficient two-stage active-set algorithm [Cristofari et al. 2017]. Numerical results are finally provided to show that the proposed method is competitive with existing state-of-the-art algorithms.

Keywords: Nonlinear Optimization, Augmented Lagrangian, Bound Constrained Subproblem

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Feature Selection in SVM via k-Norms

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Abstract: We focus on the Feature Selection problem in the Support Vector Machine (SVM) framework by minimizing the ℓ_0 pseudo–norm of the normal vector to the separating hyperplane. The objective is to control the number of non-zero components of such vector, while maintaining satisfactory classification accuracy. In our model the polyhedral norm $\|.\|_{[k]}$, consisting of the sum of k maximal components (in modulus) of any vector, plays a significant role. We come out with a DC (Difference of Convex) optimization problem that is tackled by means of DCA algorithm. The results of a number of numerical experiments on benchmark classification datasets are reported.

Keywords: Sparse Optimization, Support Vector Machine, k-Norm

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On the Use of k-Norms in MINLP Models for Feature Selection

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Abstract: We discuss a Feature Selection problem in the Support Vector Machine (SVM) framework for binary classification. The formulation is an optimization problem embedding the objective of keeping as small as possible the number of nonzero components of the solution point. In standard approaches the model is introduced by using the l_0 pseudo–norm that counts the number of nonzero components of any vector. We present two reformulation of the problem. The first, the classic "big M" one, is easily obtained by introducing a set of bin variables counting the sparsity of the feature vector. The second reformulation is obtained by using a class of polyhedral norms, known as k-norm, defined as the sum of the k largest components (in modulus) of any vector. The resulting problem is a Mixed Integer Nonlinear Programming (MINLP) formulation for which a DC (Difference of Convex) decomposition is introduced. We focus on the continuous relaxations of the two presented formulations.

Keywords: SVM, Feature Selection, DC Optimization

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Multiple Instance Learning via Spherical Classifiers and DC Optimization

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Abstract: Unlike standard supervised learning, where a classifier is trained based on a set of feature vectors (instances) each associated to a class label, in the Multiple-Instance-Learning (MIL) approach a classifier is trained with respect to a set of bags, each containing multiple instances. In particular, in the MIL setting each bag has an associated label, but the individual instance labels are ambiguous. We consider a Multiple Instance Learning problem where the objective is the binary classifications of bags of instances, and we adopt spherical separation as a classification tool. We propose a DC (difference-of-convex) decomposition of the resulting nonconvex and nonsmooth MIL loss-function, and we tackle such DC model by resorting to a specialized nonsmooth DC optimization algorithm, based on objective function linearization and bundling. We report on the results obtained by applying the proposed approach to some benchmark test problems.

Keywords: Classification, Multiple Instance Learning, DC Functions

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F8: Optimization in Eco-Sustainable Transportation

Chair: **Maurizio Bruglieri**

Optimization and Business Modeling in Car-Sharing Services: A Taxonomic Review

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Abstract: More recently, car-sharing service has changed the people mobility shifting from private car ownership to service use. It is gaining momentum due to the growing awareness of the environmental impact of private cars and the development of ICT technologies (Hayashi et al., 2014). The increasing demand makes needed a better understanding and control of such a complex system. It is made up of different actors interacting with each other, including citizens, companies and public authorities in charge of integration with the public transport network and regulating the competition among car-sharing operators. Despite the emerging importance of this type of mobility and the vast scientific literature in this field, to our knowledge, an extensive and structured analysis to classify the research and determine its mainstreams is missing. This study reviews 137 papers from 2001 by applying a repeatable taxonomy and deriving trends and research perspectives, analyzing the multi-facet aspects of car-sharing. In particular, we investigate four issues: the analysis of the user behaviors, the forecast of the service demand, the use of optimization tools for the design and management of the service and the business development and its effect in driving the research. Results highlight that the optimization models deal mainly with the operational aspects (e.g., service design, infrastructure and fleet management, relocation problem), while the economic, and managerial issues of this service, as user profiles and tariff schemes (Perboli et al., 2018), have little attention in the literature, compromising the sustainability of the car-sharing industry. This gap is evident when we look at the revenues generated by the companies, still marginal compared to the capital in use. These findings suggest that the business models and their link with the operational models, need to be integrated and embedded into optimization tools, to support the profitability of car-sharing companies.

Keywords: Business Model, Car-Sharing, Optimization

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On the Optimization of Charge and Relocation Operations in Electric Carsharing Systems

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Abstract: In recent times, Smart MOBility (SMOB) systems have attracted a lot of attention, since they are considered a fundamental component of modern smart cities, as recognized by national and international establishments and by major companies active in the landscape of digital economy. A major example of SMOB service is represented by carsharing. Nowadays, by carsharing is intended a mobility service that allows a user to rent a car for very short period of times, for example a few (tens of) minutes, using a smartphone application and paying a per-minute fee. In this work, we consider a reservation-based carsharing system that allows one-way user trips through a fleet of electric vehicles and uses a set of stations for their recharge. The carsharing operator manages a team of agents for relocation actions aimed at rebalancing the distribution of vehicles. We propose a new Integer Linear Optimization model that integrates the reservation and relocation phases of vehicles, taking into account battery consumption and recharge actions, and a matheuristic for its solution. Computational tests considering real instances from a major Italian carsharing company are presented to assess the performance of our new approach.

Keywords: Carsharing, Relocation, Integer Linear Programming

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Vehicle Routing Problem in Urban Area: The Role of Parking Availability in Mitigating Environmental Impact

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Abstract: In this work we face the problem of delivering a given amount of goods in urban areas arising from e-channel department stores, with the aim of minimizing the overall distribution costs [Cerulli et al.]. Costs considers traveling components, loading and other operative aspects, environmental issues. In the business to consumer distribution problem, we have to determine the fleet of not homogeneous vehicles (trucks, wagons, vans, picks-up) to be used for satisfying the demands of clients coming from e-channels, and their related itineraries, given the traveling limits imposed by the urban government. We have to respect the maximum route length constraints and the use the appropriate vehicles for each kind of street. In addition, the pollution produced during parking is taken into account.

Keywords: Vehicle Routing, Environmental Management, Parking

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The Green Vehicle Routing Problem with Reserved Capacitated Stations

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Abstract: The Green Vehicle Routing Problem (G-VRP) aims at routing Alternative Fuel Vehicles (AFVs), based at a common depot, for serving a set of customers. Each route starts and ends from/at the depot, serving a subset of customers. Due to its limited driving range, an AFV may stop at Alternative Fuel Stations (AFSs) along its route. While in the literature the AFS capacity is assumed unlimited, we address the extension of the G-VRP with Capacitated AFSs where at most η AFVs can be simultaneously refueled at an AFS with η fueling pumps. We model it by both Arc and Path based Mixed Integer Linear Programming. The latter model (P-MILP) considers only feasible nondominated paths. We also design two efficient slightly different P-MILP based Cutting Planes methods where in the relaxations, the AFS capacity constraints are dropped. Moreover, at each iteration, in the former, a cut is added for restoring the capacity constraint violated by the current solution while, in the latter, a set of cuts are included for restoring the capacity constraints that may be luckily violated later. For preventing possible queues at AFSs, the possibility of reserving them is considered. Then, our approaches are extended introducing time windows at AFSs for modelling their availability. Results, on both benchmark and realistic instances, are compared in scenarios with and without AFS reservation.

