# ECCO XXXVII CONFERENCE 2024

## Book of abstracts

**Gent, Belgium, 6-8 June 2024**

# Contents

# Welcome to ECCO XXXVII

Welcome to the 37th Conference of the European Chapter on Combinatorial Optimization (ECCO XXXVII), proudly hosted by KU Leuven in the historic city of Gent, Belgium. We are delighted to have you join us for this event, and we look forward to the many interesting discussions that will take place in the coming days.

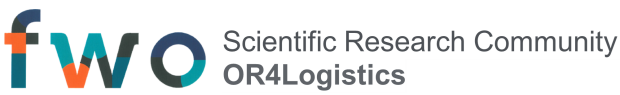
Over the next few days, you will have the opportunity to attend 44 insightful talks, organized into 12 parallel sessions. In addition, we are honored to present 4 plenary lectures delivered by our distinguished invited speakers, who will provide valuable perspectives and insights into the latest developments in our field.

We hope you have an enjoyable and fruitful conference!

Greet Vanden Berghe
Tony Wauters
Conference chairs







# Organization

## Program committee

Jacek Blazewicz, Poznań University of Technology
Bo Chen, University of Warwick
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Paolo Toth, Università di Bologna
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## Organizing committee

Greet Vanden Berghe (chair), KU Leuven
Tony Wauters (co-chair), KU Leuven
Jeroen Gardeyn, KU Leuven
Pieter Smet, KU Leuven
Robin Tourlamain, KU Leuven

# Program overview

## Thursday, June 6

| | | |
|---|---|---|
| 8:30-9:30 | Registration & welcome coffee | L209 |
| 9:30-10:00 | TA-1: Opening session | L226 |
| 10:00-11:00 | TB-1: Plenary session<br>*My T. Thai* | L226 |
| 11:00-11:30 | Coffee break | L209 |
| 11:30-13:00 | Parallel sessions<br>*TC-1: Algorithms*<br>*TC-2: Scheduling* | <br>L226<br>M228 |
| 13:00-14:30 | Lunch break | L209 |
| 14:30-16:00 | Parallel sessions<br>*TD-1: Data structures*<br>*TD-2: Heuristic scheduling* | <br>L226<br>M228 |
| 16:00-16:30 | Coffee break | L209 |
| 16:30-18:00 | Parallel sessions<br>*TE-1: Travelling salesperson*<br>*TE-2: Timetabling* | <br>L226<br>M228 |
| 18:00 | Belgian fries and beers | Campus |

## Friday, June 7

| | | |
|---|---|---|
| 9:00-10:00 | FA-1: OR4Logistics plenary session<br>*Stefan Irnich* | L226 |
| 10:00-10:30 | Coffee break | L209 |
| 10:30-12:00 | Parallel sessions<br>*FB-1: Complexity*<br>*FB-2: Machine learning* | <br>L226<br>M228 |
| 12:00-13:30 | Lunch break<br>Board meeting | L209<br>E037 |
| 13:30-15:00 | Parallel sessions<br>*FC-1: Graphs*<br>*FC-2: Logistics* | <br>L226<br>M228 |
| 15:00-15:30 | Coffee break | L209 |
| 15:30-17:00 | Parallel sessions<br>*FD-1: Fairness* | <br>L226 |
| 17:00-18:00 | FE-1: Plenary session<br>*Thomas Magnanti* | L226 |
| 19:00 | Conference dinner | Brasserie Pakhuis |

## Saturday, June 8

| | | |
|---|---|---|
| 10:00-11:30 | Parallel sessions<br>*SA-1: Location* | L226 |
| 11:30-12:00 | Coffee break | L209 |
| 12:00-13:00 | SB-1: Plenary session<br>*El-Ghazali Talbi* | L226 |
| 13:00-13:30 | SC-1: Closing session | L226 |
| 13:00-14:30 | Lunch break | L209 |
| 14:30 | Departure from campus for guided tour | |

