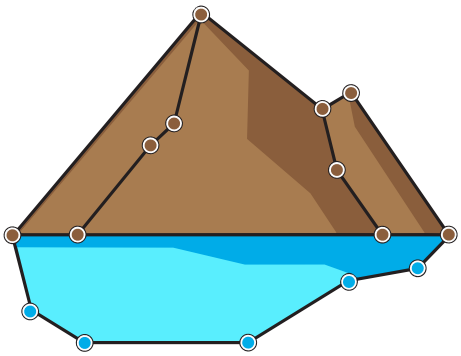


6th EURO Young Workshop

Lugano 2026

6^{th} EUROYoung Workshop

October 14–16, 2026

Lugano (Switzerland)

Book of Abstracts

EURO THE ASSOCIATION OF EUROPEAN OPERATIONAL RESEARCH SOCIETIES

EUROYoung FOR EARLY-STAGE O.R. RESEARCHERS

This book contains all the abstracts accepted for presentation at the 6$^{\text{th}}$ EUROYoung Workshop, held in Lugano, Switzerland from the 14$^{\text{th}}$ to the 16$^{\text{th}}$ of October, 2026. The Workshop is organized by the EUROYoung Forum of EURO, the European Association of Operational Research Societies. The book of abstracts includes 35 contributions, grouped into 9 sessions, along with 3 additional plenary lectures delivered by internationally renowned professors, addressing highly relevant and timely topics, and 1 panel session featuring all plenary speakers. Abstracts are presented in chronological order, organized by day and by session.

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Contents

Session I: Supply Chain & Distribution **1**
Tuğçe Canbilen Sutiçen: A Matheuristic for the Multi-Commodity Two-Echelon Inventory Routing Problem with Perishable Products 2
Lavinia Ghilardi: Mixed Integer Formulations for Supply Chain Reconfigurations 3
Nandan Kumar Singh: An EOQ Model for Imperfect Quality Items with Backorder under Sampling Inspection: A Case of EV Battery Inspection . . 4

Plenary Session I **5**
Alberto Ceselli: From Models to Decisions: Designing and Validating Optimization-Based Decision Systems 6

Session II: Public Transit, Logistics & Mobility **7**
Oleg Horshkov: An Exact Solution Approach for a Direct Delivery Scheduling Problem in Intralogistics 8
Ruoyu Hu: Multi-stage Stochastic Optimization for Public Food Distribution under Capacity Uncertainty and Disruption Risk 9
Alex Fabián Barrales-Araneda: Solution Approaches for Timetabling and Vehicle Scheduling in Mixed-Fleet Public Transport 10
Louise Lallemand: New Formulation for the Choice-Based Capacitated Line Planning Problem 11

Session III: Healthcare Operations & Service Systems Management **12**
Alberto Guastalla: The Stochastic Team Orienteering Problem 13
Alfaima L. Solano-Blanco: Resource Constrained Scheduling and Routing Problem for Agricultural Operations Planning 14
Yiming Hou: On a Class of Nonlinear Facility Location Problems 15
Martina Doneda: A Multi-granular Approach for No-shows Management in Appointment Scheduling 16
Alessandro Druetto: Parallel Batch Scheduling for Sterilization Operations . . 17

Session IV: Industrial Production & Machine Scheduling **18**
Angjelo Zojzi: A Data-Driven Assignment Method for Incoming Alarms in Security Operations Centers 19
Rafał Jednoróg: Vision-Based DXF Generation for Metalworking SMEs: A Practical Image Processing and Economic Feasibility Study 20
Annalisa Castelletti: A Column Generation Approach for the Single Batch-Processing Machine Scheduling Problem, with Non-identical Jobs, Compatible Families and Sequence-dependent Setups 21
Elwin Freudiger: Job Scheduling with Tardiness, Inventory and Overtime Penalties 22

Simon Cosyns: Predicting the Feasibility and Flexibility of Sports Schedules . 23

Session V: Game Theory, Behavioral Economics & Social Impact **24**
Andrea Benso: Cooperation in Repeated Games with Network Monitoring and Communication 25
Saeedeh Khalilpour Zargabad: Personalized Return Policies Under Customer Heterogeneity 26
Sara Tavakoli: Rethinking Regional Energy Poverty: An Intersectional Modelling Approach 27

Plenary Session II **28**
Daniel Kuhn: Metrizing Fairness 29

Session VI: Bilevel & Hierarchical Optimization **30**
Emanuele Pizzari: Influencing Followers' Green Behaviour: a Bilevel Optimisation Approach to Waste Management 31
Eneko Clemente: Dimensionality Reduction in Bilevel Linear Programming . . 32
Simon Stevens: Bilevel Optimization with a Piecewise-Linear Follower 33
Elena Rener: Single Machine Adversarial Bilevel Scheduling Problem of the Total Tardiness 34

Session VII: Network Optimization & Distributed Algorithms **35**
Alberto Bertoncini: A Branch and Price Approach for Latency Aware VNF Placement 36
Dimitri Rusin: A Distributed Multiobjective Optimization Algorithm Based on the Alternating Direction Method of Multipliers 37
Bart van Rossum: Bucket-Based Column Generation for Nested Path Problems 38
Chek-Manh Loi: Drone Air Traffic Control: Tracking a Set of Moving Objects with Minimal Power 39

Panel Session **40**

Session VIII: Discrete Structures, Matroids & Graph Theory **41**
Áron Jánosik: Hypergraph Representation of All Matroids 42
Bence Mátravölgyi: Cyclic Ordering of Split Matroids 43
Hongjin Wu: Threshold Graphs are Globally Synchronizing 44

Plenary Session III **45**
Monique Laurent: Polynomial Optimization 46

Session IX: Polynomial Optimization & Column Generation **47**
Utkarsh Detha: Primal-Dual Interior Point Methods for Non-symmetric Cones 48
Johannes Schmucker: Exploiting Structural Properties in Polynomial Optimization 49
Enrico Brambilla: A Column Generation Approach via Lagrangian Decomposition for the Multidimensional Multiple-Choice Knapsack Problem 50
Filippo Ranza: A Column-Generation Approach for the Irregular Shape Bin Packing Problem 51

Session I
Supply Chain & Distribution

Wednesday, October 14th | 9:00 – 10:00

Chair: Andrea Mancuso



Tuğçe Canbilen Sutiçen
A Matheuristic for the Multi-Commodity Two-Echelon Inventory Routing Problem with Perishable Products



Lavinia Ghilardi
Mixed Integer Formulations for Supply Chain Reconfigurations



Nandan Kumar Singh
An EOQ Model for Imperfect Quality Items with Backorder Under Sampling Inspection: A Case of EV Battery Inspection

A Matheuristic for the Multi-Commodity Two-Echelon Inventory Routing Problem with Perishable Products

Tugce Canbilen-Suticen[1], Argyris Kanellopoulos[2], Tom Van Woensel[1]

[1] Eindhoven University of Technology, Eindhoven, The Netherlands
[2] Wageningen University & Research, Wageningen, The Netherlands

Abstract: Inventory routing problems are central to the efficient management of distribution systems, particularly for perishable goods such as fresh agricultural products. In such settings, ordering, transportation, and inventory decisions must be coordinated over time to reduce waste, maintain service levels, and ensure product freshness [1]. These challenges are amplified in multi-echelon systems with multiple products and limited shelf life.

In this work, we study a multi-commodity, multi-period two-echelon inventory routing problem motivated by a short agricultural supply chain. The system consists of multiple suppliers, distribution centers, and customers, where products are collected from farms, consolidated at distribution centers, and delivered to customers over multiple periods. The problem integrates routing, ordering, delivery quantity, and inventory decisions while accounting for perishability and capacity constraints.

We formulate the problem as a mixed-integer linear program that jointly captures routing and inventory dynamics across both echelons. The combination of multi-commodity flows, perishability constraints, and multi-period planning results in a computationally challenging problem that is difficult to solve optimally for realistic instance sizes [2].

To address this challenge, we develop a matheuristic that combines an adaptive large neighborhood search framework with embedded MILP-based partial optimization. The approach exploits the structure of the problem by separating routing and inventory decisions while preserving their interaction, enabling the efficient solution of large-scale instances.

Keywords: Inventory-routing problem; perishable products; matheuristics; Adaptive large neighbourhood search.

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Tugce Canbilen Suticen is a PhD candidate in the Department of Industrial Engineering and Information Sciences at Eindhoven University of Technology. Their research focuses on optimization problems in transportation and logistics, especially inventory routing for perishable products, and develops matheuristic approaches that combine optimization with Adaptive Large Neighborhood Search. Before starting their PhD, they worked as research assistant at Middle East Technical University, gaining experience in teaching and research while earning their master's degree.

MIXED INTEGER FORMULATIONS FOR SUPPLY CHAIN RECONFIGURATION

Lavinia M.P. Ghilardi[1,2], Lucy Anthony [1,2], Olga Walz [3], Steffen Klosterhalfen [3], Calvin Tsay[1,2]

[1] Department of Computing, Imperial College London, London, SW7 2AZ, UK
[2] Centre for Process Systems Engineering, Imperial College London, London, SW7 2AZ, UK
[3] BASF, Ludwigshafen, 67056, Germany

Abstract: Supply chains are interconnected networks of processes and operations that produce and deliver high-value products. These chains are increasingly affected by structural changes driven by the energy transition, which encourages sustainable alternatives, or by other external factors that can, for instance, reshape trade routes. Most existing studies have focused primarily on two types of problems: complete supply chain redesign [4] or short-term disruption management [1]. However, complete redesigns are often impractical in real-world settings, while short-term disruption approaches fail to capture broader structural changes. This work instead seeks partial reconfigurations of supply chains that optimise both economic profitability and operational feasibility. The problem can be formulated as a mixed-integer linear program, but solving it remains challenging due to the global scale and high interconnectedness of supply chains. To tackle this, various heuristics are investigated to obtain solutions that scale to large instances. The proposed methods are applied to an agricultural waste case study [3] involving reconfigurations following a scheduled process removal. Results [2] demonstrate that the approach can significantly reduce computational time while maintaining high-quality solutions. Future work will explore case studies from other sectors, as well as additional reconfiguration problems, such as the introduction of new processes and alternative sustainable products.

Keywords: supply chains, mixed-integer linear programming, heuristics.

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Lavinia Ghilardi is a Research Associate at the Department of Computing at Imperial College London. Their research combines optimization and machine-learning methods for the design and operation of complex energy and chemical systems, supporting sustainability and efficiency in real-world applications. Previously, she obtained a PhD in Energy and Nuclear Science and Technology from Politecnico di Milano, Italy.

An Economic Order Quantity Model for Imperfect Quality Items with Backorder Under Sampling Inspection: A Case of Electric Vehicle Battery Inspection

Nandan Kumar Singh[1], Guneshwar Anand[2]

[1] FORE School of Management, New Delhi
[2] Xavier School of Management, Jamshedpur

Abstract: Today's businesses work in a globalized world where supply chains span many countries. As businesses outsource more product design and manufacturing operations to other supply chain members, ensuring the quality of end products has become a challenge, often beyond the firms' in-house process capabilities to control. This can lead to product recalls, which result from a lack of quality assurance in the manufacturing or design processes of one or many supply chain partners and can affect many products manufactured over extended periods (Chao et al. 2009), leading to substantial present and future costs to a company. One possible solution is to do a full inspection of all received items. However, conducting a full inspection is costly and may not be a feasible solution for all firms, as the cost of the inspection process varies as per the type of product and the industry. Hence, conducting a full inspection may not always be the optimal strategy. One alternative way to address this problem is to do a sampling inspection of received items. However, in the case of sampling inspection, there is a chance that the defective item will reach the customer. The customer will return the defective item to the firm, which will incur an additional cost (cost of accepting the defective item) to the firm. Hence, we see that the trade-off between full inspection and sampling inspection is a function of inspection cost and cost of accepting the defective item. Our paper focuses on understanding this trade-off between the inspection cost and the cost of accepting the defective item. In this context, we ask the following questions: (i) What is the optimal order quantity under the sampling inspection? (ii) What is the optimal planned backorder size of the manufacturer under the sampling inspection?