Keywords: Cutting Planes, Fuel Station Reservation, Vehicle Routing Problem

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The Collaborative Relocation in One-Way Electric Carsharing Systems

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Abstract: In Vehicle Sharing Systems (VSSs), users can rent a vehicle paying a charge depending only on the actual time of use. In one-way VSSs, they are also allowed to delivery a vehicle to a station that may be different from the one of pick-up. This of course introduces flexibility but also poses the problem of re-balancing the demand and the supply of vehicles between the stations by means of operators. We address the Electric Vehicles Relocation Problem (EVReP) assuming that the operators directly drive vehicles (indeed cars in our application) from a station of pick-up to one of delivery, moving by folding bicycles from a station of delivery to one of pick-up, as in Bruglieri et al. (2014) and Bruglieri et al. (2017). Collaboration among operators is also possible through the "carpooling", i.e., an operator can give a lift to the others moving from a station of pick-up to one of delivery. We study the economic sustainability of the collaborative EVReP through a Mixed Integer Linear Programming (MILP) formulation assuming that a revenue is associated with each relocation request satisfied and an hourly cost with the operators used. The MILP allows routing and scheduling the operators with the objective of maximizing the total profit, i.e., the difference between the total satisfied request revenue and the total operator cost. The constraints allow satisfying the requests within their time windows and taking into account the limited EV battery autonomy. Through numerical experiments on real like instances, we show that the collaboration among operators can improve the total profit of the carsharing system. Moreover, the new MILP formulation outperforms the previous ones also in terms of computational time being based on two-indices variables by elimination of their dependency on the relocation operators.

Keywords: Mixed Integer Linear Programming, Pick-up and Delivery Problem with Time Windows, Operator Based Relocation

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F9: Rail Port Operations

Chair: **Daniela Ambrosino**

The Design of a Port Authority Rail Application Module - How to Manage the Need for National Standardization with Local Requirements

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Abstract: Port Authorities should be the key players in the design of rail services, which are provided to end users of the port logistics hub. The objectives should combine public and private business goals, such as: low times and costs for the movement of goods and carriers, controls and authorizations procedures. The "Port Authorities Design" must include railway infrastructures, administrative and operational design of the services, optimization of the last mile information. Today Ports of Genoa is implementing a RAIL SW module, which is combined with a high automation of rail network and control systems. Current regulation for public administrations on procurement provide for the reuse of existing software. There are projects in place that aim to standardize services nationwide. However, an effective Rail Module Design must also comply with specific requirements:

- the insertion in the overall information system of the ADSP (port community system) in all its "front-end"and "back-end" components;
- the specific variables of the infrastructural and operational context both in the AS IS and in the TO BE scenario.

Is it possible to succeed in reconciling these two apparently opposing needs, namely national standardization and the specific port context? The work briefly describes possible constraints and requirements of the local context, highlighting how they can be effectively taken into account in the design of the Port Authority Rail module.

Keywords: Port Authority, Port Community System, Rail Module, Design

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A Mathematical Approach for Managing the Train Loading Process

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Abstract: The container import flows due to mega vessels approaching maritime container terminals may generate a lot of congestion and this makes even more important to use rail modality for transferring containers outside the terminal very quickly [1]. Generally, the unloading operations from the ships are performed as fast as possible, without following any storage strategy, since the information related to the containers' departure trains is not available. Thus, it is extremely important to efficiently manage the train loading process. This process begins in the rail yard, where containers are stored and wait for their loading on a train. Some reach stackers are generally used to move containers from the storage area to the tracks, where one or more cranes load containers on the wagons of the train. The position of a container in the storage area is given in terms of stack and tier. Sometimes it is necessary to perform some re-handles for being able to load the train as required. Given a train load plan to be met, given containers in the storage area and given the reach stackers moving containers from the storage area to the tracks (where, it is assumed that one crane loads the containers on the wagons), the problem is to decide which operation is performed by each reach stacker at each time step and, in case of reshuffles, which is the new position of the re-handled containers. The train load plan is given in terms of a sequence of containers to be loaded on the train, considering that the train must be loaded sequentially by the crane [2]. We propose a mathematical model for defining the best sequence of activities to assign containers to each available reach stacker for picking them up from their stacks, either transferring them near the train for their loading or moving them in a new yard position if a reshuffle is required. The main aim is to load the train as fastest as possible by minimizing the unproductive operations of the reach stackers.

Keywords: Train Loading Process, Sequencing Reach Stackers Activities

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A Fixed-Parameter Tractability Result for the Train Marshalling Problem

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Abstract: The Train Marshalling Problem (TMP) is a combinatorial problem concerning the rearrangement of trains whose cars have different destinations. The process takes place in a shunting yard where a single entering rail bifurcates into a certain number of parallel auxiliary rails that, at their end, merge back into a single exiting rail. The shunting process works as follows. First the cars of an incoming train are shunted one by one on the auxiliary rails, where they form trains corresponding to subsequences of the original train. Then these trains are extracted one by one from the auxiliary rails and get reconnected in some order on the exiting rail. The TMP is the problem of determining the minimum number of auxiliary rails needed so that in the outgoing train all the cars with the same destination occur consecutively. The problem is NP-hard and is known to be Fixed Parameter Tractable (FPT) with respect to the number of the different destinations of the cars as parameter. Here we show that the TMP is FPT with respect to its optimal value as well. To this aim we present a non-deterministic automaton that solves the decision version of the TMP by simulating the assignment of the cars to the rails. The FPT result is proved by estimating the number of states that the automaton can possibly reach under a basic condition that has to be satisfied by every yes-instance.

Keywords: Fixed-Parameter Tractable Problem, Non-Deterministic Automaton

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Intermodality and Rail Transport: Focus on Port Rail Shunting Operations*

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Abstract: The presence of many actors interacting in the intermodal transport where rail modality is involved, causes some inefficiencies and some bottlenecks. These bottlenecks make the intermodal transport rigid and less fluid than the road transport. Operation research approaches can be useful as support for the decision makers in order to improve the process and to favour the development of rail transport. Thus, this work aims at describing the entire rail transport process within the intermodal transport in order to high light the critical points that can be improved; in particular, both port rail shunting activities, and port rail terminal operations are discussed. A focus on a novel critical aspect never investigated before (at least for the author knowledge) is reported: the port rail shunting re-scheduling problem. A discussion on possible approaches for solving this problem is presented, together with a first approach based on a space-time network.

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F10: New Last-Mile Transportation Paradigms Under Clever Resource Usage and Prominent Technologies

Chair: **Francesca Guerriero**

Trucks and Drones Cooperation in the Last-Mile Delivery Process

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Abstract: We investigate the problem of routing a fleet of trucks equipped with drones in last-mile delivery process. The customers can be served by either a truck or a drone within the owns time window. Each truck carries drones and both can perform deliveries. The drone takes off from a truck located either at a customer or at the depot and it must land on the same truck after visiting a customer. All customers have to be served at minimum cost, considering time window, capacity, and flying endurance constraints. We propose a mixed integer linear program (MILP) along with a heuristic procedure based on a multi-start framework. We carried out experiments on modified benchmark instances. We analyze the behavior of the considered transportation system by mean of the solutions provided by the MILP. The proposed formulation solves instances with up to 15 customers. The solutions of the MILP are used as benchmark to assess the effectiveness of the proposed heuristic.

Keywords: Last-Mile Delivery, Truck-Drone Delivery, Multi-Start Heuristic

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A Variable Neighborhood Search for the Vehicle Routing Problem With Occasional Drivers and Time Windows

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Abstract: We present a Variable Neighborhood Search algorithm for a Vehicle Routing problem variant with crowd-shipping. We consider a heterogeneous fleet composed of conventional vehicles and some ordinary drivers, called occasional drivers, who accept to deviate from their route to deliver items to other people for a small compensation. The objective is to minimize total costs, that is conventional vehicles costs plus occasional drivers compensation. We compare the results obtained by using the proposed procedure with the optimal solution costs obtained by solving a mathematical model with CPLEX. The Variable Neighborhood Search is highly effective and solves large-size instances within short computational times.