# Plenary speakers

## Prof. My T. Thai

*University of Florida, United States*

**TB-1, Thursday, June 6, 10:00**

### Accelerating Viral Marketing: From Combinatorial Strategies to Learning-Based Solutions

The landscape of viral marketing is evolving rapidly, demanding innovative approaches to maximize influence and cost-effectiveness in billion-scale networks. This keynote explores cutting-edge advancements in viral marketing optimization, transcending traditional combinatorial approaches to learning-based strategies. Our journey begins with a traditional $(1-1/e)$-approximation algorithm with accelerated sampling frameworks, further demonstrating an almost exact solution for this NP-hard problem. Shifting gears to heterogeneous multiplex networks, we introduce combinatorial algorithms that effectively navigate complex overlapping user dynamics, capturing the influences between and within multiple networks. Embracing machine learning, we unveil a transformative framework designed to overcome fundamental obstacles in traditional non-learning-based approaches. Finally, our exploration concludes with MIM-Reasoner, which exploits the reinforcement learning with probabilistic graphical models to address the viral marketing across various platforms.

## Prof. Stefan Irnich

*Johannes Gutenberg University Mainz, Germany*

**FA-1, Friday, June 7, 9:00**

### Shortest Path Problems With Resource Constraints

In most vehicle routing and crew scheduling problems solved by column generation-based methods, the subproblem is a variant of the shortest path problem with resource constraints (SPPRC). The SPPRC has contributed to the success of these methods in at least two ways: First, its resource constraints provide a flexible tool for modeling complex cost structures as well as a wide variety of rules that define the feasibility of a route or a schedule. Second, efficient algorithms are available for at least for some important variants of the SPPRC. The talk presents selected examples of modeling with SPPRC and an overview of state-of-the-art methods for solving SPPRC.

*Supported by FWO Scientific Research Community OR4Logistics (grant number W001321N).*

## Prof. Thomas Magnanti

*Massachusetts Institute of Technology, United States*

**FE-1, Friday, June 7, 17:00**

### Designing Transportation and Telecommunications Networks

Network design is a broad topic that has many applications and poses many challenges for the field of combinatorial optimization. The basic issue is to meet the delivery of goods (e.g., people, freight, messages) from sources to destinations by constructing a network of physical links or routes that incur a fixed cost for installation. The links or routes might be capacitated and the network might have special structure. In this presentation I will discuss some combinatorial and integer programming issues and results, with an emphasis on transportation and telecommunications networks.

## Prof. El-Ghazali Talbi

*Université de Lille, France*

**SB-1, Saturday, June 8, 12:00**

### Metaheuristics for the automated design and configuration of Deep Neural Networks

In recent years, research in metaheuristic optimization approaches in the automatic design and configuration of deep neural networks has become increasingly popular. Although various approaches have been proposed, there is a lack of a comprehensive survey and taxonomy on this hot research topic. In this talk, we propose a unified way to describe the various metaheuristics that focus on common and important search components of optimization algorithms: representation, objective function, constraints, initial solution(s), and variation operators. In addition to large-scale search space, the problem is characterized by its variable mixed design space, it is very expensive, and it has multiple blackbox objective functions. Hence, this unified methodology has been extended to advanced optimization approaches, such as surrogate-based, multi-objective, and parallel optimization.

# Detailed program

## Thursday 11:30-13:00

### TC-1: Algorithms

**Chair:** J. Musial



### TC-2: Scheduling

**Chair:** S. Gawiejnowicz



## Thursday 14:30-16:00

### TD-1: Data structures

**Chair:** J. Gardeyn

### TD-2: Heuristic scheduling

**Chair:** L. Demir



## Thursday 16:30-18:00

### TE-1: Travelling salesperson

**Chair:** P. Richter



### TE-2: Timetabling

**Chair:** P. Smet

## Friday 10:30-12:00

### FB-1: Complexity

**Chair:** P. De Causmaecker



### FB-2: Machine learning

**Chair:** P. Lukasiak



## Friday 13:30-15:00

### FC-1: Graphs

**Chair:** A. Hertz

### FC-2: Logistics

**Chair:** H. Verplancke



## Friday 15:30-17:00

### FD-1: Fairness

**Chair:** L. Garcia Tercero



## Saturday 10:00-11:30

### SA-1: Location

**Chair:** F. Rauh

# Practical information

## Venue

The conference is hosted at KU Leuven-Gent, Gebroeders De Smetstraat 1, Gent. All talks and breaks take place on the second floor of buildings L and M. To reach the conference rooms, follow the route indicated by the red dashed in Figure 1, starting from the Gebroeders De Smetstraat.