Sampling inspection with planned backorder for the imperfect quality (SIPBIQ) have not been well studied in the literature. This is an extremely important issue as it impacts the profit of the firm. We contribute to this literature by modelling SIPBIQ and study the impact of cost of accepting a defective item and inspection cost. A closed form solution is obtained for the optimal order size and the planned backorder size. Additionally, we provided mathematical results demonstrating that the optimal order size and planned backorder are monotonic as supply quality degrades. For perfect supply quality, the optimal planned order quantity and backorders, Q^*, J^*, and the respective optimal expected cost per unit time reduce to the classical EOQ (with backorders).
Keywords: Sampling Inspection, EOQ, Defective item; EV Battery.

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Dr. Nandan K Singh is an Assistant Professor in the Operations Management and Decision Science Area at FORE School of Management, New Delhi, India. He was a postdoctoral fellow in Production and Operations Management Department at the Indian Institute of Management Bangalore. His articles have been published in journals such as Decision Sciences, Journal of Operational Research Society, and IEEE Transactions on Engineering Management.

Plenary Session I

Wednesday, October 14th | 10:00 – 11:00

Chair: Saverio Basso



Alberto Ceselli
From Models to Decisions: Designing and Validating Optimization-Based Decision Systems

Alberto Ceselli

From Models to Decisions: Designing and Validating Optimization-Based Decision Systems

Operations Research has developed, over decades, powerful methodological foundations for modeling and solving complex decision problems. Yet strong model and solver performance does not automatically translate into operational use or impact. In fact, the operational performance of an optimization method depends not only on the formulation and algorithms, but also on the data, the representation of uncertainty, the surrounding workflow, and the way recommendations are interpreted and implemented.

I argue that increasing the impact of optimization requires moving from isolated models and algorithms toward the integrated design of the full chain from data to decision. Drawing on both academic and industrial case studies, I will examine how interactions with data pipelines, software components, and human decision-makers affect model formulation, algorithm design, validation, and implementation, including instances in which technically strong solutions were overridden, substantially revised, or failed to produce the expected operational effect.

The discussion will distinguish model-level performance from the acceptance, implementation, and operational effects of optimization recommendations. It will also identify research opportunities concerning data integration, model validation, interactive optimization, and the incorporation of user feedback. The objective is to show how the methodological strengths of Operations Research can be retained while optimization is embedded in decision processes that can be evaluated in practice.



Alberto Ceselli is a Full Professor in the Department of Computer Science at the University of Milan. He received his Ph.D. in 2006 and spent research periods as a visiting scholar at leading European institutions, including TU Berlin, Politecnico di Milano, INRIA Sophia Antipolis, RWTH Aachen, Université Paris XIII, and ESSEC Business School. His research focuses on computational integer programming, prescriptive data analytics, and bridging optimization with data-driven decision-making. He is actively engaged in technology transfer, collaborating with industry on applications in network optimization, smart cities, and digital industry. He also coordinates the department's relations with its industrial advisory board.

Session II
Public Transit, Logistics & Mobility

Wednesday, October 14th | 11:20 – 12:40

Chair: Tullio Villa



Oleg Horshkov
An Exact Solution Approach for a Direct Delivery Scheduling Problem in Intralogistics



Ruoyu Hu
Multi-stage Stochastic Optimization for Public Food Distribution under Capacity Uncertainty and Disruption Risk



Alex Fabián Barrales-Araneda
Solution Approaches for Timetabling and Vehicle Scheduling in Mixed-Fleet Public Transport



Louise Lallemand
New Formulation for the Choice-Based Capacitated Line Planning Problem

An Exact Solution Approach for a Direct Delivery Scheduling Problem in Intralogistics

Oleg Horshkov[1], Julia Lange[1], Timo Gschwind[1]

[1] University of Kaiserslautern-Landau, Kaiserslautern, Germany

Abstract: In make-to-order manufacturing systems like customized floorboard production, intralogistics transport is crucial for timely order fulfillment. Customer orders should leave the company at certain time points, with which the completion times of the corresponding production orders often do not fully align. Since storage capacities in the production as well as shipping areas and the intermediate storage place are limited, the coordination of transport and storage activities constitutes a challenging planning problem.

To deliver orders to the shipping area and pickup orders from the production area, three types of direct transports with predefined origins and destinations can be used. As introduced by Lange and Gschwind [3] for the case of unique orders, these so-called trips must be selected, scheduled and assigned to vehicles from a homogeneous fleet. We extend the planning problem by considering product groups so that several production orders and initial inventories may be available to fulfill a customer order. In addition, limited capacity in the intermediate storage area requires scheduling decisions for stored orders. Consequently, we propose the first mixed-integer programming (MIP) formulation for the direct delivery scheduling problem with intermediate storage and order matching. Following Emde and Zehtabian [1] and Gschwind et al. [2], the problem is represented as determining a sequence of trips for each vehicle in a trip-based graph, ensuring that all orders are fulfilled while simultaneously minimizing both the total travel time and the number of vehicles deployed.

Computational results obtained by general MIP Solver allow for initial managerial and methodological insights. To improve scalability, we derive an exact decomposition approach that separates order matching and trip selection, handled in the master problem, from routing and scheduling decisions addressed at the subproblem level. A computational study evaluates the impact of the decomposition relative to the direct MIP solver approach.

Keywords: intralogistics; scheduling and routing; mixed-integer programming model; decomposition.

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Oleg Horshkov is a PhD candidate at the Chair of Logistics at University of Kaiserslautern-Landau, Germany. His research focuses on optimization problems in intralogistics, particularly integrated vehicle routing and scheduling. His work involves mixed-integer linear programming as well as heuristic and exact decomposition approaches. He received his M.Sc. in Business Administration and Engineering from the same university.

Multi-stage Stochastic Optimization for Public Food Distribution under Capacity Uncertainty and Disruption Risk

Ruoyu Hu[1], Douglas Alem[1], Aakil Caunhye[1]

[1] University of Edinburgh, Edinburgh, United Kingdom

Abstract: Public food distribution networks often operate under substantial uncertainty in warehouse availability. In such systems, facilities are not dedicated to a single program, and capacity available for emergency or social food distribution may vary as warehouses simultaneously support multiple public operations. Some facilities face the risk of being temporarily claimed or repurposed by government authorities, creating disruption risks whose realization unfolds progressively over the planning horizon. Motivated by Brazil's National Food Supply Company (CONAB), which coordinates public food distribution through a network of federal and local warehouses, this study proposes a multi-stage stochastic optimization framework for public food assistance planning under uncertain facility availability and capacity constraints. Strategic decisions, including facility prepositioning, role configuration as local or nationally coordinated depots, and backup assignment structure [1], are determined before disruptions are revealed, while allocation decisions adapt sequentially as facility availability is realized across stages. The formulation extends the reliable facility location problem from a single-stage expected-value treatment of disruption risk to a multi-stage recourse setting in which capacity constraints are enforced conditional on observed disruption scenarios [2]. The framework is grounded in empirical analysis of the 2022 CONAB food distribution operation. Network-level metrics, including spatial complexity indices and workload entropy measures, reveal heavy concentration on a small subset of coordinating facilities and show that capacity limitations can substantially distort distance-efficient assignments [3]. These findings inform the modeling assumptions and establish the practical need for disruption-aware network planning. The study aims to connect public food distribution practice with multi-stage stochastic facility planning, investigating how the interaction between disruption risk and capacity constraints reshapes network structure [4], and how proactive role configuration with staged recourse can mitigate excessive concentration and structural fragility in public distribution systems.

Keywords: Stochastic programming; Reliable P-median problem; Public food distribution; Disruption risk; Capacity constraints; Humanitarian logistics.

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Ruoyu Hu is a PhD candidate in the Business School at the University of Edinburgh. His research focuses on optimizing logistics and supply chains under information delays and resource uncertainty, specializing in multi-stage stochastic programming and robust decision-making frameworks. He has published in *Omega* and presented at major international conferences including EURO 33 & 34. Before starting his PhD, he obtained an MSc in Supply Chain Management from Cranfield University and worked in human resources and operations at Xiamen Airlines, gaining practical experience in process optimization and cross-functional coordination.

Solution Approaches for Timetabling and Vehicle Scheduling in Mixed-Fleet Public Transport

Alex Barrales-Araneda[1], Valentina Cacchiani[1] Emanuele Tresoldi[2]

[1] Department of Electrical, Electronic and Information Engineering "Guglielmo Marconi", University of Bologna, Viale Risorgimento 2, 40136, Bologna, Italy
[2] Department of Computer Science "Giovanni degli Antoni", University of Milan, Via Celoria 18, 20135, Milan, Italy

Abstract: Public transport planning involves closely interrelated decisions, particularly in defining service timetables and assigning vehicles to operate them. These decisions become more challenging in systems with mixed fleets of electric and conventional buses, where scheduling must account for both standard operational requirements and electric-specific constraints such as limited range, recharging operations, and charging resource availability (see e.g., [2]). In this work, we study the problems of timetabling and vehicle scheduling to determine the trip selection and the vehicle assignment. The objective is to balance passenger service quality, measured through deviations from target headways, with operating costs related to fleet usage, excess waiting times, pull-in/pull-out movements, and CO_2 emissions.

Two heuristic solution approaches are proposed: a sequential approach, in which timetabling is solved first and vehicle scheduling is then performed on the basis of the selected trips; and an integrated approach, in which timetable design and vehicle scheduling are jointly addressed. In both cases, timetabling is formulated with a compact model on a directed graph (see [1]), whereas vehicle scheduling is modeled through an exponential-size formulation. The resulting models are solved within a column generation framework, where different variable-fixing strategies are investigated to evaluate their impact on solution quality and computational performance.

The proposed methods are tested on real-world instances from the MINOA Challenge Professional, which represent large-scale and operationally realistic planning scenarios. The sequential and integrated approaches are compared in terms of overall objective value, computation time, number of vehicles used, extra waiting time at terminals, and frequency regularity. The computational analysis highlights the trade-off between service quality and operational efficiency, and provides insights into the benefits and limitations of integrating timetable design and vehicle scheduling in mixed-fleet settings.

Keywords: public transport; timetabling and vehicle scheduling; heuristic and matheuristic algorithms.

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Alex Barrales-Araneda is a PhD student at DEI, University of Bologna, focusing on optimizing sustainable public transportation. He graduated in Industrial Engineering and obtained a Master's in Industrial Engineering from the University of Bío-Bío. His research applies optimization and machine learning to vehicle routing and planning. He has also worked on FONDEF projects related to pattern recognition, crime pattern analysis, and optimization in security and logistics.

New Formulation for the Choice-Based Capacitated Line Planning Problem

Louise Lallemand[1], Léa Ricard[1], Michel Bierlaire[1]

[1] Transport and Mobility Laboratory (TRANSP-OR), EPFL, Lausanne, Switzerland

Abstract: Public transportation network design aims to maximize the level of service provided to passengers under budget constraints. While this objective is often modeled through simplified indicators such as travel time or profit, user satisfaction can be more realistically captured using utility-based measures derived from discrete choice models (see e.g., [3]; [1]).