Keywords: Vehicle Routing, Crowd-Shipping, Variable Neighborhood Search

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Efficient Solutions for the VRP with Occasional Drivers and Time Windows

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Abstract: In this talk, several efficient solution approaches will be described to efficiently compute high-quality approximate solutions for a vehicle routing problem (VRP) variant with a crowd-sourced delivery policy. We considered a heterogeneous fleet composed of conventional capacitated vehicles and occasional drivers, i.e., ordinary people who accept to deviate from their route to deliver items to other people, for a small compensation. Furthermore, we have also defined time windows for both the customers and the occasional drivers. The objective is to minimize total costs, that is conventional vehicles costs plus occasional drivers compensation. To efficiently solve the problem we have designed different metaheuristic algorithms, including a Variable Neighborhood Search (VNS) and a GRASP. To assess the performance of our proposals, we compared the results obtained by using them with the optimal solution costs obtained by solving the mathematical model of the problem with CPLEX. Computational results indicate that these randomized heuristics are able within short computational times to find near-optimal solutions even in case of large size instances.

Keywords: Vehicle Routing Problem, Crowd-Shipping, Occasional Drivers

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A Framework to Transform Truck-and-Drone Coordination Problems into Traveling Salesman Problems

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Abstract: There exists an emerging literature that considers a class of coordination problems between a truck and one or more drones. The rules defining feasible sets of actions for the truck and drones, frequently called operations, vary significantly from paper to paper. [1,2] We show that a broad range of truck-and-drone coordination problems may first be recast as an equality generalized TSP (E-GTSP) and subsequently as an asymmetric traveling salesman problem (ATSP), where the number of nodes in the ATSP is equal to the number of non-dominated operations. We may then leverage the capabilities of exact or heuristic TSP solvers to solve the ATSP. Whenever we solve the ATSP exactly, we can extract an optimal solution to the original truck-and-drone coordination problem. We also extend this transformation framework to multi-truck variants, where a variety of objectives and constraints (e.g., truck capacity constraints) can be accommodated. Bounds on the size of the resulting ATSP are established. We also discuss methods for pruning non-promising operations, which reduces the size of the resulting ATSP. Computational results are presented.

Keywords: Drones, Vehicle Routing, Traveling Salesman

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F11: Combinatorial Optimization

Chair: **Silvano Martello**

A New Exact Approach for the Bilevel Knapsack with Interdiction Constraints

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Abstract: We consider the Bilevel Knapsack with Interdiction Constraints, an extension of the classic 0-1 knapsack problem formulated as a Stackelberg game with two agents, a leader and a follower, that choose items from a common set and hold their own private knapsacks. First, the leader selects some items to be interdicted for the follower while satisfying a capacity constraint. Then the follower packs a set of the remaining items according to his knapsack constraint in order to maximize the profits. The goal of the leader is to minimize the follower's profits. The presence of two decision levels makes this problem very difficult to solve in practice: the current state-of-the-art algorithms can solve to optimality instances with 50-55 items at most. We derive effective lower bounds and present a new exact approach that exploits the structure of the induced follower's problem. The approach successfully solves all benchmark instances within one second in the worst case and larger instances with up to 500 items within 60 seconds.

Keywords: Bilevel Knapsack with Interdiction Constraints, Exact Approach, Bilevel Programming

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The LEGO Construction Problem

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Abstract: The LEGO Construction Problem is the problem of deciding which bricks to place where in a predefined 3D construction. The input consists of coloured voxels that each correspond to the size of a LEGO unit, such that all LEGO bricks are multiples of this LEGO unit. While we must place bricks of a predefined colour on all visible voxels of the construction, the non-visible bricks on the inside have no colour constraints and can even be hollowed out if the construction remains stable. A solution to the LEGO Construction Problem is feasible if all bricks are placed within the design domain, the bricks do not overlap, all colour constraints are obeyed, and all bricks connect into a single connected component. The objective is to minimise the number of bricks used while maximising the strength of the construction. Finding stable constructions require advanced search methods, because relatively small constructions lead to a colossal amount of possible brick combinations. We formulate this problem as a three-dimensional set-packing problem with additional connectivity constraints. We simplify the set of available bricks to have the same height; this naturally decomposes the problem into multiple two-dimensional set-packing problems with linking constraints between the layers. The problem is then tackled by a combination of exact and heuristic techniques.

Keywords: Packing, Brick Bonding, LEGO

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The Multiple Multidimensional Knapsack with Family-Split Penalties

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Abstract: The Multiple Multidimensional Knapsack Problem with Family-Split Penalties (MMdKFSP) is introduced as an original variant of both the more classical 0-1 Multi-Knapsack and Multidimensional Knapsack problems. It reckons with items categorized into families and where if an individual item is selected to maximize the profit, all the items of the same family must be selected as well. Items belonging to the same family can be assigned to different knapsacks; however, in this case, split penalties are incurred. This problem arises in resource management of distributed computing contexts and Service Oriented Architecture environments. This paper provides an exact algorithm for the MMdKFSP based on the exploitation of a specific combinatorial Benders' cuts approach. Computational experiments on different sets of benchmark test problems show the effectiveness of the proposed algorithm. The comparison against a state-of-the-art commercial solver confirms the validity of the proposed approach addressing also the scalability issue.

Keywords: Knapsack Problems, Benders' Cuts, Resource Assignment

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The k-Color Shortest Path Problem*

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Abstract: This paper proposes a mathematical model and an exact algorithm for a novel problem, the k-Color Shortest Path Problem. This problem is defined on a edge-colored weighted graph, and its aim is to find a shortest path that uses at most k different edge-colors. The main support and motivation for this problem arise in the field of transmission networks design, where two crucial matters, reliability and cost, can be addressed using both colors and arc distances in the solution of a constrained shortest path problem. In this work, we describe a first mathematical formulation of the problem of interest and present an exact solution approach based on a branch and bound technique.

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F12: OR Applications in Routing

Chair: **Mauro Dell'Amico**

Booking of Loading/Unloading Areas

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Abstract: Urban distribution of parcels and goods usually requires vehicles to temporarily stop at roadside to allow for the driver to perform the last leg of the delivery by foot. The stops take place in designated areas, called loading/unloading (L/U) areas, composed of one or more parking spots. In this paper the introduction of a booking system for the management of the L/U areas in a city center is studied as a way to eliminate double parking. A booking management system and the arising routing problem are presented. In this booking management, distributors book in sequence according to their preferences, but subject to the reservations that have already been placed. The solution provided by the booking system is discussed and compared with the current use of the L/U areas, where the distributors do not consider the availability of a parking spot and resort to double parking if none is available.

Keywords: Booking, Routing, Loading and Unloading Areas

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The VRP with Private and Shared Delivery Location in E-Commerce

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Abstract: In the last years, the advent of e-commerce radically changed customers purchasing habits. Nowadays people can choose among thousands of alternatives, and receive their goods directly at home. Unfortunately, one of the main drawback of this distribution system is that more than 15% of delivery attempts fails because the customer is not at home and it would not be possible to delivery the parcel to a neighbor or a doorkeeper. If we exclude the latter case the number of unattended deliveries grows up to 40%, [1]. This would results in a strong increase of costs for the transportation company. To overcome this issue, shared delivery locations, also name collection points, have been introduced, accessible 24/7 and equipped with smart digital lockers, where customers may pick-up their parcel when it is more convenient for them. This delivery strategy strongly reduces transportation costs but it decreases customers satisfaction, because the last leg of the distribution must be carried out by the customers, [2]. Furthermore, elder people, or people with disability, may experience some difficulties to reach the nearest collection point. In this paper a new mixed delivery strategy is proposed. 1. to receive their delivery at home within a short time window they indicate within which they must attend at home. 2. to receive their delivery at one of the collection points they indicated in their order (near home, near the office, and so on..) receiving a small compensation for the discomfort to pick it up at the collection point. 3. to let the company to decide whether to delivery their package at home, within their preferred time window or in one of the DLTs they indicated, obtaining a small compensation. The goal of the problem is to minimize total company costs (transportation plus compensation) while respecting customers preferences. I proposed a mathematical formulation and a matheuristic to address the resulting combinatorial optimization problem. Computational results show the efficiency and the effectiveness of the matheuristic. A comparison between the newly proposed delivery strategy and classical only home delivery and only shared locations delivery show that the mixed approach allow to strongly reduce company cost and, at the same time, to completely respect customers preferences.