Figure 1: Campus plan. Enter the campus from the Gebroeders De Smetstraat. To reach the conference rooms, follow the path indicated by the red dashed line. The social activity on Thursday, June 6 will take place in front of building B.

Figure 2 shows the location of the conference rooms in buildings L and M. The registration desk is located in room L209 on the second floor of building L. Conference talks are held in rooms L226 and M228, both of which are equipped with video projectors that have HDMI ports. We kindly request that presenters transfer their presentation onto a single laptop before their session begins. All presenters should locate and introduce themselves to their session chair prior to the start of the session. To allow sufficient time for questions, all presenters should prepare a 20-minute presentation, regardless of the number of presentations scheduled in their session.

Lunch and coffee breaks are served in room L209.


Figure 2: Floor plan of the second floor of buildings L and M. The conference rooms are highlighted in red. The dashed line shows how to get from one room to another.

## Social activities

On Thursday June 6th, we invite all participants to joins us at 18:00 for authentic Belgian fries paired with locally brewed beer. This event will take place at the center of campus in front of building B (see the map in Figure 1).

The conference dinner will take place on Friday, June 7th at 19:00. We are pleased to welcome all participants to Brasserie Pakhuis, located at Schuurkenstraat 4, 9000 Gent. The restaurant is approximately 1.5km from the conference venue and can be reached on foot within 25mins. The recommended route is show in Figure 3.

On Saturday June 8th, we invite all participants to explore Gent's rich history with a guided tour of the city center. We will depart from the conference venue at 14:30, after lunch. The guided tour will conclude in the city center.