In this work, we study the line planning problem (LPP), which consists of selecting a set of transit lines and their operating frequencies from a predefined line pool, subject to operational and budget constraints and given a fixed origin–destination demand matrix. Most studies consider the system optimum (SO) formulation, where passenger assignment is determined by the planner. However, this assumption may lead to unrealistic trade-offs between individuals. To better represent passenger behavior, we adopt a user equilibrium (UE) setting in which passengers independently choose their routes to maximize their utility (see, e.g., [2]). This behavioral assumption leads to a bilevel optimization problem, which significantly complicates the solution process. Previous studies have addressed this difficulty through single-level reformulations based on strong duality (see, e.g., [2]) or through system-optimum relaxations (see, e.g., [4]). In this work, we first follow a classical single-level reformulation relying on strong duality arguments, similar to Georigk & Schmidt [2]. Then, we compare it to a second formulation that relaxes the strong duality assumption, allowing the integration of more realistic discrete choice models within the passenger assignment. Finally, we address the computational complexity through the use of decomposition methods to enhance scalability.

Keywords: line planning problem; discrete choice model; user equilibrium; bilevel optimization.

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Louise Lallemand is a PhD candidate in the Department of Civil Engineering at Ecole Polytechnique Fédérale de Lausanne. Her research focuses on the modelling and the resolution of optimization problems, particularly line planning problem and network design. She studies the integration of discrete choice models into optimization problems, developing exact and scalable methods for bilevel and choice-based optimization problems arising in public transportation systems.

Session III
Healthcare Operations & Service Systems Management

Wednesday, October 14th | 14:00 – 15:40

Chair: Laura Davila-Pena



Alberto Guastalla
The Stochastic Team Orienteering Problem



Alfaima L. Solano-Blanco
Resource Constrained Scheduling and Routing Problem for Agricultural Operations Planning



Yiming Hou
On a Class of Nonlinear Facility Location Problems



Martina Doneda
A Multi-granular Approach for No-shows Management in Appointment Scheduling



Alessandro Druetto
Parallel Batch Scheduling for Sterilization Operations

The Stochastic Team Orienteering Problem

Alberto Guastalla[1], Jean-François Côté[2], Roberto Aringhieri[1]

[1] Department of Computer Science, University of Turin, Italy
[2] CIRRELT, Université Laval

Abstract: The Team Orienteering Problem (TOP) is a well-known combinatorial optimization problem that can be described through a complete graph in which each node has a profit and each arc has a cost. The objective is to find a set of m different routes collecting the maximal sum of profits from the visited nodes without exceeding a specific time budget for each of them. Each route must start from the source node and must end to the destination one. This abstract focuses on the stochastic version of the TOP: the Stochastic Team Orienteering Problem (STOP). The STOP considers uncertain travel times modelled as random variables and incorporates a set of chance constraints to focus the search on reliable routes. We model the STOP as a two-stage stochastic integer program and propose an exact solution method based on the Integer L-shaped method. The first-stage problem is modelled as an adaptation of the two-index formulation proposed in [1], while the second-stage problem involves evaluating the recourse function corresponding to the first-stage solution. We introduce a new set of optimality cuts subdivided into three different schemes: (i) the solution-based (or classical) optimality cuts [2], (ii) the route-based optimality cuts [3] and (iii) the customer-based optimality cuts [4]. We propose several valid inequalities and two constraints liftings to strengthen the first-stage formulation of the STOP. Finally, computational results provide a comprehensive analysis of the algorithm using the standard TOP benchmark dataset from the literature.

Keywords: stochastic programming, team orienteering problem, exact algorithm, valid inequalities.

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Alberto Guastalla is a postdoctoral researcher in Operations Research at the Department of Computer Science of the University of Turin (Italy). His work focuses on optimization in transportation and logistics, with particular emphasis on vehicle routing problems with profits.

Resource Constrained Scheduling and Routing Problem for Agricultural Operations Planning

Alfaima L. Solano-Blanco[1], Sonja Rohmer[2], Raf Jans[2], Tom Van Woensel[1]

[1] Eindhoven University of Technology, Eindhoven, The Netherlands
[2] HEC Montréal, Montréal, Canada

Abstract: Agricultural operations planning remains inherently challenging. The production of crops requires a sequence of operations over a growing season, such as soil preparation, seeding, irrigation, and harvesting. Agricultural companies must therefore schedule diverse tasks across multiple fields and route the related heterogeneous resources while accounting for skill compatibility, time windows, precedence, resource synchronisation, and downtime. Together, these considerations make planning difficult, motivating the use of technological solutions to support decision makers in efficiently planning these operations. Problems that combine scheduling and routing, as in this case, have been studied in analogous contexts, such as home healthcare, and technician maintenance, where optimisation models have proven effective in supporting operational decisions [1]. Although some work has begun to address agricultural operations [2, 3], it does not fully account for the combination of features that characterise this context. In this study, we address this gap by modelling this problem as a resource-constrained scheduling and routing problem (RC-SRP) to gain insights into how agricultural operations can be scheduled efficiently. We propose a column generation based heuristic to tackle the complexity of handling skill compatibility, time windows, precedence, resource synchronisation, and downtime simultaneously. Inspired by the operations of one of the largest organic agricultural producers in the Netherlands, we consider farming configurations with multiple crops and varied spatial arrangements, comparing their implications on completion times, costs, and operational decisions. In doing so, we aim to explore how more sustainable farming practices affect decision-making and operational efficiency.

Keywords: Operations research in agriculture; scheduling; vehicle routing problem; column generation heuristic.

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Alfaima L. Solano-Blanco is a PhD candidate in the Department of Industrial Engineering & Innovation Sciences at Eindhoven University of Technology. Her research focuses on optimisation problems for production planning and logistics, including scheduling and routing problems, for sustainable agri-food systems. Before starting her PhD, she worked as a lecturer at Universidad de los Andes, gaining experience in optimisation under uncertainty, decision support systems and transdisciplinary research for circular economy.

On a Class of Nonlinear Facility Location Problems

Yiming Hou[1], Bismark Singh[2], Tarkan Tan[1], Oleg A. Prokopyev[1]

[1] University of Zurich, Zurich, Switzerland
[2] University of Southampton, Southampton, United Kingdom

Abstract: We study a class of nonlinear choice-based facility location problems motivated by the siting of recycling centers, building on recent work on balanced and fair recycling facility location [1, 2]. The model combines multinomial logit choice probabilities with a nonlinear penalty for deviations from target facility utilization, leading to a fractional binary optimization problem. This formulation aims to balance user accessibility while accounting for capacity congestion and user choice behavior. First, we study the computational complexity and structural properties of the model. Then, we develop exact and heuristic solution methods. Preliminary computational experiments on real-life data illustrate the value of the proposed modeling approach, its managerial implications, and the performance of the solution methods.

Keywords: integer programming; nonlinear programming; local search; location problems.

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Yiming Hou is a PhD student in the Department of Business Administration at the University of Zurich. Her research focuses on two-stage decision-making problems in operations research, particularly mixed-integer and bilevel optimization, as well as choice-based optimization. Her work studies applications such as network interdiction and fair facility location, with the goal of developing and solving models that improve resource allocation and equity under strategic or behavioral responses.

A Multi-granular Approach For No-shows Management In Appointment Scheduling

Martina Doneda[1], Elena Fusco[2], Giuliana Carello[2]

[1] University of Bergamo, Dalmine (BG), Italy
[2] Politecnico di Milano, Milan, Italy

Abstract: No-shows represent a significant challenge in appointment scheduling, as missed appointments can lead to operational inefficiencies [3]. This research addresses this issue by investigating various scheduling techniques to deal with no-shows in function of information granularity [2], spanning from a baseline model with aggregated daily capacity to a more detailed slot-based scheduling, testing several policies within an Integer Linear Programming (ILP) architecture. Policies include include uniform reaction, day-specific adjustments, and temporal-based strategies for both proactive overbooking [1] and service time reduction (applying discounting factors to the expected appointment durations) as means to protect the system against no-shows [4].
At the most fine granularity, we test policies on individual-specific risk scores by implementing a machine learning (ML) pipeline for individual no-show risk prediction using a real dataset from the Brazilian public health system. Individual probabilities are integrated into the scheduling framework, enabling tailored risk management policies where capacity constraints are expressed in terms of expected attendance.
The various approaches are evaluated ex-post using Monte Carlo simulation. Aggregated baseline models are effective in preventing overtime, but they result in significant resource wastage. The visit time-reduction model has a balanced behaviour, while the ML-driven one drastically improves efficiency.
In summary, this work proves that moving from homogeneous assumptions to individualized risk profiles allows for more efficient management of resources but, crucially, also provides managerial tools for scenarios in which data granularity is low, so that more efficient capacity management can be achievable regardless of the what information is available.

Keywords: healthcare; machine learning; no-show; scheduling.

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Martina Doneda is a post-doc researcher in the Department of Management, Information and Production Engineering at the University of Bergamo. She received her PhD (summa cum laude) from the Department of Electronics, Information and Bioengineering Department of the Polytechnic of Milan with a thesis titled "On data & decision making: perspectives from healthcare applications considering representativeness and analytical scope", in which she explored the synergies between operations research and data science from a managerial perspective. Before pursuing her PhD, she was a research fellow in Italy's National Research Council.

Parallel Batch Scheduling for Sterilization Operations

Alessandro Druetto[1], Andrea Grosso[2]

[1] Computer Science Department, Università degli Studi di Torino, Turin, Italy
[2] Department of Mathematics, Università degli Studi di Torino, Turin, Italy

Abstract: In [3] Schlembach et al. propose a Column Generation procedure for managing the sterilization operations of surgical instruments. The sterilization process is modeled as a parallel batch scheduling problem on parallel identical machines with job release dates (see [2]).

In the practical setting described, each surgical instrument j to be sterilized (job) is released at the end of some surgical operation performed during the day. A number m of identical sterilizing machines is available, where the surgical instruments are processed in batches that must be formed and scheduled. Capacity constraints have to be taken into account in order to form the batches since each instrument j has some size s_j and the sterilizing machine "trail" has a limited capacity q. The instruments belong to different families, and each family has its own requirements about the temperature and the time required for sterilization; specifically, each batch must be composed of jobs/instruments from the same family f that induces a given processing time p_f. Schlembach et al. choose the total flow time as performance measure, leading to a scheduling model that can be written, adapting the classical three-field notation, as $Pm|\text{p-batch}, \text{fam}, p_j = p_f, r_j, s_j \leq q| \sum_j F_j$.

Adapting ideas from [1], we develop an arc-flow reformulation that is able to optimally solve all instances studied by Schlembach et al., including the real-world ones, in less than one second. We also elaborate on the techniques developed in [3] by equipping their Column Generation procedure with a fast pricing routine based on Dynamic Programming. Furthermore, by introducing a Lagrangian-based procedure to solve the Reduced Master Problem, we get comparable results with far less generated columns – an order of magnitude less, on average. Eventually, we extend the computational study by generating "difficult" instances, that proved to be practically hard to solve.

Keywords: health services; batch scheduling; mixed-integer programming; column generation; sterilization operations.

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Alessandro Druetto is a postdoctoral researcher in Computer Science at the University of Turin, Italy. His work lies at the intersection of operations research, mathematical optimization, and advanced scheduling, with applications in embedded systems, healthcare, and data hiding. He earned his PhD with honors in 2023 and has published in leading international journals and conferences, while actively contributing to teaching, peer review, and the global research community.