Keywords: Vehicle Routing, Shared Delivery Locations, Matheuristic

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A Milk Collection Problem with Gradual Blending

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Abstract: In this article we study a raw milk collection problem considering several grades of milk. A milk processing plant collects milk from a set of farms. Each farm produces one out of three possible grades of milk (known before the collection) which are a function of the Somatic Cells (SC) per ml of milk. The milk collection is carried by a homogeneous truck fleet. Each truck has one compartment and it is allowed the blending of small amounts of different grades of milk in the same compartment when it is to maximize the profit. The milk arriving to the plant in each truck is classified in one of the three ranges (grades) of quality. These ranges are defined by the country's legislation or by the company according to the SC count per ml. The objective is to maximize the profit considering the revenues of milk received at the plant and the transportation costs. We present computational results for a real case in southern Chile.

Keywords: Milk Collection, Vehicle Routing, Milk Blending

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The Traveling Repairman Problem App for Mobile Phones: A Case on Perishable Product Delivery*

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Abstract: Delivering perishable food as soon as possible has been always a challenge for producers, amplified in recent years, by a more and more competitive global market. The problem can be tackled as a routing problem with consideration of the arrival time at the customer's location, taking into account the perishability of the products planned to be delivered. Since in real-world applications customers' requests dynamically arrive during the execution of the transportation process, building vehicle routes in an on-going fashion is a challenge to be addressed. This paper describes a mobile solution that heavily relies on the use of mobile phones and integrates a well known heuristic method for the problem at hand. A case concerning the delivery of perishable food to a set of restaurants will serve as a base for illustrating the potential benefits of such a system.

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S1: OR Applications - 2

Chair: **Antonio Sforza**

A Graph-Based Analysis on the Growth and Migration of MDA-MB-231 Breast Cancer Cells

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Abstract: Cells migration as well as their growth are due to several interactions, e.g., with either other (close) cells or the micro-environment. The analysis of both such phenomena plays a key role especially during the tissue formation/regeneration and in tumorigenesis and, in many cases, can also give a significant support to cancer pharmacogenomic studies. We focus attention on the analysis of both growth and migration of the MDAMB-231 breast cancer cells, since the breast cancer is actually registering the highest mortality of any cancer in women worldwide. More specifically, we aim at analyzing the changes of the same breast tissue for increasing hour intervals. For this purpose, we propose optimization-based approaches to support such an analysis by studying the images of in vitro human breast cells produced in different time instants by a microscope with 25x magnification. Firstly, each image is converted into a proper cell-graph. Then, in order to evaluate the similarity among two cell-graphs, each related to an image of the same tissue in a different instant of time, a Maximum Common Edge Subgraph Problem (MCESP) is solved. We model the MCESP through Integer Linear Programming (ILP) and, in order to efficiently address realistic instances, we also design a Tabu Search meta-heuristic. Moreover, a hybrid solution approach combining the Tabu Search with ILP is also proposed. Preliminary numerical results, carried out on both a set of benchmark instances and a set of realistic case studies, show the promising performances of our approaches compared to those of the literature.

Keywords: Cell-Graph, ILP-Matheuristic, Tabu Search

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Dining at a Conference

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Abstract: Gerhard Ringel proposed the Oberwolfach Problem (OP) for the first time in 1967 while attending a conference at the Mathematical Research Institute of Oberwolfach. In conferences held at the Institute, participants usually dine together in a room with circular tables of different sizes, and each participant has an assigned seat. Ringel asked whether there exists a seating arrangement for people and meals so that all pairs of participants are seated next to each other exactly once. More formally, the problem asks whether the complete graph Kv decomposes into edge disjoint copies of a 2-regular graph F of order v. In Combinatorial Design Theory, so-called difference methods represent a well-known solution technique and construct solutions in infinitely many cases exploiting symmetric and balanced structures. This approach reduces the problem to finding a well-structured 2-factor which allows to build solutions that we call 1- or 2-rotational according to their symmetries. We tackle OP by modeling difference methods with both Optimization tools and a polynomial-time algorithm and correspondingly solve instances with up to 120 participants within 60. This work shows thereby that both theoretical and empirical results may arise from the interaction between Combinatorial Design Theory and Operation Research.

Keywords: Combinatorial Design, Optimization, Oberwolfach Problem

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Operational Research Methodologies for the Pompei Archeological Park

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Abstract: Pompei Ruins constitute a unique set of civil and private buildings, monuments, sculptures, frescoes and mosaics. With its 0.66 square kilometer the Archeological Park of Pompei (PAP) is one of the biggest archeological sites in the world, recognized by UNESCO as World Heritage Site, with 3.5 million of visitors per year. PAP subscribed a framework agreement with University "Federico II"' of Naples to develop a scientific cooperation aimed to promotion, accessibility and dissemination of the site. In this context a research agreement with the Department of Electrical Engineering and Information Technology has been defined, devoted to identify and apply Operational Research models and methods to support the service management of the Park on two issues: guidance of the visitors and internal security. The first issue has been tackled as a TSP or an Orienteering Problem, to design a visitor path considering their needs and preferences in terms of entrance/exit points, typology of the internal sites, thematic paths, with the constraints on available time, path length, time windows of the sites (Gavalas et al. 2014, Gunawan et al., 2016). This optimization module will become the core of an app able to find the best customized visit route, based on the dynamic database of the Pompei Ruins. The second issue has been approached in terms of visibility and covering analysis of the camera surveillance system already implemented in the park. Results obtained will be presented together with some work and research perspectives.

Keywords: OR Emerging Applications, Tourist Strip Design

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Integrating Vehicle Routing and Resource Allocation in a Pharmaceutical Network*

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Abstract: A problem integrating resource allocation and transportation is considered here as an extension of the well-known vehicle routing problem. It was proposed by a pharmaceutical company, for which items (blood samples) have to be typically transported from doctor offices to laboratories (where the items are analyzed by machines) by a fleet of identical vehicles. The following specific features are considered: multiple pickups, multiple depots, multiple products, transfers, due dates, service level, and dropout level. The goal consists in minimizing the employed resource (i.e., machines, vehicles) and the traveling times of the vehicles. We propose an iterative solution method based on the following sequence of steps: build sectors, build routes, assign vehicles to routes, try to find a solution with fewer machines. Numerical experiments are reported and discussed from a managerial standpoint.

Keywords: Vehicle Routing, Heuristics, Resource Allocation, Integrated Logistics, Pharmaceutical Network

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Project Selection in a Process of IT Innovation

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Abstract: An Italian company, which some years ago activated an Information Technology (IT) innovation process, has had to manage several requests pertaining to the funding of new IT projects or of introducing procedure improvements. An office was charged of requirement acquisition and analysis, to map the company needs and to implement the most "interesting" and/or urgent requests. It gathered approximately one thousand requests every year from the 15-20 sectors of the company, analysed the characteristics the proposers had indicated, and evaluated and ranked the requests. Around 10 million euros were allocated for IT interventions every year. After some years, while the request number was growing and the budget reducing, some doubts arose about the reliability of the acquired data, on costs and benefits of each IT intervention, and therefore about selection criteria and ranking. For this reason, an in-depth study of the procedure and its results was developed. This is a classic problem of "project selection". Several studies analysed this kind of problem and some multicriteria methods were proposed and used to facilitate decisions in relation to possible investments or programs and, with the same logic, in relation to offers, suppliers or human resources (see for instance Norese and Viale, 2002; Viezental et al, 2010; Zopounidis and Doumpos, 2002). Strength and weak points of the adopted procedure of scoring and ranking the requests were identified and used to investigate the problem and to analyse the impact of the data and the data treatment on the results. A new approach was then defined, which included a new problem structuring, a multicriteria evaluation model and a procedure, to improve the whole process of IT innovation. The presentation will describe the methodological tools that were used to identify and communicate the past experience critical points, and to activate a new procedure, together with its results.