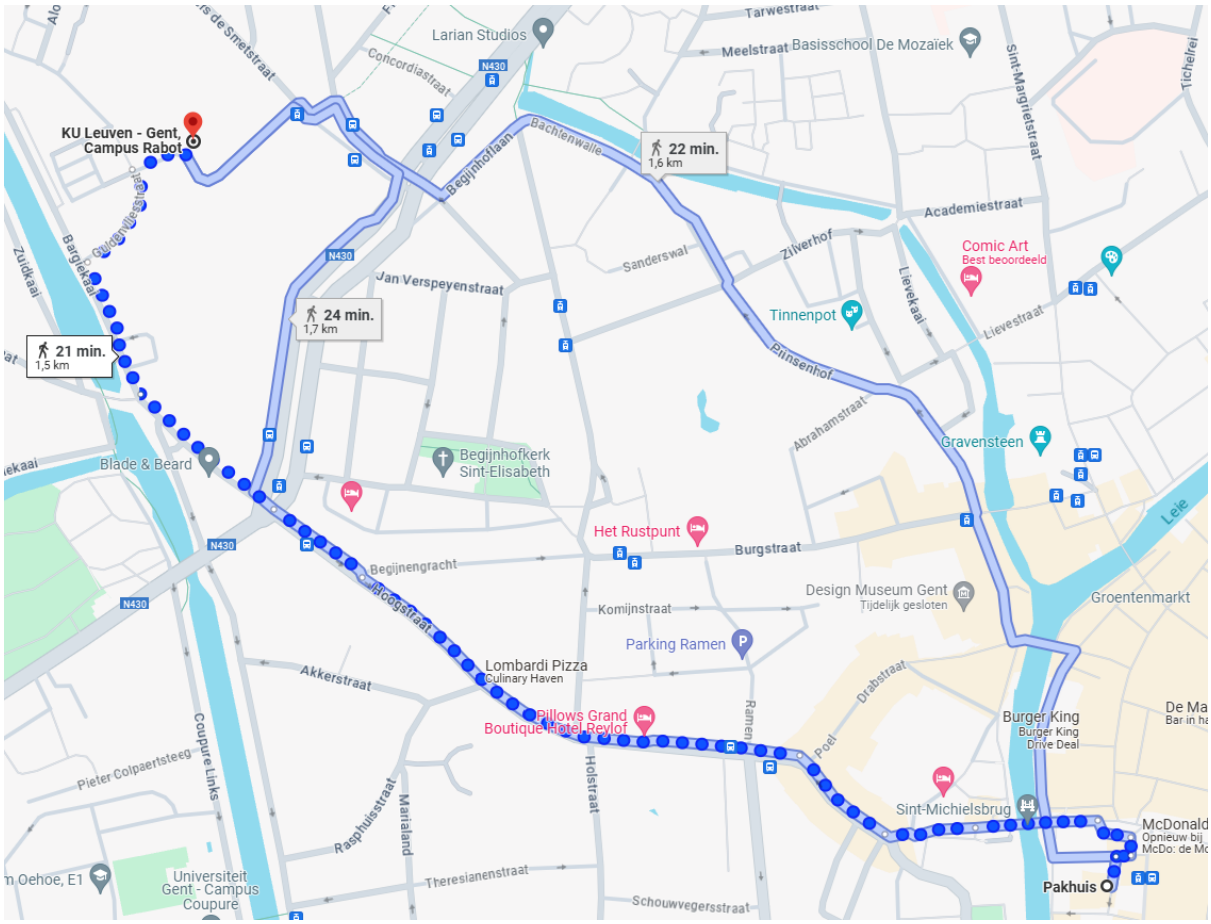


Figure 3: Walking route to the conference dinner location Brasserie Pakhuis.

# Abstracts

# A combinatorial optimization approach to query-guided document set expansion

Arne Deloose
Data Analysis and Mathematical Modelling, Ghent University

Jan Verwaeren
Data Analysis and Mathematical Modelling, Ghent University

Bernard De Baets
Ghent University

Document set expansion is a fundamental problem in Information Retrieval, entailing the augmentation of an initial document set with additional relevant documents retrieved from a larger corpus. While query-based techniques, such as query expansion and refinement, offer effective means to modify initial queries and retrieve supplementary documents, they are inherently limited by their dependence on an initial query and relevance feedback. In contrast, embedding methods provide a promising avenue by representing documents in a feature space, facilitating expansion or contraction based on similarity measures. However, existing approaches often fail to reconcile the advantages of both query reformulation and embedding-based models.

To address these shortcomings, we propose a novel method that integrates query reformulation and embedding-based techniques into a unified framework. Our method aims to augment (allowing for both expansion and contraction) document sets with desirable properties, including high intra-set document embedding similarity, fidelity to the initial document set, and simplicity of description through low-complexity queries. The problem is formalized as a combinatorial optimization problem that can be solved using Mixed Integer Linear Programming. Additionally, to overcome the large computational cost of solving the resulting MILP problem, a computationally efficient heuristic search algorithm is implemented and validated.

# Algorithms supporting analysis of mass spectra of metabolites and lipids

Marcin Borowski
Institute of Computing Science, Poznan University of Technology

In recent years, advancements in mass spectrometry technology have led to a significant increase in the amount of data generated during the analysis of metabolites and lipids. However, analyzing these data can be challenging due to their complexity and diversity. To address this challenge, we have developed an advanced algorithm that can assist in the analysis of mass spectra associated with metabolomics and lipidomics. The algorithm uses data acquired during mass spectrum analysis and reference databases to identify and determine the corresponding fragments of chemical compounds. Additionally, based on the properties of functional groups, the algorithm predicts possible bonds between the found compounds and constructs ready-made combinations. Researchers can customize the search area for potential compounds and functional groups using a configurable file, as the algorithm has a flexible design. When we tested the algorithm on several mass spectra, we obtained promising results. Based on these results, we generated reports detailing the configuration file settings, corresponding mass spectrum compounds, and identification suggestions. These reports were analyzed and presented in the experimental section of the work, where we concluded the effectiveness of the algorithm and its potential applications in practical use. The conclusions of our work confirm that the described algorithm can be a valuable tool in the analysis of mass spectra in metabolomics and lipidomics, contributing to a more efficient and accurate study of small-molecule chemical compounds in organisms. Given its flexibility and adaptability to different research needs, it can prove useful for a wide range of scientists and researchers in the field.