Session IV
Industrial Production & Machine Scheduling

Wednesday, October 14th | 16:00 – 17:40

Chair: Alessandro Minoli



Angjelo Zojzi
A Data-Driven Assignment Method for Incoming Alarms in Security Operations Centers



Rafał Jednoróg
Vision-Based DXF Generation for Metalworking SMEs: A Practical Image Processing and Economic Feasibility Study



Annalisa Castelletti
A Column Generation Approach for the Single Batch-Processing Machine Scheduling Problem, with Non-identical Jobs, Compatible Families and Sequence-dependent Setups



Elwin Freudiger
Job Scheduling with Tardiness, Inventory and Overtime Penalties



Simon Cosyns
Predicting the Feasibility and Flexibility of Sports Schedules

A Data-Driven Assignment Method for Incoming Alarms in Alarm Receiving Centers

G. Arcidiaco[2], V. Morandi[1], M.G. Speranza[1], A. Zojzi[1,2]

[1] University of Brescia, Brescia, Italy
[2] Multiprotexion s.r.l., Italy

Abstract: We present a fair and dynamic data-driven framework for assigning incoming alarms to the operators of the Alarm Receiving Centers at Multiprotexion s.r.l., a company providing 24/7 real-time security monitoring. Accurately predicting each alarm's duration is crucial to anticipate operators' workload and enable a fair, real-time assignment. Our main contribution is an end-to-end framework integrating a Machine Learning (ML) duration oracle within a Mixed Integer Linear Programming model (MILP), following the "Predict-then-Optimize" paradigm [2]. To the best of our knowledge, this problem has received little attention in the operations research literature. The closest setting is call center operations [1], which differs fundamentally, as our operators handle heterogeneous, multi-step actions across diverse alarm types. We trained an ML oracle on 4 years of historical alarm events, with more than 10 million observations and over 100 features, including stress, fatigue dynamics, and geospatial factors. Excluding outliers, durations range from a few seconds to about 15 minutes, with an average of roughly 4 minutes. The oracle achieves a Mean Absolute Error (MAE) of 39 seconds, against 107 and 82 seconds for the historical average and median, respectively. Embedded in a real-time operational loop, the oracle estimates the duration of incoming alarms and the residual duration of already assigned ones. These estimates are input to the optimization model that continuously and dynamically assigns alarms to minimize workload imbalances via inequality measures such as the Gini Index and the Mean Absolute Deviation [3]. Compared to the company's previous assignment policy, our Rolling Horizon framework reduces workload imbalances by approximately 70%. To ensure robustness against anomalies, the framework also includes a rejection loop that temporarily buffers and re-optimizes rejected assignments in the next time period.

Keywords: Data-driven Optimization; Machine Learning; Mixed Integer Programming.

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Angjelo Zojzi is an industrial PhD student at the University of Brescia and a Data Scientist and AI Specialist at Multiprotexion s.r.l. His current research applies Machine Learning and Deep Learning to Operations Research to solve practical scheduling and assignment optimization problems. His research interests also explore the integration of Large Language Models and AI agents into the Operations Research heuristics domain.

Vision-Based DXF Generation for Metalworking SMEs: A Practical Image Processing and Economic Feasibility Study

Rafał Jednoróg[1]

[1] Kozminski University, Warsaw, Poland

Abstract: Small and medium-sized enterprises (SMEs) in manufacturing frequently face custom or repair orders for which no digital technical documentation is available. In such cases, preparing fabrication-ready drawings from a physical part or template becomes a time-consuming manual task requiring specialized computer-aided design (CAD; digital technical drawing/modeling) skills, which increases lead times and may render low-volume jobs economically unattractive. This paper presents a lightweight decision-support tool that automates this stage by generating Drawing Exchange Format (DXF; a standard vector file format used in CAD/CAM workflows) files directly from photographs of physical parts. The system was designed for resource-constrained SMEs and combines a simple desktop interface with an offline image-processing pipeline for contour detection, geometric scaling, vectorization, and CAD-compatible export.

The contribution of the study is twofold. First, it proposes a practical workflow innovation that reduces a recurrent operational bottleneck in small-batch metalworking. Second, it evaluates the business relevance of the approach through a real industrial repair case involving replacement blade segments for an agricultural auger. In that setting, a worker without advanced CAD expertise was able to produce usable cutting files after brief instruction, reducing drawing-preparation time from approximately two hours to a few minutes. This translated into substantially lower labor input, faster response to customer demand, and improved profitability of an order that would otherwise involve disproportionate engineering effort.

The results show how narrowly targeted automation can improve process efficiency and expand the feasible set of custom manufacturing jobs in SMEs. More broadly, the paper highlights how simple, domain-specific digital tools can support operational decision-making and productivity growth without requiring expensive artificial intelligence (AI) infrastructure or advanced in-house technical capabilities.

Keywords: operations research; process automation; SME manufacturing; decision support; computer vision.

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Rafał Jednoróg is a PhD candidate and researcher at Kozminski University in Warsaw, Poland. His work combines data science, economics, and applied artificial intelligence, with research interests spanning computer vision, automation, and the economic impact of digital technologies. His current research focuses on practical AI solutions for industry, especially tools that improve productivity and decision-making in resource-constrained environments.

A column generation approach for the Single Batch-Processing Machine Scheduling Problem, with Non-identical jobs, Compatible families and Sequence-dependent setups

Castelletti Annalisa[1], Druetto Alessandro[2], Mansini Renata[1], Rener Elena[3]

[1] Dept. of Information Engineering, University of Brescia, Via Branze 38, 25123 Brescia, Italy
[2] Dept. of Computer Science, University of Torino, Via Pessinetto 12, 10149 Torino, Italy
[3] Dept. of Business Administration, University of Bern, Engehaldenstrasse 4, 3012 Bern, Switzerland

Abstract: The Single Batch-Processing Machine Scheduling Problem, with Non-identical Jobs, Compatible Families and Sequence-dependent Setups (SBPM-NCS), was recently introduced by [1] as a challenging extension of the classical single-machine parallel-batching problem [3]. Jobs can be processed simultaneously in batches, the processing time of each batch is determined by its longest job, and the objective is to minimize the makespan in presence of family compatibility constraints and sequence-dependent setup times. The mixed-integer linear formulation proposed in earlier work captures these features exactly, but becomes difficult to solve on medium- and large-size instances. To address this issue, we propose a column generation–based approach relying on an arc-flow formulation, building upon the frameworks of [2]. Feasible solutions are represented as paths in a directed multigraph, where nodes encode both the position in the sequence and the dominant family of the current processed batch. Each arc corresponds to a feasible batch and is associated with a cost accounting for both batch processing times and sequence-dependent setup contributions. The formulation involves an exponential number of variables and is solved via a Restricted Master Problem, which is iteratively enriched through column generation. The pricing problem consists in identifying batches (columns) with negative reduced cost. We derive its structure and show that it can be reformulated, for fixed positions, as a cardinality-constrained knapsack problem, where item profits are given by dual variables, while weights correspond to job sizes, and feasibility is enforced through capacity and cardinality constraints, together with family constraints. The resulting pricing problem is solved to optimality via a pseudo-polynomial dynamic programming algorithm. Preliminary computational results indicate an improvement in the initial lower bound and competitive solution quality within reasonable computational times.

Keywords: Combinatorial optimization; scheduling; parallel-batching; column generation.

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Annalisa Castelletti is a PhD student in the Department of Information Engineering at the University of Brescia. Her research focuses on combinatorial optimization for scheduling problems, including machine scheduling, batch scheduling, and dynamic rescheduling, with emphasis on exact and decomposition-based approaches, particularly column generation and MILP formulations, for large-scale and computationally complex optimization problems. During her PhD, she has been collaborating with industry on real-world scheduling problems, contributing to bridging the gap between theory and practice.

Job Scheduling with Tardiness, Inventory and Overtime Penalties

Elwin Freudiger[1], Olivier Gallay[1], Nicolas Zufferey[2]

[1] University of Lausanne, Lausanne, Switzerland
[2] University of Geneva, Geneva, Switzerland

Abstract: This paper addresses a single-machine production scheduling problem arising in a real-world industrial context, where a set of non-resumable jobs must be assigned to a daily production schedule over a finite planning horizon. The problem is optimized in a lexicographic manner, aiming to minimize, in order, tardiness, inventory penalties, and overtime [1]. An imposed computing-time limit of 30 minutes must be respected.

The originality of the problem lies in the consideration of (i) inbound and outbound inventory penalties to reflect storage capacity violations, and (ii) both a soft limit on daily processing times to account for uncertainty and setup times, as well as a hard constraint on shift duration. To reflect real-life production scheduling with limited space, maximum outbound and inbound inventory volumes are imposed. If these thresholds are exceeded, additional space may be found, but this undesirable situation negatively impacts production efficiency and is therefore penalized. Each production day is subject to a shift capacity constraint of $C = 8$ hours, while a soft limit of $L = 7$ hours is imposed to account for uncertainty in processing times, setup operations, and the potential insertion of urgent jobs. Overtime penalties are incurred when this limit is exceeded.

To solve this problem, three approaches are developed and compared. First, a constructive heuristic is designed to generate feasible solutions, reflecting practical decision-making. Second, a mixed-integer linear programming (MILP) formulation is proposed to compute exact solutions for small and medium sized instances. Third, a metaheuristic based on Tabu Search is implemented to improve solution quality for larger instances [2,3]. A computational study is conducted on a set of realistically generated instances, reflecting varying levels of job incompatibility, processing times, and volumes. The results highlight the trade-off between solution quality and computation time, as well as the effectiveness of the metaheuristic approach. Managerial insights are also provided.

Keywords: Production Scheduling; Inventory Management; Metaheuristics.

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Elwin Freudiger is a PhD candidate in the Department of Operations at the University of Lausanne. Their research focuses on optimization in logistics and supply chains, with an emphasis on inventory and production planning, using machine learning and metaheuristic approaches. Prior to their PhD, they worked as an Optimization and Simulation specialist at ProcSim, contributing to projects in healthcare and industrial systems.

Predicting the Feasibility and Flexibility of Sports Schedules

Simon Cosyns[1], David Van Bulck[1], Dries Goossens[1]

[1] Ghent University, Belgium

Abstract: Creating a feasible schedule for a sports tournament is a complex task that becomes increasingly difficult as the number of teams grows. Even for a small number of teams, the presence of various constraints leads to a combinatorial challenge. To manage this complexity, a common technique is the "first-break-then-schedule" approach, popularized by Nemhauser and Trick [2]. In this decomposition, one first assigns a so-called Home-Away Pattern (HAP) to every team, indicating when the team plays home and when away. With the resulting HAP-set, we attempt to find a compatible opponent schedule. Finding an optimal schedule according to a specific objective often requires extensive backtracking between these two stages. While Van Bulck et al. [3] proposed an efficient framework using Benders' decomposition to formalize this backtracking, the process remains computationally expensive because every iteration requires a feasibility check of the HAP-set. This research proposes a proactive alternative: a Machine Learning model designed to quickly predict the viability of HAP-sets and rank them before they enter the scheduling phase. Beyond basic feasibility, whether there exists a valid opponent schedule given the HAP-set, we investigate HAP-set flexibility, which characterizes the degree of freedom available when assigning matches to rounds. We focus specifically on the spread of a HAP-set, defined as the sum over all matches of the number of rounds in which that match can potentially be played (Lambers et al. [1]). Since a more flexible HAP-set offers more scheduling possibilities, we hypothesize that higher flexibility correlates with better objective values. By prioritizing HAP-sets with high predicted spread, we aim to significantly reduce the search space and accelerate convergence toward optimal tournament schedules. Furthermore, the Machine Learning models may provide valuable insights into which features influence HAP-set feasibility or flexibility.

Keywords: sports scheduling; machine learning; round-robin tournaments; home-away patterns; Benders' decomposition.

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Simon Cosyns is a PhD candidate in the Department of Business Informatics and Operations Management of Ghent University. His research focuses on optimization problems in sports, particularly tournament scheduling, using an integration of machine learning and integer programming. Before starting his PhD, he completed the Master Data Analytics at the same institution, gaining experience in predictive modeling and data-driven decision-making.