Keywords: Models and Methods of Multicriteria Evaluation, Ranking, Sorting

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S2: Inventory

Chair: **Paolo Brandimarte**

A Real Case on Making Strategic Logistics Decisions with Production and Inventory Optimization Models*

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Abstract: A real case is described of the use of industrial optimization models (linear/integer programming) for logistics decisions in the medium term (annual planning) and strategic decisions. The application of these models to optimize annual operations and make strategic decisions on the sizing of storage capacity is studied. The optimization models are built with the author's software, which is capable of proposing and solving problems of the required size: thousands of equations, tens of thousands of variables and hundreds of thousands of non-zero coefficients. The models demonstrate the enormous power of this methodology and its potential savings in production/transport costs, which were as much as 20% in the case in this work.

Keywords: Logistics, Strategic Decisions, Optimization

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A Bi-Objective Mixed Integer Model for the Single Link Inventory Routing Problem Using the ϵ-Constraint Method*

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Abstract: In this paper, we study an Inventory Routing Problem for the Single Link case. In this problem, products must be transported from an origin point to a destination in order to meet the demand. The products can be delivered in a finite number of periods and the destination has a constant rate in each period. There are two costs associated with the problem: transportation cost and inventory cost. In the literature, the approaches usually are developed to the mono-objective problem, i.e., minimize both the inventory and transportation costs in a single function. However, for real companies, an analysis of these different costs is extremely important to define new policies. In order to deal with this literature gap, we develop a biobjective method that considered the ϵ-constraint approach to deal with these two objectives. In numerical experiments, new instances based on the literature are presented and solved to optimality using an optimization solver. The experiments show that the model returns an efficient set of non-dominated solutions. Finally, the results indicate that using the proposed method, decision makers will have a powerful tool to construct the Pareto front.

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Models for Disassembly Lot Sizing Problem with Decisions on Surplus Inventory*

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Abstract: We consider a single product Disassembly Lot Sizing Problem with Disposal (DLSPD) which is a problem arising in the context of disassembly systems. This is the problem of determining the quantity and time of the returned products to be disassembled while satisfying the demand of their parts or components over a planning horizon. Disassembly operation generates several components simultaneously. And, the demands are independent and not balanced which can generate unnecessary surplus inventory during planning horizon. Aggregate (AGG) formulation can be use to model this problem by considering disposal decision. Linear-Programming (LP) relaxation of this model doesn't give very good lower bound, especially for the large size instances. We aim to improve lower bound of the problem. Facility Location based (FAL) formulation and additional constraints (Valid Inequalities (VIs)) for the LP relaxation of AGG model are proposed. Computational results on generated instances show that LP relaxation of FAL and AGG with additional constraints (AGG-VIs) can obtain very strong lower bound within a very short computational which is useful for the varied DLSPD (multi-level, multi-product,...).

Keywords: Reverse Logistics, Disassembly Lot Sizing Problem, Inventory, Disposal Option, Linear Programming (LP) Relaxation, Inequalities

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A Robust Approach to the Integrated Inventory Replenishment, Lateral Trans Shipments, and Routing PROBLEM in a Single-Commodity Supply Chain

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Abstract: Inventory control is an influential aspect in operations management for it directly and significantly affects the financial results. We discuss a system comprised of retailers facing unknown demand. In each period, replenishments are made according to a predetermined order-up-to quantity. Lateral trans shipments are performed after demand is realized but not yet materialized, in order to minimize expected excess and shortage of inventory and costs. However, trans shipments have a non-negligible cost. Thus, a routing aspect arises as an important decision. Lateral trans shipments literature (Coelho et al. (2012), Herer et al. (2006)) provides recommendations on what quantities to deliver between locations. Those recommendations usually cannot be performed "as is" and managers must plan the route by themselves, which can be a complex decision. The route affects and is affected by the transshipment locations and quantities. Disregarding the interaction between these two aspects would result, in practice, in sub-optimal solutions. Sufficient inventory quantity on the vehicle must be assured at every stage to meet the planned transshipment at delivery points. Thus, finding the optimal route to perform the trans shipments is different from finding an optimal route for supplying goods (Traveling Salesman Problem) or from pick-up and delivery problems (Jemai et al. (2013)). In our research, we studied the integrated problem of lateral trans shipments and routing. Our research suggests an optimal solution that simultaneously minimizes the system's total cost. We compared our results to a similar optimal transshipment model for which we artificially added an optimal route. Our model performed better in all the instances examined. We performed a numerical analysis and suggested a simple heuristic as well. In addition, we take a robust approach to deal with uncertainty aspects in the problem. The research presents a method, that would lower inventory levels and transportation distances, enables managers to perform lateral trans shipments in practice, being given a precise, optimal route to carry it out.

Keywords: Robust Optimization, Routing, Lateral Trans shipments

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Learning Inventory Control Rules for Perishable Items by Simulation-Based Optimization*

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Abstract: We consider an inventory control problem for quickly perishable items, such as fresh produce, at the retail store level, assuming a fixed shelf life. Demand is affected by both uncertainty and seasonality within the week, as sales feature a peak close to weekends. Another complicating factor is customer behavior and inventory issuing: In the case of a first-in-first-out (FIFO) pattern, older items are sold first, whereas a last-in-first-out (LIFO) pattern is more critical as newer items are sold first, which may increase scrapping. These and possibly other complicating factors make elegant mathematical modeling not quite feasible. Hence, we experiment with simulation-based optimization approaches integrating a discrete-time simulation model with direct search methods like simplex and pattern search. The approach is rather flexible, and learning simple rules has a definite advantage in terms of management acceptance. One aim is to compare simple order-up-to rules, based on overall available inventory, against more complex rules that take inventory age into account. Since more complex rules require more effort in implementation, it is important to understand under which circumstances their use is justified. We also want to study the effect of economic parameters, demand uncertainty and skewness, as well as FIFO/LIFO behavior. Preliminary computational experiments are reported, including a comparison with simple news vendor-based heuristics.

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S3: Graphs

Chair: **Raffaele Cerulli**

Finding Dense Subgraphs

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Abstract: The problem of finding the densest subgraph has a lot of applications in graph mining, particularly in social network analysis. Depending on the application, finding dense subgraphs can be used to determine regions of high importance, similar characteristics or more interaction. The densest subgraph extraction (DSE) is a fundamentally a non-linear optimization problem. Despite the non-linear optimization nature of the problem, it can be solved in polynomial time by Goldberg's (1983) algorithm is based on the solution of a series of max-flow computations. Charikar (2000) has also proposed another exact method to solve the DSE which uses a linear programming model of polynomial size, hence providing an alternative polynomial time approach. Despite the polynomial run-time nature of these exact algorithms, for graphs with millions of nodes and edges, the solution time for an exact approach could be prohibitive. Asahiro et. al. (2000) had proposed a 0.5 approximation heuristic which is very fast in practice. Our work combines the heuristic and exact methods to find a better dense subgraph without sacrificing the time performance.

Keywords: Social-Networks, Dense-Subgraphs, Heuristics

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A Genetic Algorithm for Minimum Conflict Weighted Spanning Tree Problem*

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Abstract: The Minimum Conflict Weighted Spanning Tree Problem is a variant of the Minimum Spanning Tree Problem in which, given a list of conflicting edges modelled as a conflict graph, we want to find a weighted spanning tree with the minimum number of conflicts as main objective function and minimize the total weight of spanning trees as secondary objective function. The problem is proved to be NP-Hard in its general form and finds applications in several real-case scenarios such as the modeling of road networks in which some movements are prohibited. We propose a genetic algorithm designed to minimize the number of conflict edge pairs and the total weight of the spanning tree. We tested our approach on benchmark instances, the results of our GA showed that we outperform the other approaches proposed in the literature.