# Exact algorithms for the satellite image selection problem

Tomasz Żok
Institute of Computing Science, Poznan University of Technology

Sylwester Swat
Poznań University of Techonology

Maciej Antczak
Institute of Computing Science, Poznan University of Technology

Jedrzej Musial
Institute of Computing Science, Poznan University of Technology

The demand for satellite imagery has increased significantly in recent years, with customers from various sectors seeking a bird's-eye view of the Earth's surface for applications such as environmental monitoring, urban planning, defense, and intelligence gathering. As technology advances, providing higher resolutions, more frequent updates, and a broader spectrum of data, the potential use cases for satellite imagery have expanded significantly. Governments, businesses, and even individual consumers are realizing the value of satellite imagery and seeking ways to incorporate it into their decision-making processes.

Several factors must be considered when choosing the right satellite images for your needs. One of the most important is the coverage of the area of interest. Ensuring that the satellite imagery covers the location with enough detail is crucial. Another essential consideration is cloud coverage, which can obscure the view of the Earth's surface and make it challenging to obtain usable images. Finally, cost is vital when selecting satellite imagery, as prices vary widely depending on the provider, image resolution, and discount policies.

To model these scenarios, we propose a "Satellite Image Selection Problem" and present it in combinatorial terms. We compare several exact algorithms on a benchmark dataset from real satellite photos of selected world areas.

This work was supported by grant no. POLLUX-XI/15/Serenity/2023.

# Satellite Image Mosaic Selection Problem: Current state and research directions

Jedrzej Musial
Institute of Computing Science, Poznan University of Technology
Jacek Blazewicz
Institute of Computing Science, Poznan University of Technology

Satellite imaging solutions are widely used to study and monitor various regions of the Earth. However, a single satellite image can cover only a limited area. In cases where a larger area of interest is being examined, several images must be combined to create one larger image, called a mosaic. As the number of available satellite images has increased significantly, selecting the optimal combination of images to build a mosaic has become increasingly difficult. The number of photos covering one location can reach hundreds. This is even more difficult if the user is interested in optimizing several parameters. Users must manually select the images they want to include on the cover without a computational approach. Providing a feasible solution (or selection of solutions) from which users can choose a cover is crucial to saving money and time, given that high-resolution satellite imagery is expensive.

The Satellite Image Mosaic Selection (SIMS) problem is a new optimization problem rapidly gaining attention due to its short-term practical application (NP-hard). In doing so, it is important to recognize that a problem can be defined in many ways or with many requirements and constraints. First of all, we can talk about a single-objective problem (mainly taking into account the cost) and a multi-objective problem (here there may be many goals). For all variants, various problem-solving techniques are used, such as sophisticated versions of branch-and-bound solutions, constraint programming, mixed-integer linear programming, Pareto local search algorithms, various solvers, etc.

SIMS problem modeling is expected to evolve rapidly in the near future, with many very practical variations. The most promising seems to be the development of a very accurate cloud cover model that will be able to almost perfectly reproduce the distribution of clouds in the image, as well as other emerging artifacts. You should also remember at least such features (which may be crucial) of the profession such as resolution, angle of incidence, time of taking a photo, temporal consistency of a series of photos, color level, contrast, saturation, and many others.

Research is partially supported by the Luxembourg National Research Fund (FNR) & the National Centre for Research and Development (NCBR) under the SERENITY Project (ref. C22/IS/17395419; POLLUX-XI/15/Serenity/2023).

# Makespan minimization for independent jobs with shared additional operations on parallel identical machines

Joanna Berlińska
Faculty of Mathematics and Computer Science, Adam Mickiewicz University, Poznań

Yakov Zinder
University of Technology Sydney,

Bertrand Lin
Institute of Information Managementy, National Yang Ming Chiao Tung University

We analyze a set of independent jobs that have to be executed on parallel identical machines. Each job has a set of associated additional operations. If a machine executes a given job, it also has to process all the additional operations associated with this job. An additional operation that is associated with several jobs assigned to the same machine needs to be processed by this machine only once. Our goal is to assign the jobs to the machines so as to minimize the time needed for the completion of all jobs and their additional operations. We show that even very restricted particular cases of the considered problem are strongly NP-hard. For the general case, we propose two mixed integer linear programs, as well as a broad class of polynomial-time approximation algorithms with a performance guarantee that is valid for any algorithm in this class. We show that for one of the strongly NP-hard particular cases mentioned above, the considered class contains the best possible approximation algorithm. The performance of the mixed integer linear programs and several approximation and heuristic algorithms is compared by means of computational experiments.