Session V
Game Theory, Behavioral Economics & Social Impact

Thursday, October 15th | 09:00 – 10:00

Chair: Alan Osorio-Mora



Andrea Benso
Cooperation in Repeated Games with Network Monitoring and Communication



Saeedeh Khalilpour Zargabad
Personalized Return Policies Under Customer Heterogeneity



Sara Tavakoli
Rethinking Regional Energy Poverty: An Intersectional Modelling Approach

Cooperation in Repeated Games with Network Monitoring and Communication

Andrea Benso[1]

[1] University of Lyon, INRIA, INSA Lyon, CITI, France

Abstract: We consider a repeated game in which players, viewed as nodes of a network, are connected. Each player observes her neighbors' moves only; thus, monitoring is private and imperfect. At each stage, players can communicate only with their neighbors and each player, for any subset of her neighbors, sends the same message to any player of that subset. Thus, communication is local and both public and private. Both communication and monitoring structures are given by the network. Our research question asks for which networks a folk theorem holds, that is, under which conditions all feasible and strictly individually rational payoffs can be sustained as equilibrium payoffs. In particular, we study perfect Bayesian equilibria, meaning that at each decision point, players take the optimal action given their beliefs and other agents' strategies. Renault and Tomala in [1] showed that a necessary condition for a folk theorem to hold is that the network be 2-connected, meaning that for any two players there exist two distinct paths linking them. We show that, for any number of players, the latter condition is not only necessary, but also sufficient.

Keywords: Folk theorem, Imperfect private monitoring, Networks, Repeated games.

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Andrea Benso is a postdoctoral researcher at INRIA, Lyon as part of the MARACAS Team. His research focuses on Information Theory and Game Theory, in particular about problems related to statistical signal processes and repeated games with imperfect monitoring. During his PhD, he worked on topics in quantum computing, in particular on quantum finite automata.

Personalized Return Policies Under Customer Heterogeneity

Saeedeh Khalilpour[1], Joao Quariguasi Frota Net[1], Ali Hassanzadeh[1]

[1] University of Manchester, Manchester, United Kingdom

Abstract: Product returns play a critical role in shaping customer purchasing behavior, particularly in online and omnichannel retail environments. While generous return policies are known to stimulate demand [1], they also impose significant operational and financial costs on retailers [4]. Existing research has largely focused on designing uniform return policies [3]. Related work also considers quality risk in returns [2]. In contrast, this work explores the potential value of personalized return policies that account for heterogeneity in customers' responses to return leniency.

This study considers a setting in which a retailer decides whether to offer different levels of return leniency to individual customers, recognizing that customers may differ in both their likelihood of purchase and their propensity to return products. We propose a simple and transparent decision framework that captures the fundamental trade-off between demand stimulation and return-related costs. The framework is intentionally kept general and minimal, serving as a baseline for understanding when personalized return policies may be preferable to uniform ones from a profit perspective.

The proposed approach highlights how customer-level differences can influence the effectiveness of return leniency and provides insights into the conditions under which personalization may be economically justified. The model is designed to remain flexible and extensible, allowing future work to incorporate richer behavioral assumptions, additional policy dimensions, or data-driven learning mechanisms. Overall, this research aims to contribute to the growing literature on operationally grounded personalization by offering a simple yet insightful perspective on customer-specific return policy design.

Keywords: return policies; customer heterogeneity; operations management; personalization; retail operations.

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Saeedeh Khalilpour is a PhD candidate in Operations and Supply Chain Management at the University of Manchester. Her research focuses on return policy design and operational decision-making in retail and omnichannel settings.

Rethinking Regional Energy Poverty: An Intersectional Modelling Approach

Sara Tavakoli[1], Pedro Sampaio[1], Ali Hassanzadeh[1]

[1] University of Manchester, Manchester, UK

Abstract: Energy poverty remains a persistent policy challenge across Europe, particularly in the context of the ongoing energy transition and rising pressure on household energy affordability [2]. Despite extensive research, its underlying drivers are often treated as separate and additive. This study examines whether such approaches are sufficient to capture how vulnerability actually forms at the regional level. This assumption of separable effects can lead to misclassification of vulnerable groups and limit the effectiveness of policy targeting.

To address this, a three-level modelling framework is developed in which intersectionality is operationalised as a mediating structure linking socio-economic characteristics to energy poverty [1]. Rather than treating drivers as independent, the framework captures how combinations of characteristics interact to produce vulnerability.

The analysis uses regional data for England and combines statistical and machine learning methods to identify underlying patterns in the data. The results show that similar levels of energy poverty can emerge from different combinations of conditions. While a socio-economic gradient, related to labour market position, education, and health, plays a dominant role, additional intersectional patterns capture life-stage differences and energy system characteristics, particularly heating types.

This suggests that identifying where energy poverty occurs is not enough on its own. What matters is identifying the root causes of energy poverty and how different drivers intersect to produce it. Modelling these relationships provides a more useful basis for place-based policy, especially in the context of Europe's energy transition.

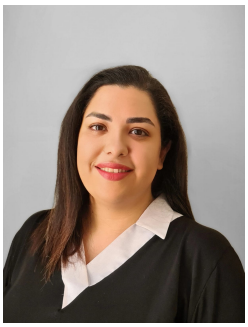
Ongoing work extends this approach to finer spatial scales and develops a policy-oriented modelling framework. This is intended to function as a policy lab tool to assess how different interventions may affect different population groups, with particular attention to fairness across regions.

Keywords: Energy poverty; Intersectionality; Regional modelling; Socio-economic vulnerability; Machine learning; Place-based policy.

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Sara Tavakoli is a PhD candidate at the Alliance Manchester Business School, University of Manchester. Her research focuses on modelling energy poverty and regional vulnerability, with a particular emphasis on intersectionality and the interaction of socio-economic and housing-related factors. She develops quantitative frameworks that combine statistical and machine learning approaches to better understand how structural drivers of energy poverty emerge across regions and to support more effective, place-based policy design.

Plenary Session II

Thursday, October 15th | 10:00 – 11:00

Chair: Stefano Huber



Daniel Kuhn
Metrizing Fairness

Daniel Kuhn

Metrizing Fairness

We study supervised learning problems that have significant effects on individuals from two demographic groups, and we seek predictors that are fair with respect to a group fairness criterion such as statistical parity (SP). A predictor is SP-fair if the distributions of predictions within the two groups are close in Kolmogorov distance, and fairness is achieved by penalizing the dissimilarity of these two distributions in the objective function of the learning problem.

In this paper, we identify conditions under which hard SP constraints are guaranteed to improve predictive accuracy. We also showcase conceptual and computational benefits of measuring unfairness with integral probability metrics (IPMs) other than the Kolmogorov distance. Conceptually, we show that the generator of any IPM can be interpreted as a family of utility functions and that unfairness with respect to this IPM arises if individuals in the two demographic groups have diverging expected utilities. We also prove that the unfairness-regularized prediction loss admits unbiased gradient estimators, which are constructed from random mini-batches of training samples, if unfairness is measured by the squared L2-distance or by a squared maximum mean discrepancy. In this case, the fair learning problem is susceptible to efficient stochastic gradient descent (SGD) algorithms.

Numerical experiments on synthetic and real data show that these SGD algorithms outperform state-of-the-art methods for fair learning in that they achieve superior accuracy-unfairness trade-offs - sometimes orders of magnitude faster.processes that can be evaluated in practice.



Daniel Kuhn is Professor of Operations Research at the College of Management of Technology at EPFL, where he holds the Chair of Risk Analytics and Optimization (RAO). His current research interests are focused on data-driven optimization, the development of efficient computational methods for the solution of stochastic and robust optimization problems and the design of approximation schemes that ensure their computational tractability. This work is primarily application-driven, the main application areas being engineered systems, machine learning, business analytics and finance. Before joining EPFL, Daniel Kuhn was a faculty member in the Department of Computing at Imperial College London (2007-2013) and a postdoctoral research associate in the Department of Management Science and Engineering at Stanford University (2005-2006). He holds a PhD degree in Economics from University of St. Gallen and an MSc degree in Theoretical Physics from ETH Zurich. He is the editor-in-chief of Mathematical Programming.

Session VI
Bilevel & Hierarchical Optimization

Thursday, October 15th | 11:20 – 12:40

Chair: Alex Bortolotti



Emanuele Pizzari
Influencing Followers' Green Behaviour: a Bilevel Optimisation Approach to Waste Management



Eneko Clemente
Dimensionality Reduction in Bilevel Linear Programming



Simon Stevens
Bilevel Optimization with a Piecewise-Linear Follower



Elena Rener
Single Machine Adversarial Bilevel Scheduling Problem of the Total Tardiness

Influencing Followers' Green Behaviour: a Bilevel Optimisation Approach to Waste Management

Massimiliano Caramia[1], Emanuele Pizzari[2]

[1] Dipartimento Ingegneria dell'Impresa, Università degli Studi di Roma Tor Vergata, Rome, Italy
[2] Istituto per le Applicazioni del Calcolo, Consiglio Nazionale delle Ricerche, Rome, Italy

Abstract: Municipal waste generation is projected to reach 3.40 billion tonnes per year by 2050 [5], making effective collection systems a pressing challenge for local authorities. Waste management networks involve interconnected tasks governed by decision-makers at different hierarchical levels whose objectives may conflict [4]. These systems must also address all three pillars of sustainability, i.e., economic, environmental, and social [1, 3].

Bilevel optimisation [2, 6] provides a natural framework for such hierarchical interactions: in our case, a public authority (leader) determines the collection schedule and sets incentive policies, while citizens (followers) decide how to sort and dispose of their waste so as to maximise their own benefit. A central difficulty is *instability*: when the follower's problem admits multiple optimal solutions, the leader cannot predict which one will be realised, and the gap between optimistic and pessimistic objective values can be substantial. We investigate incentive mechanisms embedded in the leader's problem to influence citizens' behaviour and reduce or eliminate this instability. Moreover, waste generation is stochastic. Incorporating demand uncertainty leads to a stochastic bilevel program in which the leader must ensure feasibility of the collection plan under a prescribed service level.

We present bilevel formulations that capture the strategic interaction between authority and citizens, the stochastic nature of demand, and sustainability considerations. We discuss modelling choices aimed at stability and tractability, and report preliminary results on instances of varying size.

Keywords: Bilevel optimisation, waste management, stability, incentive design, stochastic.

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Emanuele Pizzari is a researcher in the Institute for Applied Computing (National Research Council). His research focuses on bilevel optimisation problems, especially on waste management and sustainability issues.

Dimensionality Reduction in Bilevel Linear Programming

Eneko C. Clemente[1], Oleg A. Prokopyev[1]

[1] University of Zurich, Zurich, Switzerland

Abstract: We discuss recent results by Clemente and Prokopyev (2025) on dimensionality reduction in bilevel linear programming. We consider bilevel programs that involve a leader, who first commits to a mixed-integer decision, and a follower, who observes this decision and then responds rationally by solving a linear program (LP). Standard approaches often reformulate these bilevel optimization problems as single-level mixed-integer programs by exploiting the follower's LP optimality conditions. These reformulations introduce either complementarity or quadratic constraints, which become increasingly numerous and burdensome as the number of constraints in the follower's problem grows. This growth is arguably the main computational bottleneck for solving these problems at scale. Accordingly, we propose a dimensionality-reduction approach that projects the follower's constraints into a compressed representation of smaller size. Building on this representation, we develop a surrogate duality theory, from which we derive a feasibility-based lower bound and a surrogate-dual upper bound on the leader's optimal objective function value. We also demonstrate the existence of a family of projections that ensures provable approximation guarantees. Rather than searching for those projections, we employ linear sketching techniques, offering probabilistic approximation guarantees and highlighting trade-offs between dimensionality reduction and approximation quality. Finally, our preliminary numerical experiments illustrate the computational promise of dimensionality reduction techniques in bilevel programming.

Keywords: bilevel linear programming; surrogate duality; linear sketching; dimensionality reduction.

Clemente, Eneko C. and Oleg A. Prokopyev (2025). *Dimensionality Reduction in Bilevel Linear Programming*. URL: `https://optimization-online.org/2025/11/dimensionality-reduction-in-bilevel-linear-programming/`.