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Computing Dissimilar Pairs of Paths

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Abstract: While finding a path between two nodes is the basis for several applications, the need for alternative paths may have different motivations. For instance, in telecommunications a backup path can replace a first one if a failure occurs, when routing hazardous materials it is useful to prevent possible accidents that affect a certain region, and repeating paths is avoided in money distribution, to decrease the risk of robberies. The search for solutions that handle such issues has been investigated from different perspectives, like ranking paths, disjoint paths or dissimilar paths. In this work we review literature on finding alternative paths and explore exact methods for finding pairs of paths that optimize two dissimilarity measures. Because these metrics are fractional, the problems are solved using a parametric approach applied to different IP formulations. The methods are tested on randomly generated networks obtained from publicly available instances. The results are compared in terms of the run time and of the solutions' dissimilarity.

Keywords: Pairs of Paths, Dissimilarity, Fractional Linear Programming

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Polyhedral Analysis of the 2-Edge-Connected Minimum Branch Vertices Problem

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Abstract: Given an undirected graph $G = (V, E)$, 2-Edge-Connected Minimum Branch Vertices (2ECMBV) problem, consists of finding a 2-edge-connected subgraph $G' = (V, E')$, with the minimum number of branch vertices, namely vertices with degree greater than two in E'. This problem has application in the field of optical network, and it is Np-Hard. We introduce an integer linear programming (ILP) formulation of the problem and derive facet results for the corresponding polyhedron. The model is integrated in a Branch and Cut algorithm.

Keywords: Branch Vertices, Network Survivability, Branch and Cut

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The Concurrent Shortest Path Problem

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Abstract: Our cities are turning into smart cities thanks to numerous projects that are solving many problems affecting metropolis. For example, with the spread of self-driving cars, more and more problems need to be solved to make these vehicles more efficient. Consider, for example, the handling of crossroads performed by the Intersection Management System [Liu], or motion planning for local optimization [Katrakazas], or the control system performed by smart roads to handle the trajectory of various concurrent vehicles [Varaiya]. The main contribution of our work is modeling the Concurrent Shortest Path Problem considering a discrete time horizon to define a spatial and temporal movement of each vehicle. According to our representation of the problem, it is possible to avoid collisions between vehicles both changing the path of a vehicle, or the time in which it crosses a specific node/arc of the graph. In this work, we introduce two algorithms to solve the problem in a reasonable time: (i) a constructive Greedy approach (ii) a Genetic Algorithm. The computational results show that our approaches can produce routes able to minimize the mean journey time, the max arrival time and the waiting time of each vehicle.

Keywords: Concurrent Shortest Path, Vehicle Routing, Genetic Algorithm

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S4: Travelling Salesman and Arc Routing Problems

Chair: **Renata Mansini**

A Metaheuristic Algorithm for the Probabilistic Orienteering Problem

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Abstract: The Probabilistic Orienteering Problem is a variant of the orienteering problem where customers are available with a certain probability. In a previous work, we approximated its objective function value by using Monte Carlo Sampling method and solved the problem with a random start iterative 2-opt local search. Tabu Search is a metaheuristic that has been widely used in combinatorial optimization problems to avoid local optimality in heuristic local search procedure. In this work, we design and implement Tabu Search heuristic for solving the Probabilistic Orienteering Problem. We also present a computational study on how different design choices affect the performance of the method.

Keywords: Probabilistic Orienteering Problem, Tabu Search, Metaheuristic Algorithms

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Algorithmic Strategies for a Fast Exploration of the TSP 4-OPT Neighborhood*

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Abstract: The 4-OPT neighborhood for the TSP contains $\Theta(n^4)$ moves so that finding the best move effectively requires some ingenuity. Recently, de Berg et al. have given a $\Theta(n^3)$ dynamic program, but the cubic complexity is still too large for using 4-OPT in practice. We describe a new procedure which behaves, on average, slightly worse than a quadratic algorithm. This is much faster than the DP procedure, achieving speedups of 2 to 3 orders of magnitude on all instances we tested.

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A Computational Evaluation of Online ATSP Algorithms*

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Abstract: We prove that state-of-the-art online asymmetric traveling salesman problem algorithms can successfully be used in real time practical systems, in terms of both solutions quality and computational efficiency. At the same time, we show that such a good behaviour can only be obtained by a careful fine tuning of the algorithms, often clashing with their theoretical analysis.

Keywords: Asymmetric Traveling Salesman, Online Algorithms, Experimental Analysis

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The Refrigerated Traveling Salesman Problem

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Abstract: In recent years, the cold food chains have registered an impressive development, due mainly to customer life style changes. As a consequence, the problem of transportation of refrigerated food is becoming crucial, in order to guarantee product quality, efficiency, and sustainability. In this work, the Refrigerated Traveling Salesman Problem (RTSP) is studied, whose objective is to find a Hamiltonian circuit that minimizes the fuel consumption, which depends on traction and refrigeration fuel requirements. For the refrigeration load, we consider both the transmission and the infiltration components (Meneghetti et al., 2018), while the traction fuel requirements are modeled following the CMEM approach dividing them into the weight, engine, and speed modules (Franceschetti et al, 2017). As a consequence the total fuel consumption depends on the distance travelled, the load on each arc, the vehicle speed, and the outdoor temperature. The problem takes into account different speed levels (Cacchiani et al, 2018), due to traffic congestion during the day, and different temperature values, depending on the variation of outdoor temperature along a day and among different months of the year. We formulate the RTSP as a Mixed Integer Linear Programming (MILP) model and a Constraint Programming (CP) model, and we propose a Local Search solution method based on the Simulated Annealing metaheuristic. Experiments are still ongoing, first results of the comparison of the exact methods with the SA metaheuristic will be shown at the conference.

Keywords: Refrigerated Routing, MILP Model, Local Search

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Kernel Search: An Application to the Time-Dependent Rural Postman Problem

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Abstract: The Time-Dependent Rural Postman Problem (TDRPP) is a variant of the well-known Rural Postman Problem, in which the arc travel times may vary over time due, for instance, to traffic congestion. In Calogiuri et al. [2], the authors propose an efficient branch-and-bound algorithm able to solve problem instances with 60 nodes, 120 arcs and up to 70% of required arcs. In this work, we introduce a variant of the heuristic framework Kernel Search to deal with problem instances of larger size. Kernel Search, originally presented in Angelelli et al. [1], is a general purpose method for the solution of mixed integer linear programming problems based on the concept of kernel as a subset of variables which are likely to take a non-zero value in an optimal solution. The method solves a sequence of restricted mixed integer subproblems involving the variables in the kernel set plus some additional ones opportunely selected. Proposed approach exploits the arc-path formulation introduced in Tan and Sun [3], and uses it along with other strategies to formulate restricted subproblems solved by means of both the Branch-andBound proposed in [2] and an off-the-shelf MIP solver (Gurobi). Preliminary results on new benchmark instances seem to be very promising.

Keywords: Time-Dependent Rural Postman Problem, Kernel Search, Branch-and-Bound

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S5: Optimization in Telecommunication Networks and Queueing Systems

Chair: **Franco Davoli**

Modeling of Traffic Flows in Internet of Things Using Renewal Approximation*

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Abstract: This paper proposes a versatile approach to model aggregated traffic flows in the Internet of Things (IoT) using renewal approximation. The modeled traffic originates from a large number of sources or devices consisting of a set of sensors mixed with classical elastic random traffic modeled as Poisson arrival process.The work shows the exact derivation in the simple case for periodic sensors. It shows further results in the mixed case with periodic sensors and a background process. The renewal approximation allows to derive the required number of sensors such that the aggregated traffic can be approximated as Poisson process.