# Tactical assembly line feeding problem

Gohar Porbar
Industrial Systems Engineering, Ghent University

El-Houssaine Aghezzaf
Industrial Management, Ghent University

Veronique Limère
Business Informatics and Operations Management, Ghent University

Emmanouil Thanos
Computer Science, KU Leuven

With the increasing variety of product models and the growing need for flexibility in mixed model assembly lines, the number of required parts at the border of line (BoL) is increased. To efficiently utilize the limited space at the BoL, various feeding policies may be implemented. However, this leads to additional preparation and transportation costs, as parts should be repackaged in preparation areas, frequently referred to as supermarkets. Minimizing those costs require assigning each part to suitable feeding policies. These tactical decisions must be made after the facility layout is determined. However, existing models in the literature currently overlook layout and fleet size constraints and assume a greenfield situation. To address this gap, we propose a mathematical model to assign parts to feeding policies and supermarket locations. The objective is to minimize total costs, including replenishment, preparation, transportation and usage costs, while taking into account the existing layout and fleet size constraints. By incorporating these constraints in our model, we aim to provide practical solutions which closely reflect real-world circumstances.

# Optimal rescheduling with new jobs under bounded disruption

Ulrich Pferschy
Department of Operations and Information Systems, University of Graz
Stefan Lendl
Department of Operations and Information Systems, University of Graz
Elena Rener
University of Bern

Rescheduling problems arise when a given schedule has to be modified due to an interruption or unexpected event. Following the seminal paper of Hall and Potts (2004), we consider the arrival of new orders to be integrated into a given production sequence of so-called old jobs. To avoid a major disruption of the original schedule, the completion time of each old job in the new sequence should not deviate from its original completion time in the old sequence by more than a certain threshold, no matter whether the job is processed earlier or later. We aim at minimizing a standard objective function for the joint set of jobs.

We succeed in answering an open question in the existing literature by proving that the rescheduling problem is strongly NP-hard for the minimization of the number of late jobs. Then we study more broadly the minimization of the total weighted completion time. We show weak NP-hardness (even for a single old job) and characterize several structural properties of an optimal schedule. These can be utilized for the construction of an exact dynamic programming algorithm with pseudo-polynomial running time. A fully polynomial time approximation scheme (FPTAS) is obtained from the dynamic program by three different scaling and reduction steps. We also present a polynomial time algorithm with bounded approximation ratio based on the relation to a scheduling problem with an unavailability period.

# Job scheduling in time-dependent shop systems

Stanislaw Gawiejnowicz
Faculty of Mathematics and Computer Science, Adam Mickiewicz University in Poznan

We consider time-dependent scheduling on two or three shop machines. The processing times of jobs are proportional functions of the job starting times, there are no precedence constraints among jobs, and the criterion of schedule optimality is the maximum completion time. We prove that some two-machine problems of this type can be solved in a polynomial time with the use of appropriately modified rule or an algorithm known earlier for counterparts of these problems with fixed job processing times. We also show, based on results of conducted numerical experiments, that similarly modified other rules for classic shop scheduling problems generate near-optimal schedules for three-machine time-dependent shop problems of this type.

# Ordered interactions in combinatorial problems

Alberto Torrejón Valenzuela
Department of Statistics and Operations Research, University of Seville

Justo Puerto
Estadistica e I.O., Universidad de Sevilla

Víctor Blanco
Institute of Mathematics, Universidad de Granada

The application of ordered optimisation approaches to combinatorial problems has been widely studied in the literature. Examples of problems which involve straightforward sorting procedures are the well-known ordered location problems, ordered weighted average problems or ordered hub location problems, but it also covers other disciplines such as voting problems, portfolio optimisation, outlier detection or machine learning, among others.