Clemente Eneko is a PhD candidate in the Department of Business Administration at the University of Zurich. His research lies at the intersection of mathematical programming, game theory, and learning, with applications to revenue management.

Bilevel Optimization with a Piecewise-Linear Follower

Henri Lefebvre[1], Oleg Prokopyev[2], Martin Schmidt[3], Simon Stevens[3]

[1] LIRMM, University of Montpellier, CNRS, Montpellier, France
[2] University of Zurich, Department of Business Administration, Zurich, Switzerland
[3] Trier University, Department of Mathematics, Trier, Germany

Abstract: In this talk, we study optimistic bilevel problems in which the follower solves a linearly constrained problem with a continuous and piecewise-linear objective function that may be nonconvex. To the best of our knowledge, this class has not yet been studied in the literature. We therefore establish first foundational results, including existence of optimal solutions and complexity results for different variants of the problem class. We prove Σ_2^p-hardness in general via a reduction from a Σ_2^p-hard bilevel knapsack problem studied in Caprara et al. [1]. This hardness persists even when every piecewise-linear function consists of only two pieces. In contrast, the problem is polynomial-time solvable when the number of lower-level variables is fixed and the number of pieces is polynomially bounded. Beyond complexity, we derive a hierarchy of lower and upper bounds and propose a solution approach for solving the problem to global optimality.

Keywords: Bilevel optimization; Piecewise-linear functions; Computational complexity; k-optimality; Branch-and-cut

References

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Simon Stevens is a PhD candidate in the Department of Mathematics at Trier University. His research focuses on robust optimization problems with decision-dependent uncertainties as well as bilevel optimization and the interfaces between these two fields. Before starting his PhD, he studied Mathematics at Trier University and graduated with a Master's Degree in 2024.

Single Machine Adversarial Bilevel Scheduling Problem of the Total Tardiness

Andrea Grosso[1], Federico Della Croce[2], Elena Rener[3], Vincent T'kindt[4]

[1] University of Turin, Turin, Italy
[2] Polytechnic University of Turin, Turin, Italy
[3] University of Bern, Bern, Switzerland
[4] Polytechnic University of Tours, Tours, France

Abstract: Bilevel scheduling problems emerge in a variety of domains, including manufacturing and information systems, where local schedulers interact with a leader agent within a system characterized by asymmetric information and self-interested behavior.

In the specific field of machine scheduling, probably the first work about bilevel scheduling is [1] where a bilevel flow-shop problem is formulated and solved via a two-level branch and bound. Later, [2] identified Constraint Programming as a promising framework for addressing bilevel scheduling problems. To the authors' knowledge, [3] is the first work aiming to a broad investigation of several adversarial scheduling problems.

Our study focuses on a particular case where a local scheduler aims to minimize the total tardiness by scheduling jobs on a single machine. These jobs must first be directed to the leader, which selects only a subset of them. We consider the adversarial analysis, which evaluates the worst-case situation for the local scheduler, i.e., the case where the minimum total tardiness is the maximum among all possible job selections. In a practical setting the leader is not necessarily a malevolent agent; instead it can represent some higher-level manager that will assign jobs to the plant/machine by an independent criterion, whereas the plant's supervisor solves the scheduling problem in order to cope with a possible worst-case assignment. In addition, the adversarial formulation provides a natural framework for evaluating system robustness and stress-testing the scheduling system under unfavorable conditions.

We prove that the problem is Σ_2^p-complete. From a computational perspective, an exact method is proposed that incorporates a tailored upper bound and effective dominance rules that significantly reduce the search space. Computational results show that the proposed method is able to solve instances with up to 160 jobs to optimality within reasonable computational time.

Keywords: bilevel scheduling; single machine; total tardiness.

References

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Elena Rener is a Research Assistant in the Department of Business Administration at University of Bern. Her research focuses on optimization problems in production, particularly on scheduling and rescheduling under disruptions. She primarily uses mathematical programming and combinatorial optimization techniques to develop efficient exact algorithms for these problems.

Session VII
Network Optimization & Distributed Algorithms

Thursday, October 15th | 16:20 – 17:40

Chair: Marilena Palomba



Alberto Bertoncini
A Branch and Price Approach for Latency Aware VNF Placement



Dimitri Rusin
A Distributed Multiobjective Optimization Algorithm Based on the Alternating Direction Method of Multipliers



Bart van Rossum
Bucket-Based Column Generation for Nested Path Problems



Chek-Manh Loi
Drone Air Traffic Control: Tracking a Set of Moving Objects with Minimal Power

A Branch and Price approach for latency aware VNF placement

Alberto Bertoncini[1], Alberto Ceselli[1], Christian Quadri[1]

[1] University of Milano, Department of Computer Science, Milan, Italy

Abstract: The Virtual Network Function (VNF) placement problem has gained relevance in the context of service orchestration. The shift from centralized cloud infrastructures to edge computing enables the deployment of latency-sensitive services closer to end users, reducing response times and mitigating the limitations of on-board execution. However, the use of distributed and heterogeneous edge resources introduces critical challenges, especially for real-time applications like autonomous vehicles. In this context, placement must satisfy both resource constraints and Quality of Service (QoS) requirements.

In a preliminary investigation [3], we proposed a mathematical formulation for the VNF placement problem that jointly considers latency and resource constraints for fixed input-output microservice compositions. However, the scalability of such formulation is limited by the presence of quadratic constraints. To address such drawback, we develop a reformulation by linearization. From a modeling point of view, it shifts the perspective from service placement to the placement of microservice dependencies.

Experiments show that this reformulation is computationally more tractable, but yet not scalable. Following effective approaches to similar problems from the literature [1, 2], we propose a further reformulation, based on the Dantzig-Wolfe decomposition principle resulting into a Master Problem (MP) enforcing global resource availability across selected patterns and one subproblem for each input-output microservice sequence. This decomposition is paired with a column generation mechanism, iteratively solving a Restricted MP, and each subproblem, producing microservice chain placements satisfying end-to-end QoS latency constraints.

A distinctive methodological feature of our approach is the following: subproblems arising due to our decomposition scheme are partially overlapping. This overlap arises from complex service compositions, where a single microservice can be shared across multiple dependencies and thus appear in different service sequences, modeled as pattern columns within the decomposition scheme. We present and discuss choices in algorithm design which we introduced to handle such an overlapping.

Our methods enable a more effective exploitation of the chain-based representation of data flows and allow targeted improvements of the pricing subproblems, ultimately enhancing the efficiency of the column generation procedure.

Keywords: VNF; QoS; BranchAndPrice; Optimization; Placement.

References

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Alberto Bertoncini is a PhD student in the Department of Computer Science at University of Milan. His research focuses on optimization problems for service placement in edge-cloud continuum, through hybrid techniques comprehensive of mathematical programming, heuristic approaches and reinforcement learning. Before starting his PhD, he worked as a data scientist at Latitudo Srl and as data engineer at Reply Cluster, gaining experience data management and data-driven decision-making.

A Distributed Multiobjective Optimization Algorithm Based on the Alternating Direction Method of Multipliers

Dimitri Rusin[1], Ali Hassanzadeh[1], Joshua Knowles[2], Manuel López-Ibáñez[1]

[1] Alliance Manchester Business School, University of Manchester, United Kingdom
[2] Cambridge Research Center, SLB, United Kingdom

Abstract: We study the problem of optimizing multiple objectives in a distributed setting [1]. Every objective is owned by an independent agent who must keep it confidential, yet wants to approximate the Pareto front of both his own and the other agents' objectives. This setting is inspired by companies in a supply chain who want to cooperate with each other to achieve their objectives, yet must not disclose their own due to legal obligations.

We restrict our study to the case where all optimizable variables are continuous. The main idea is to form multiple weighted-sum scalarizations of the objectives and to optimize every scalarization via the popular alternating direction method of multipliers (ADMM, [2]).

ADMM is a generalization of Lagrangian relaxation of the constraints of a single-objective convex optimization problem. If we want to minimize $f(x_1, x_2) = f_1(x_1) + f_2(x_2)$ whilst ensuring $x_1 = x_2$, we can instead solve $\max_\lambda \min_{x_1,x_2} \mathcal{L}(x_1, x_2, \lambda) = f_1(x_1) + f_2(x_2) + \lambda\ (x_1 - x_2)$. This problem can be solved by applying local search on (x_1, x_2) and then updating λ with gradient descent. After a sufficient number of iterations, we will converge to the optimum of $f_1(x_1) + f_2(x_2)$, with $x_1 = x_2$.

In our multiobjective setting, we scalarize our objectives into a convex combination, that is $f(x) = \alpha\ f_1(x) + (1-\alpha) f_2(x)$, with $\alpha \in [0, 1]$. We sample different weight vectors and, in this way, approximate the convex part of the Pareto front. We measure the number of points exchanged between the two agents as well as the quality of the approximated Pareto set. We perform these experiments on unimodal as well as multimodal functions such as the Rosenbrock function.

Our main contribution lies in a distributed algorithm which computes an approximation to the Pareto front of a given multiobjective continuous optimization problem under a restricted communication budget between the objectives' owners.

Keywords: multiobjective optimization; interwoven systems; alternating direction method of multipliers.

References

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Dimitri Rusin is a PhD candidate within the Alliance Manchester Business School at the University of Manchester.
His research focuses on distributed optimization problems that arise in supply chains. He analyses methods that automatically train heuristics for solving such problems, but also doesn't shy away from trying established techniques.
Before starting his PhD, Dimitri worked as a research engineer on IOH-Profiler, whereby he gained knowledge in benchmarking optimization algorithms.

Bucket-Based Column Generation for Nested Path Problems

Bart van Rossum[1], Alexandre Jacquillat[2], Rolf van Lieshout[1]

[1] Operations, Planning, Accounting & Control, Eindhoven University of Technology, Eindhoven, The Netherlands

[2] Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States of America

Abstract: Many transportation problems can be modelled as path problems, where a set of elements must be covered by a least-cost set of paths. Well-known examples include vehicle routing and railway crew scheduling. Since the number of paths is exponential, column generation is the (exact) method of choice for such problems. A large number of novel problem variants feature a nested subpath-path structure that classical column generation algorithms fail to exploit. In such problems, a path is composed of subpaths, each of which must individually satisfy a local feasibility constraint, while the sequence of subpaths must jointly satisfy a global feasibility constraint. Examples include the balanced multi-period vehicle routing problem (MPVRP), where a route is a sequence of daily customers and a driver schedule is a sequence of routes subject to a bound on total distance, and integrated crew scheduling and rostering, where a duty is a sequence of tasks and a roster is a sequence of duties.

State-of-the-art column generation algorithms for nested subpath-path problems typically proceed by first enumerating a set of non-dominated subpaths and then concatenating them to promising paths [1, 2]. The enumeration phase solves a shortest path problem with resource constraints for each possible subpath domain, retaining only subpaths that cannot be dominated by any concatenation of shorter subpaths. The number of non-dominated subpaths can grow exponentially with instance size, rendering the approach computationally intractable on large instances.

In this work, we propose an exact, bucket-based pricing algorithm designed for computational efficiency in subpath-path settings, avoiding ex-ante enumeration of non-dominated subpaths. Instead, the algorithm partitions the space of subpaths into so-called buckets and limits the search to at most one subpath per bucket, which are then concatenated to paths. When this search fails to identify a negative reduced cost path, the bucket partitioning is iteratively refined. To control graph size, buckets whose minimum reduced cost contribution cannot improve the incumbent solution are periodically merged.

We show that the bucket-based pricing algorithm solves the pricing problem to optimality in finite time, propose several refinement and merging strategies, and evaluate its computational performance on a series of balanced MPVRP and robust railway crew scheduling instances. Our method compares favourably to the state-of-the-art in both applications, enabling us to solve larger instances.

Keywords: column generation; vehicle routing; crew scheduling; decomposition; shortest path.