Keywords: Internet of Things, Traffic Modeling, Renewal Approximation

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The Shortest Queue System with Jockeying

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Abstract: We introduce a Markov queueing system with Poisson arrivals, exponential services and jockeying between two of parallel and equivalent servers. An arriving customer admits to the shortest line (when the lines are equal the customer admits to any line with probability 1/2). Every transition, of only the last customer in line, from the longer line to the shorter line is accompanied by a certain fixed cost. Thus, a transition from the longer queue to the shorter queue occurs whenever the difference between the lines reaches a certain discrete threshold (T = 1, 2,...). In this study we focus on the stochastic analysis of the number of transitions of an arbitrary customer, during the sojourn time in system.

Keywords: Shortest Queue, Jockeying

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A Multiband Robust Optimization Approach to Green 5G Virtual Network Function Placement

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Abstract: The 5th Generation of wireless telecommunications systems, commonly known as 5G, will be a disruptive technology that will strongly rely on Network Function Virtualization, namely running network functions on virtual machines that are hosted in cheap commodity hardware servers. In this work, we present a Multiband Robust Optimization model for optimally placing virtual network functions in 5G-based virtualized infrastructures, taking into account resource request uncertainty and adopting a green paradigm that pursues energy minimization. In order to solve the resulting complex Mixed Integer Linear Programming problem, we propose a new matheuristic and we present computational results indicating its superior performance with respect to a state-of-the-art solver.

Keywords: 5G Virtual Network Function, Robust Optimization, Matheuristic

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Flow Assignment in Multi-Core Network Processors*

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Abstract: In modern telecommunication networks, the trend toward "softwarization" is shifting the execution of switching and protocol functionalities from specialized devices to general purpose hardware located in data centers or at the network edge. Incoming flows generated by User Equipment are processed by different functional modules executed in Virtual Machines (VMs). The paper considers a modeling and control architecture in this environment, for the assignment of flows to the first functional blocks in a chain of Virtual Network Functions (VNFs) and the balancing of the load among the VMs where they are executed.

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S6: Optimization for Sustainable Energy Systems

Chair: **Michele Robba**

A Relocation Model for Electric Free-Floating Car-Sharing Services

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Abstract: Free-floating is the new paradigm of car-sharing. This type of service overcomes the constraint of the stations and allows one-way trips freely within a specified area. Despite the increase of level of service, free-floating poses a problem for the spatial distribution of the vehicles, due to a possible unbalance between the users-demand and the availability of vehicles. In such cases, the service provider has to develop strategies to reallocate the vehicles and restore an optimal distribution of the fleet. In case of services using electric-vehicles, the problem is more complicated, due to the need of plug-in the vehicles to charging stations when needed. This work is part of Sharing Cities, a H2020 project that aims at creating a smart district with "near-zero" emissions in 3 different "lighthouse" cities. The aim was to develop a new model for vehicle relocation problem for an electric free-floating service. The project consists of a demand forecast model, an estimation model for spatial imbalance between demand and offer and a relocation model. The first one considers several factors (strikes, holydays, weather) for forecasting to estimate demand based on historical data. The estimation model for spatial imbalance allows a classification of different zones of the city into areas where the number of vehicles needs to be increased; where it's aligned with the request and where it needs to be decreased. Two strategies for vehicle reallocation have been develop: an user-based strategy, which aim to control the balance of the fleet by influencing the behavior of users offering pricing incentives and an operator-based one where cars are moved by operators of the service provider: a greedy heuristic (nearest neighbor) algorithm has been implemented to identify the itineraries able to maximize the number of relocations made by the operators. The proposed model has been designed and calibrated using real data from the city of Milan and the results are now available.

Keywords: Free-Floating Car-Sharing, Relocation Model, Electric Mobility

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Extensive Analysis of Models and Indicators for the Optimal Location of Electric Vehicle Charging Stations

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Abstract: Electric vehicles have become, in the recent years, a clean and sustainable alternative to traditional vehicles. They are in fact economically and technically comparable to the fuel ones. Nevertheless, one of the problems that still affect the electric cars industry is the lack of a proper infrastructure to re-charge the vehicles. In this work, we study the optimal location of charging stations for electric vehicles through the application and comparison of several different location models from the literature. Motivated by a real case study concerning the district of Biella in Italy (a research project funded by Ener.bit Srl, http://www.enerbit.it/), we want to emphasize that does not exist the best location model but, instead, different models might be jointly considered to face a certain set of requirements and objectives. Therefore, a battery of Key Performance Indicators (KPIs) have been developed and calculated for the solutions given by the different models. The analyzed KPIs include measures about the covering capabilities, the robustness, the equity, the dispersion, and the accessibility of the resulting solutions. Moreover, since charging infrastructures are commonly supposed to be located through several progressive interventions over a defined time-horizon, we also provide ad-hoc KPIs measuring the changes in solutions and their objectives over time. Finally, the use of a comparative analysis of several models allows us to provide additional insights on the decision process itself. Our approach has been successfully applied to address the specific real case and its general applicability is shown by reporting the results obtained on random generated instances simulating areas characterized by specific geographical and demographic features.

Keywords: Electric Vehicles Charging Stations, Optimal Location, Key Performance Indicators

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Solving a Home Energy Management Problem by Simulated Annealing

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Abstract: Energy consumption is an important issue within the context of smart buildings. Due to different availability and cost of energy during the daytime, it is possible to optimize the schedule of domestic appliances, in order to minimize the total expenses. This gives rise to the home energy management problem (Beaudin and Zareipour, 2015), which turned out to be NP-complete. In this work, we consider the energy scheduling problem for a domestic setting proposed and modeled by Della Croce et al (2017), called SHASP (Smart Home Appliances Scheduling Problem). SHASP includes uninterruptable appliances, power threshold, solar energy, and a consumption-based objective function. We solve the SHASP problem by means of a Simulated Annealing approach based on a complex neighborhood structure. The solver is dependent on a set of parameters, which comprises the classical ones of Simulated Annealing and others related to the neighborhood structure. Therefore, we perform an extensive and statistically-principle tuning phase using the Hammersley point set (Hammersley and Handscomb, 1964) and F-race (Birattari et al, 2010), in order to find the best configuration of all the parameters. The experimental analysis shows that our solver outperforms all four methods proposed in the original work by Della Croce et al (2017) on almost all available instances.

Keywords: Home Energy Management, Appliance Scheduling, Simulated Annealing

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Optimal Charging and Routing of Electric Vehicles

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Abstract: At international level different new policies have been developed to reduce greenhouse gas emissions in the atmosphere. The result is an increase of green technologies for energy production and transportation. Electric vehicles (EVs) need to be charged in the fastest time possible and smart grids should afford such a request. Moreover, new technologies of charging stations and EVs give now the possibility to perform Smart Charging (i.e., the modulation over time of EVs' charging) and Vehicle to Grid policies. In the present paper, attention is focused on users' perspective, on the basis of an available infrastructure of charging stations of known location, type, and electrical constraints. In particular, the problem is the one of optimal routing and charging of EVs to satisfy a freight transportation service, and it corresponds to a modification of the well known vehicle routing problem (VRP). Though the interest on EVs has grown in the last decade, scientific articles are mainly focused on smart grids and on the mitigation of a distributed demand of energy (Yagcitekin et al. (2016), Ferro et al. (2019)). Few articles regarding the routing of EVs are present, and they are starting to appear in the recent literature (Hiermann et al. (2016)). This is the reason why formalizations differ from each other, several variants have been considered, and authors focused on specific objectives and do not consider other ones. In the present contribution, the following new features are considered: the characteristics of the charging stations have been detailed considering different power levels for the recharging process; models for the electrical consumes take into account the territory characteristics (slope of roads), the variable vehicle mass, different speeds, and the electric drive efficiency; time windows, classical VRP constraints, partial recharges, and time-variant energy prices have been included.