The ordered description of these problems usually relies on a vector of weights that multiplies the ordered costs in the objective function. However, the range of problems that can be studied within an ordered framework is limited to the linearity of such models. By means of a quadratic approach to ordered optimisation, considering a matrix of weights instead of a vector, the number of problems to be modelled is considerably multiplied, allowing, among others, to minimise interaction between costs or to model more specific objective functions which require quadratic terms, such as the variance. On the other hand, introducing ordered interactions as a modeling feature increases the complexity of the problems at hand, which motivates the study of efficient resolution methods that allow the scalability of these problems.

The following work motivates this new approach, which allows a higher level of generalisation of several combinatorial problems, particularly location problems, providing a mathematical formalisation of this approach, describing exact models as solution methods, and performing empirical comparison between these different solutions methods.

# A 3-space dynamic programming heuristic journey for the cubic knapsack problem

Franklin Djeumou Fomeni
AOTI, University of Quebec in Montreal

Ibrahim Dan Dije
AOTI, UQAM

Leandro Coelho
Operations and Decision Systems, Université Laval

The 0-1 cubic knapsack problem (CKP) is a combinatorial optimization problem, which can be seen as a generalization of both the 0-1 quadratic knapsack problem (QKP) and the linear knapsack problem (KP). This problem is by definition strongly NP-hard. Its mathematical formulation has a cubic objective function of binary decision variables and one single linear knapsack constraint. Some applications of the CKP include the satisfiability problem Max 3-SAT, facility location problem, network alignment problem as well as screening and treating sexually transmitted diseases. Unlike its quadratic and linear counterparts, the CKP has not received much attention in the literature. Only one research article can, so far, be found in the literature proposing solution methods for the CKP. Their work presents a greedy heuristic algorithm, which provides an initial solution for a commercial solver that uses a linearized formulation of CKP. Results are reported for CKP instances with up to 60 decision variables.

In our work, we propose a deterministic heuristic solution approach for the CKP based on dynamic programming with the particularity of implementing it through a journey in three spaces. Namely, the space of linear, quadratic as well as of cubic variables. Indeed, a well known approach for linearizing 0-1 polynomial optimization problems is to introduce new binary decision variables in order to replace the individual monomials and to use McCormick-like inequalities to avoid the nonlinearity in the constraints set. The newly introduced decision variables are often referred to as the lifted-space variables. The space of lifted variables has widely been explored and studied for the derivation of cutting planes to strengthen the linear relaxation of the original 0-1 polynomial optimization problem. In this presentation, we aim to show that the space of lifted variables can also be explored to derive efficient heuristic methods for such problems using dynamic programming. We particularly study the case of the cubic knapsack problem. Our algorithm runs in $O(n^4c)$ times, with n and c being the number of items and knapsack capacity, respectively. The computational results show that the algorithm can yield solutions within 0.01% of optimality. Moreover, some comparison with an existing heuristic from the literature shows that our algorithm can dominate in terms of the quality of the solution obtained.

# An exact approach for minimizing permission-switching overhead in control-flow graphs

Jeroen Gardeyn
Computer Science, KU Leuven

Adriaan Jacobs
Computer Science, KU Leuven

Memory Protection Key (MPK) is a popular mechanism to improve software security by granting or revoking access to sensitive memory regions at runtime. This access can be controlled and checked with specialized CPU instructions.

The flow of execution between different blocks of code in a program function is described a control-flow graph (CFG). When leveraging MPK, certain blocks of the CFG require either strict granted or revoked access to a sensitive memory region. Other blocks are unconstrained, meaning the access permission can be in any state. The compiler has to insert these (expensive) MPK-instructions in between the normal program code in such a way to satisfy the security requirements while minimizing the overhead incurred by the additional instructions. This is not a trivial task since the number of feasible configurations scales exponentially with the number of unconstrained blocks, and the exact placement significantly impacts the performance overhead.