References

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[2] Jacquillat, A. & Lo, S., "Subpath-based column generation for the electric routing-scheduling problem," *arXiv preprint arXiv:2407.02640*, 2024.



Bart van Rossum is a postdoctoral fellow in the Operations, Planning, Accounting & Control group at Eindhoven University of Technology. His research interests include railway crew planning, fairness-oriented optimisation, and combinatorial optimisation in general, and features a wide range of mathematical programming techniques, with a strong focus on large-scale column generation. Bart defended his PhD dissertation *Optimising Fair Work Allocation: Applications in Railway Crew Planning* at Erasmus University Rotterdam in 2025.

Drone Air Traffic Control: Tracking a Set of Moving Objects with Minimal Power

Sándor P. Fekete[1,2], Malte Hoffmann[1], Chek-Manh Loi[1], Michael Perk[1]

[1] Department of Computer Science, TU Braunschweig, Braunschweig, Germany
[2] L3S, Germany

Abstract: A common sensing problem is to use a set of stationary tracking locations to monitor a collection of moving devices: Given n objects that need to be tracked, each following its own trajectory, and m stationary traffic control stations, each with a sensing region of adjustable range; how should we adjust the individual sensor ranges in order to optimize energy consumption? We provide both negative theoretical and positive practical results for this important and natural challenge. On the theoretical side, we show that even if all objects move at constant speed along straight lines, no polynomial-time algorithm can guarantee optimal coverage for a given starting solution. On the practical side, we present an algorithm based on geometric insights that is able to find optimal solutions for the min max variant of the problem, which aims at minimizing peak power consumption, see Figure 1. Runtimes for instances with 500 moving objects and 25 stations are in the order of seconds for scenarios that take minutes to play out in the real world, demonstrating real-time capability of our methods. See [1] for more details.

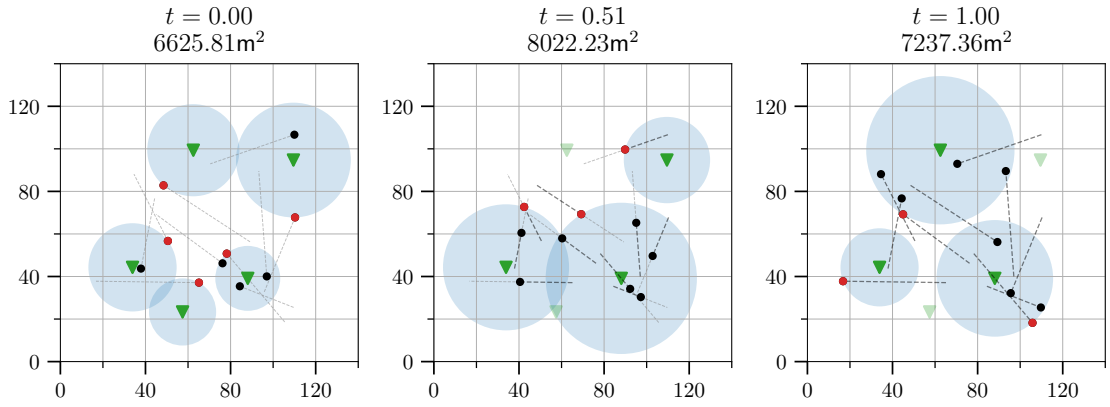
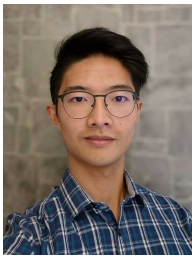


Figure 1: An optimal solution for 10 moving points and 5 stations depicted as triangles. Our algorithm can find a solution over time, that uses at most 8022.23 m^2 of area over the whole time interval. This solution is matched by a lower-bound computed by solving the static DC problem at this time step.

Keywords: set cover; kinetic problems; geometric optimization; exact optimization.

References

[1] Loi, C., Perk, M., Hoffmann, M. & Fekete, S., "Drone Air Traffic Control: Tracking a Set of Moving Objects with Minimal Power" in *IEEE International Conference on Robotics and Automation (ICRA)*. To appear. *arXiv preprint arXiv:2603.05286*, 2026.



Chek-Manh Loi is a Ph.D. student at the Department of Computer Science, TU Braunschweig. He has a Master's degree in Computer Science from the TU Braunschweig, where he also completed his Bachelor's degree. His research interests include computational geometry, optimization, and algorithm design. He has coauthored several papers on geometric covering problems. His research combines theoretical insights with practical applications to address complex challenges in his field.

Panel Session

After the PhD: Successfully Writing a Grant

Thursday, October 15th | 17:40 – 18:20

Chair: Saverio Basso, Eleonora Vercesi, Luis Felipe Vargas



Alberto Ceselli
Department of Informatics "Giovanni Degli Antoni", University of Milan, Italy



Daniel Kuhn
College of Management of Technology, Chair of Risk Analytics and Optimization, EPFL, Switzerland



Monique Laurent
Centrum Wiskunde & Informatica, and Tilburg University, Netherlands



Alessio Trivella
Duferco Innovation, Lugano, Switzerland

Session VIII
Discrete Structures, Matroids & Graph Theory

Friday, October 16th | 09:00 – 10:00

Chair: Koppány Encz



Áron Jánosik
Hypergraph Representation of All Matroids



Bence Mátravölgyi
Cyclic Ordering of Split Matroids



Hongjin Wu
Threshold Graphs are Globally Synchronizing

Hypergraph Representation of All Matroids

Kristóf Bérczi[1], Áron Jánosik[2], Bence Mátravölgyi[3], Tamás Schwarcz[4]

[1] MTA-ELTE Matroid Optimization Research Group and HUN-REN–ELTE Egerváry Research Group, Department of Operations Research, Eötvös Loránd University, and HUN-REN Alfréd Rényi Institute of Mathematics, Budapest, Hungary
[2] MTA-ELTE Matroid Optimization Research Group, Department of Operations Research, Eötvös Loránd University, Budapest, Hungary
[3] IDSIA, USI-SUPSI, Lugano, Switzerland
[4] Department of Mathematics, London School of Economics and Political Science, London, United Kingdom

Abstract: Paving matroids are rank-r matroids where each set of size at most $r-1$ is independent. The Crapo-Rota conjecture [2] suggests that the asymptotic fraction of paving matroids on n elements tends to 1 as n tends to infinity. A consequence of this conjecture would be that almost all matroids share a similar underlying hypergraph structure. This raises the question: is there a similar, even more general underlying structure for all matroids? Building upon a definition by Balcan and Harvey [1], we demonstrate that with a slight modification, the resulting class, which we introduce as cuptroids, provides such a structure. Furthermore, we define the class of captroids and examine various extensions of these concepts. We prove that cuptroids and captroids are duals of each other and are closed under taking minors while keeping the original structure. Finally, we establish additional properties concerning submodularity-modularity and the cyclic flat lattice, while highlighting several open problems that remain for these new matroid classes.

Keywords: Cyclic flats; Excluded minors; Hypergraph representation; Paving matroids.

References

[1] Balcan, M.-F., & Harvey, N. J. A., "Learning Submodular Functions", *CoRR*, abs/1008.2159, 2010.

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Áron Jánosik is a PhD candidate in the Department of Operations Research at Eötvös Loránd University, Budapest. His research focuses on combinatorial optimization and matroid theory, particularly structural behavior and properties of matroids.

Cyclic Ordering of Split Matroids

Kristóf Bérczi[1], Áron Jánosik[2], Bence Mátravölgyi[3]

[1] MTA-ELTE Matroid Optimization Research Group and HUN-REN–ELTE Egerváry Research Group, Department of Operations Research, Eötvös Loránd University, and HUN-REN Alfréd Rényi Institute of Mathematics, Budapest, Hungary
[2] MTA-ELTE Matroid Optimization Research Group, Department of Operations Research, Eötvös Loránd University, Budapest, Hungary
[3] IDSIA, USI-SUPSI, Lugano, Switzerland

Abstract: This result is based on work appearing in [1]. There is a long list of open questions rooted in the same underlying problem: understanding the structure of bases or common bases of matroids. These conjectures suggest that matroids may possess much stronger structural properties than are currently known. One example is related to cyclic orderings of matroids. A rank-r matroid is called cyclically orderable if its ground set admits a cyclic ordering such that any interval of r consecutive elements forms a basis. In this paper, we show that if the ground set of a split matroid decomposes into pairwise disjoint bases, then it is cyclically orderable. This result answers a conjecture of Kajitani, Ueno, and Miyano [3] in a special case, and also strengthens Gabow's conjecture [2] for this class of matroids. Our proof is algorithmic, hence it provides a procedure for determining a cyclic ordering in question using a polynomial number of independence oracle calls.

Keywords: Cyclic ordering, Paving matroids, Sequential symmetric basis exchanges, Split matroids.

References

[1] Bérczi, K., Jánosik, Á., & Mátravölgyi, B., "Cyclic Ordering of Split Matroids", *The Electronic Journal of Combinatorics*, vol. 33, no. 1, P1.20, 2026.

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Bence Mátravölgyi is a PhD candidate at IDSIA, USI-SUPSI, Lugano, Switzerland. His research is focused on the design and analysis of algorithms and data structures with particular interest in approximation algorithms, matroid optimization and combinatorial optimization.

Threshold graphs are globally synchronizing

Hongjin Wu[1], Ulrik Brandes[2]

[1] Centrum Wiskunde & Informatica
[2] ETH Zürich

Abstract: The study of synchronization traces back to the 17th century, when Christiaan Huygens first observed the spontaneous synchronization of pendulum clocks. Since then, synchronization phenomena have been widely studied across both natural and technological systems. For example, the flashing of fireflies, synchronization in power grids, coordinated motion in robotic networks, and Transformer architecture. The Kuramoto model, introduced by Yoshiki Kuramoto in 1975, is a central and widely accepted model for synchronization phenomena. Mathematically, it is a set of ordinary differential equations

$$\frac{d\theta_i}{dt} = \sum_{j=1}^{n} A_{ij} \sin(\theta_j - \theta_i), \qquad i \in V, \tag{1}$$

describing phase oscillators $\{\theta_i : R \to S^1\}_{i \in V}$ on the unit circle whose interactions are encoded by a graph $G = (V, E)$ with adjacency A. Here, each edge acts like a spring that pulls the two adjacent oscillators toward each other whenever their phases differ. A natural question arises: Which graphs guarantee that all nodes on the unit circle converge to a single point when linked by springs, no matter where they start? We call such them *globally synchronizing graphs*. This property is tightly linked to the benign nonconvexity of the model's energy landscape

$$E_G(\theta) := \frac{1}{2} \sum_{1 \le i,j \le n} A_{ij}\big(1 - \cos(\theta_i - \theta_j)\big). \tag{2}$$

Namely, once we show that every second-order stationary point of $E_G(\theta)$ is a fully-synchronized state, then it is provable that the graph is globally synchronizing.

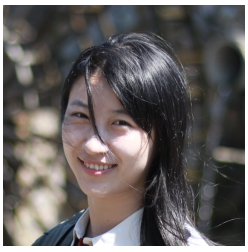
Existing guarantees for global synchronization typically require every node to connect to sufficiently many neighbors, which in turn enforces rather homogeneous degree sequences and highly dense graphs. In contrast, we identify threshold graphs as a class of graphs that lie outside this regime yet nevertheless exhibit global synchronization. More precisely, connected threshold graphs realize all admissible edge densities ranging from $2/n$ to 1, and their degree sequences are maximally left-skewed among all graphs with the same edge density, when ordered in nonincreasing order.

Our proof relies on a phasor-geometric analysis of the stationary points of the associated energy landscape. This abstract is based on our recent work [1].

Keywords: Synchronization; Nonconvex optimization; Networks; Benign nonconvexity.

References

[1] H. Wu, U. Brandes, Threshold graphs are globally synchronizing, 2025, Preprint available online.