Keywords: Optimization, Electric Vehicles, Sustainable Transportation

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S7: Logistics

Chair: **Claudia Archetti**

Solving a Bi-Objective UAV Ground Control Station Location-Allocation Problem

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Abstract: Location problems aim to determine the best locations for facilities or some type of entities according to relevant criteria. Although most of the problems are similar in that they have the objective of maximizing a type of utility or minimizing a type of cost, conceptually they may differ in constructing the objectives. Besides many problems with single objectives, there is also a growing literature addressing multiple objectives (Current et al., 1990; Karatas, 2017). In this study, we introduce a bi-objective ground control station (GCS) location-allocation problem. GCSs are designed to control multiple unmanned aerial vehicles (UAVs) that are used in in surveillance missions. This problem, arising in a military domain, attempts to maximize the probability of detection of threats and to minimize the probability of attracting these threats to attack GCSs, while determining the locations of these stations which control a set of UAVs utilized in searching regions of interest (RoIs). We first formulate the introduced problem as an integer nonlinear program, and then linearize the formulation. We finally develop a multi-objective evolutionary algorithm, NSGA-II, to solve the problem.

Keywords: Location, UAV, Mathematical Modelling

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A Mathematical Model to Face Congestion Issues in Container Terminals Through a Non-Mandatory Truck Appointment System

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Abstract: Maritime container terminals, that represent fundamental intermodal nodes of supply chain networks, are suffering increasing risks of congestion (inside and outside) due to mega vessels requiring to move large import/export containers in small amount of time. Thus, the management of trucks arriving to and departing from terminals is crucial. In this work, a non-mandatory Truck Appointment System (TAS) is investigated as a possible strategy to reduce congestion and gate queues. A TAS defines the maximum number of trucks that can approach the terminal and pass the gate during the time windows in which the working day is split, in such a way to obtain an efficient usage of resources inside the terminal, good truck service times, in addition to no congestion inside and outside the terminal [1]. The terminal is characterized by a capacity in terms of both gate lanes to activate and number of operations to execute in each time instant, while trucks that will arrive in the considered planning horizon are characterized by a preferred time of arrival, a deadline for leaving the terminal and a number of operations (tasks) to execute inside the terminal. The problem consists in determining the best number of trucks to book for each time window, in such a way to minimize the number of trucks queuing at the gate and inside the terminal along the whole planning horizon, the length of the queues and the deviation from the preferred time of arrival related to booked trucks. Inspired by [2], we propose a multi-commodity network flow model for representing a maritime container terminal and we solve a mixed integer linear programming model based on the network flow. Some preliminary results are presented.

Keywords: Truck Appointment System, Container Terminal, 0/1 Mixed Linear Programming

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The Impact of Consolidation Hubs on Epidemics Response Supply Chains

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Abstract: We focus on epidemics response supply chains and use system dynamics to model the impact of the logistics distribution structure on programs efficiency and effectiveness. The supply chain model is based on hypotheses that were developed in collaboration with WFP officers and is the base of a case study that analyzes the European response to the 2013-2016 Ebola epidemics in West Africa. The supply chain model is then integrated with an epidemic model based on Do and Lee (2016). We model the link between the epidemic and the supply chain models through a feedback loop and use real data from the Ebola response to validate our model. The model fit is good (Sterman 2000). We are able to derive valuable insights for humanitarian operation managers.

Keywords: Consolidation, Ebola Epidemics, System Dynamics

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Air Intermodal Freight Transportation: The Freight Forwarder Service Problem

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Abstract: Despite being one of the most relevant figures in international multimodal transportation, freight forwarding companies optimization problems did not receive much attention from the research community. In this work we try to fill this gap by presenting the general features of air transportation from the freight forwarder's perspective and we introduce the air transportation freight forwarder service problem (ATFFSP). A MILP formulation of the problem is proposed and tested on real-life data coming from an Italian freight forwarding company. We study the performance of the model in terms of optimality gap and time needed to reach the optimal solution. Furthermore we compare the solutions found with the ones provided by the company in order to evaluate the effectiveness of the model and its ability to find good and practical solutions. Since the proposed MILP formulation show problematic performances on instances of big size We propose a set-partitioning formulation for the problem and an exact solution approach based on complete enumeration of feasible routes. We also present heuristic algorithms exploiting the same formulation. Computational tests are made on the instances proposed which are based on real data. The results show that complete enumeration is not a practical method to find a solution, while the proposed heuristics and acceleration methods are capable of offering good solutions for large size instances. Finally, we study the possibility of opening a new warehouse facility to better manage services and we analyze the corresponding potential benefits.

Keywords: Freight Forwarders, Air Transportation, Case-Study

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S8: Game Theory

Chair: **Laura Levaggi**

Analysis of Human Movement Qualities Via an Automated Approach Based on Cooperative Games on Graphs

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Abstract: Research in computational models of human movement benefits from novel transdisciplinary approaches, leading towards methods to model higher-level features of movement and movement qualities (Camurri and Volpe, 2016; Kolykhalova et al., 2017) Here, a novel computational method for the analysis of expressive full-body movement qualities is described. The human body structure is modeled as an undirected graph, where the joints are the vertices and the edge set contains both physical links (i.e., connections between adjacent physical body joints) and nonphysical links (acting as "bridges" between parts of the body not directly connected by the skeletal structure). The edge weights depend on features obtained by using Motion Capture data. The body movement is modeled via a transferable-utility cooperative game built on the graph, where the vertices represent the players. The Shapley value is exploited to estimate the contribution of each vertex to the way a particular movement quality is transferred and to detect the "origin of movement". The method is applied to a data set of Motion Capture data of subjects performing expressive movements, recorded in the framework of the H2020-ICT-2015 EU Project WhoLoDance (no. 688865) and of the H2020-FET-Proactive 4-year EU Project EnTimeMent (no. 824160). The model is validated through an online survey, to which several dancers and choreographers participated.

Keywords: Human Movement Qualities, Transferable-Utility Games, Shapley Value

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Braess' Paradox and Cooperative Games

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Abstract: Braess' paradox explains, via a noncooperative approach, why inserting a resource in a network may reduce its performance. This approach, however, is unable to quantify the average marginal contribution of each resource to the network performance. In this presentation, we extend Braess' paradox to transportation network cooperative (TNc) games. We express the characteristic function of a TNc game in terms of a measure of congestion on the subgraphs associated with subsets of arcs. For each subgraph, the measure is computed by solving an instance of the user equilibrium problem. Numerical results show that, for our choice of the characteristic function, some resources have a negative Shapley value. Hence, on average, their removal increases network performance.

Keywords: Braess' Paradox, Cooperative Games, Shapley Value

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Multiobjective Games with Potential

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Abstract: Potential games were introduced by Monderer and Shapley and then extensively studied for their interesting properties, such as the existence of equilibria in pure strategies for finite or upper bounded games, both from a theoretical and an application point of view. In this work we analyse the extension of the notions of weighted and ordinal potential to games with vector payoffs and investigate their exact and approximate Pareto equilibria. The existence of Pareto equilibria in pure strategies in the finite case and of approximate equilibria for some classes of infinite potential games, along with the finite improvement property (FIP) are the main findings. Applications to peering games in telecommunications are also shown.

Keywords: Multicriteria Games, Potential Games, Pareto Equilibria

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A Citation Index Based on a Discrete Version of the Nash Bargaining Problem

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Abstract: A number of citation indices have been proposed for measuring and ranking the research publication records of scholars. Maybe the best known index is the one proposed by Hirsch, which is designed to reward most highly those records x that strike some balance between productivity P (number of publications) and impact I (frequency with which ones papers are cited). Nevertheless, large number of rarely cited publications will not score well, nor will a very small number of heavily cited papers. We propose a new citation index which is uniquely characterized by a set of axioms which can be seen as a discrete version of the Nash bargaining problem. Compared with the Hirsh index we can mention several advantages of the index we propose: it produces fairer ranking within subdisciplines; it improves decisiveness, fewer ties and more dynamic, the index grow over time via increments that are both more frequent and smaller; enhanced centrality and tail balancedness.

Keywords: Game Theory, Citation Indices, Research Evaluation

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