Hongjin Wu is a postdoctoral researcher in the Networks & Optimization group at the Centrum Wiskunde & Informatica (CWI) in Amsterdam. Her research interests lie in global synchronization in the Kuramoto model, with a focus on how certain graph structures eliminate spurious second-order stationary points in the associated nonconvex energy landscape.

Plenary Session IV

Friday, October 16th | 10:00 – 11:00

Chair: Luis Felipe Vargas



Monique Laurent
Polynomial Optimization

Monique Laurent

Graph elliptopes: combinatorial, geometric and algebraic aspects

The set of $n \times n$ positive semidefinite matrices with an all-ones diagonal (a.k.a. correlation matrices) is a well-studied convex set, known as the elliptope $\mathcal{E}_n$. It plays an important role within several research areas, including distance geometry, matrix completion problems, combinatorial optimization, and algebraic statistics. For instance, the elliptope $\mathcal{E}_n$ provides the semidefinite relaxation underlying the celebrated 0.878-approximation algorithm of Goemans & Williamson (1995) for the max-cut problem, and its projection $\mathcal{E}(G)$ onto the subspace indexed by the edge set of a graph G is at the core of the PSD matrix completion problem. Testing membership in $\mathcal{E}(G)$ is a basic instance of semidefinite programming feasibility problem, whose exact complexity status is still unknown.

We will discuss some old and new results about graph elliptopes. For some graph classes (chordal, series-parallel, and cycle-completable graphs), the associated graph elliptope $\mathcal{E}(G)$ admits a structural characterization involving PSD constraints and related metric polyhedra. Interestingly, this uncovers a tight link with trigonometric parametric representations of certain algebraic varieties. We aim to highlight these combinatorial, geometric and algebraic connections. As a byproduct, while - by construction - every graph elliptope $\mathcal{E}(G)$ is a spectrahedral shadow, one can show that $\mathcal{E}(G)$ is a spectrahedron (i.e., the feasibility region of an SDP) precisely when the graph G is chordal. Based on joint work with Francesco Mascarin and Simon Telen.



Monique Laurent obtained her PhD in Mathematics at the University Paris Diderot in 1986. During her PhD studies, she was a visiting researcher at New York University in the period 1984–1986. After two years as a researcher at CNET (Paris), she became a researcher at CNRS in 1988, affiliated first with University Paris Dauphine and from 1992 with École Normale Supérieure. In 1990–1992, she visited the Institute of Discrete Mathematics in Bonn as a Humboldt Fellow. From 1997, she joined CWI as a senior researcher. She was group leader of Networks and Optimization (N&O) between 2005 and 2016, and a member of the CWI Management Team between 2016 and 2021. She has also been affiliated as a part-time full professor at Tilburg University since 2009. She became a SIAM Fellow in 2017, a EUROPT Fellow in 2021, and she received the Khachiyan Prize 2023 from the INFORMS Optimization Society.

Session IX
Polynomial Optimization & Column Generation

Friday, October 16th | 11:20 – 12:40

Chair: Marta Baldomero-Naranjo



Utkarsh Detha
Primal-Dual Interior Point Methods for Non-symmetric Cones



Johannes Schmucker
Exploiting Structural Properties in Polynomial Optimization



Enrico Brambilla
A Column Generation Approach via Lagrangian Decomposition for the Multidimensional Multiple-Choice Knapsack Problem



Filippo Ranza
A Column-Generation Approach for the Irregular Shape Bin Packing Problem

Primal-Dual interior point methods for non-symmetric cones

Utkarsh Detha[1,2]

[1] MOSEK ApS, Copenhagen, Denmark
[2] Technical University of Denmark (DTU Compute), Copenhagen, Denmark

Abstract: In their influential work, Nesterov and Todd [1] generalized the primal-dual interior-point method and its theoretical/practical properties to the class of symmetric cones. Motivated by Tunçel's work [2] on primal-dual scalings for non-symmetric cones, Dahl and Andersen [3] (DA) provide a generalization of primal-dual methods to handle the (non-symmetric) 3-D exponential and 3-D power cones. They also introduce a novel higher-order correction which is very effective at improving the performance of their method.

This talk will focus on the extension of the DA method to various higher-dimensional ($\geq$ 3-D) non-symmetric cones. We will examine numerical aspects of the generalized-BFGS scaling for said cones and discuss how bounds on the scaling matrix evolve throughout the algorithm. The impact of higher-order corrections will also be evaluated. Lastly, the performance of the method will be compared to the case when the higher-dimensional cones are formulated using the 3-D cones and solved with the original DA method.

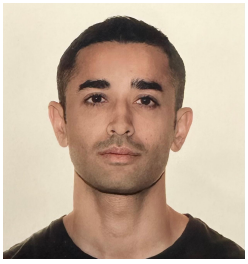
Keywords: nonsymmetric cones; interior-point; scaling.

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Utkarsh Detha is an Industrial PhD candidate at DTU Compute in collaboration with MOSEK ApS. Their research focuses on extending primal-dual interior point methods to the class of nonsymmetric convex cones. Before starting their PhD, they worked as an Optimization specialist at MOSEK ApS, gaining experience in conic optimization.

Exploiting Structural Properties in Polynomial Optimization

Daniel Brosch[1], Johannes Schmucker[2]

[1] University of Klagenfurt, Klagenfurt, Austria
[2] University of Klagenfurt, Klagenfurt, Austria

Abstract: Over the past three decades, substantial progress has been made on approximating, and sometimes even solving, *polynomial optimization problems* (POPs), where both the objective and the constraints are multivariate polynomials, and which are in general very hard problems. In particular, this has been done through the *moment-SOS-hierarchy* proposed by Lasserre [2] and Parillo [3], which approximates POPs via *semidefinite programs* (SDPs). However, the size of these SDPs increases rapidly with the number of variables or the polynomial degree, often making them intractable on modern computers.

To mitigate this issue, recent methods exploit structural properties of the polynomials such as *symmetries* and *sparsity*. In this context, Wang, Magron, and Lasserre [4,5] have proposed a hierarchy based on term sparsity, which takes advantage of polynomials with few terms.

In this talk, which is based on joint work with Daniel Brosch, we propose a symmetric variant for the term sparsity hierarchy, allowing to exploit also the symmetries of the problem. To this end, we study chordal extensions of the term sparsity pattern graph that preserve the automorphism group of the graph. In particular, we will focus on the case of S_n-invariant graphs and show that they stabilize with respect to chordality when adding more variables n. We will also compare our framework with a recent approach by Klep et al. [1] for exploiting both term sparsity and symmetry.

Keywords: large-scale polynomial optimization; semidefinite programming; term sparsity; symmetry reduction; chordal graphs.

References

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Johannes Schmucker is a PhD candidate in the Department of Mathematics at the University of Klagenfurt. Before beginning his PhD in May 2025, he completed his master's degree at the University of Klagenfurt, where he was a teaching assistant, and worked in the Reliability Department at Infineon Technologies.
His research focuses on polynomial optimization and its connections to semidefinite programming. In particular, he is interested in reducing the computational cost of solving semidefinite programs by exploiting structural properties, such as symmetry and sparsity, to enable larger instances. He also studies applications in combinatorial optimization, including the (complex) Max-Cut problem, as well as in extremal combinatorics.

A Column Generation Approach via Lagrangian Decomposition for the Multidimensional Multiple-Choice Knapsack Problem

Enrico Brambilla[1], Renata Mansini[1], Roberto Roberti[2]

[1] Dept. of Information Engineering (DII), University of Brescia, Brescia, Italy
[2] Dept. of Information Engineering (DEI), University of Padova, Padova, Italy

Abstract: The Multidimensional Multiple-Choice Knapsack Problem (MMCKP) is a complex combinatorial optimization problem that extends the classic knapsack problem by requiring exactly one item to be selected from several disjoint sets while respecting multiple resource constraints [1, 2]. Given its applications in chip multiprocessor runtime resource management and global routing of wiring in circuits, finding high-quality solutions and tight dual bounds is a critical challenge.

This paper presents a decomposition-based exact framework that reformulates the MMCKP using Lagrangian decomposition. This reformulation results in a model with an exponential number of variables, which we manage using Column Generation, that represent feasible configurations for individual resources. The primary challenge involves ensuring that these independent resource selections agree on a single set of items [3]. In our approach, we relax these consistency constraints in the master problem via Lagrangian relaxation and the pricing subproblems are reduced to one-dimensional multiple-choice knapsack problems, which can be solved efficiently via dynamic programming.

To mitigate the common convergence issues associated with column generation, such as dual degeneracy and the "tailing-off" effect, we discuss and evaluate several algorithmic enhancements. These include reduced-cost variable fixing based on initial primal heuristics, the use of dual-optimal inequalities to stabilize the master problem, and a dual heuristic to accelerate convergence of the subgradient method. Finally, we present preliminary results on benchmark instances to assess the scalability of this framework against traditional compact formulations for the MMCKP.

Keywords: knapsack problem; Lagrangian decomposition; Lagrangian relaxation; column generation

References

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[2] Cacchiani, V., Iori, M., Locatelli, A., & Martello, S., "Knapsack problems — An overview of recent advances. Part II: Multiple, multidimensional, and quadratic knapsack problems", *European Journal of Operational Research*, vol. 298, no. 1, pp. 16–34, 2022.

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Enrico Brambilla is a PhD candidate in the Department of Information Engineering at University of Brescia. His research focuses on combinatorial optimization, a field he has specialized in since his Master's thesis. His current PhD project shifts this expertise toward the energy sector, specifically investigating the optimization of battery energy storage systems (BESS) in electricity markets.

A Column-Generation Approach for the Irregular Shape Bin Packing Problem

Stefan Irnich[1], Christian Manz[1], Filippo Ranza[1]

[1] Chair of Logistics Management, Department of Business & Economics, Johannes Gutenberg University Mainz, Jakob-Welder-Weg 9, D-55128 Mainz, Germany

Abstract: We study the packing of two-dimensional irregular polygons (items) into larger rectangular containers (bins) of various sizes, in order to minimize the number of containers used. In their recent survey, Leao et al.[3] point out that nesting problems, namely identifying a feasible placement of a set of shapes into one bin, have been widely studied. However, the integration of multiple bins, with the high-level choice association of an item to a bin, and the subsequent nesting problem, has not been studied intensively.

This packing problem is solved using a tailored column-generation approach. We formalize the master problem as a Set Partitioning Formulation like the one proposed by Gilmore and Gomory[2], where each variable (column) represents one feasible way to fill a container. The pricing problem is concerned with the identification of a feasible nesting of items with maximum profit, in terms of dual cost. Since solving exactly such a nesting problem is computationally challenging for large-scale instances, we relax it into a Bounded Knapsack Problem that selects items with the largest profit under the sole constraint that the area of the selected items has to be at most equal to the area of the container. Patterns are validated using either exact or heuristic nesting algorithms. If the packing is infeasible, it is removed with a no-good cut. This procedure is iterated until a feasible pattern is found. Such a pattern constitutes a new column for the master problem. The whole procedure is optimal if the pattern validator is exact. In addition to that, we also study several pricing heuristics, that allow to identify high-quality columns fast. We present computational studies concerning our pricing heuristic and a heuristic pattern validator, based on Sparrow, a Strip Packing solver from Gardeyn et al. [1].

Keywords: Packing; Column-Generation; Pricing Heuristics.

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Filippo Ranza is a Postdoctoral researcher at the Chair for Logistics Management, Department of Business & Economics, Johannes Gutenberg University Mainz (Germany). He completed his PhD, at the Department of Information Engineering at the University of Brescia (Italy), in May 2026, with a thesis title "Last Mile Delivery in Routing Problems: New Paradigms, Models, and Algorithms". Now, he is working on bi-dimensional packing problems with a focus on both heuristic and exact methods.