In this talk, we present an abstract model of the problem, using an analogy which should be easy to follow for people unfamiliar with computer security research. We introduce a branch and bound algorithm in combination with decomposition and symmetry-breaking techniques. Our current implementation is able to reach an optimal solution for every function across a broad range of large open-source C/C++ software projects, typically within a couple milliseconds.

# The stochastic procurement and production lot-sizing problem: Models and a sample average approximation approach

Caio Tomazella
ICMC, University of São Paulo

Raf Jans
Department of Logistics and Operations Management , HEC Montreal

Maristela Santos
Department of Applied Mathematics and Statistics, University of Sao Paulo

Douglas Alem
Business School, University of Edinburgh

In this presentation, we approach the procurement and production lot-sizing problem with uncertain demand. We present three variants of the stochastic model: a static variant, in which all production and procurement decisions are made before demand realization; and two static-dynamic variants, where production is flexible enough to be delayed until demand is fully known. These models are complex and hard to be solved by a commercial solver, thus, in order to find high quality stochastic solutions, we propose an adjustable Sample Average Approximation (SAA) heuristic, which is divided into two phases. In Phase 1, the models are solved with a manageable number of scenarios several times in order to find the most prevalent decisions. In the models, these prevalent decisions are binary variables which have the same value in almost, if not all, solutions found. In Phase 2, these variables are then fixed, simplifying the stochastic model so it can be solved with more scenarios. The number of binary variables fixed in Phase 2 varies between 65% and 90%, depending on the parameters used, which explains the efficiency of the proposed method. Using the solutions obtained with the adjustable SAA, we evaluate the value of production flexibility, showing how much it affects the expected costs of the solution, and how these costs are distributed according to the possible demand realizations.

# Optimization of integrated reverse supply chain and rebalancing of disassembly lines with integer programming and constraint programming

Zeynel Abidin Cil
School of Engineering, The University of Leicester; Izmir Democracy University
Suleyman Mete
University of Gaziantep; Karlsruhe Institute of Technology (KIT)
Stefan Nickel
Institute for Operations Research (IOR), Karlsruhe Institute of Technology (KIT)

The increasing world population and amount of consumption cause increased waste. Recycling valuable materials in waste is also important for environmental awareness and cost. On the other hand, processes such as recycling, reprocessing, disassembly, etc. of end-of-life products are reverse supply chain activities and the re-marketing of used products is realized through these activities. The first stage of recycling, disassembly, can be defined as the process of completely or partially separating products into the parts that constitute them. Optimizing the disassembly line's efficiency directly impacts the process's overall performance. However, variations in the characteristics and the quantity of end-of-life products, along with fluctuations in supply and demand, necessitate task reallocation and adjustments to the cycle time. Therefore, in such instances, it becomes necessary to the rebalancing of the disassembly line. Hence, the study emphasizes the necessity of addressing the reverse supply chain and rebalancing of disassembly lines in an integrated manner, discussing the challenges faced due to the complex nature of this integration. The applicability and effectiveness of integer programming and constraint programming methods in overcoming these challenges are examined. It highlights the significant advantages of constraint programming's flexibility and the precision of integer programming in overcoming the challenges encountered. These findings contribute to the literature on reverse supply chain management and rebalancing of disassembly line, offering new directions for future research.

# Population-based heuristic algorithms for buffer allocation in unreliable production lines

Leyla Demir
Department of Industrial Engineering, Izmir Bakırçay University
Mehmet Ulaş Koyuncuoğlu
Department of Management Information Systems, Pamukkale University

The Buffer Allocation Problem (BAP) is an NP-hard combinatorial optimization problem encountered in designing production lines. The problem is mainly classified as in three categories based on the objective function: total buffer size minimization known as primal problem, production rate maximization known as dual problem, and profit maximization problem. In this study, the BAP is solved for profit maximization in unreliable production lines. The problem is formulated under the total buffer size constraint, and two population-based heuristic algorithms, i.e., Combat Genetic Algorithm (CGA) and Big Bang Big Crunch (BBBC) algorithm, are employed to solve this problem. First, the preliminary tests are carried out to determine the optimal parameters for each algorithm, and then performances of the proposed algorithms are tested on existing benchmark problems, involving small, medium, and large-sized instances. The experimental study shows that the BBBC algorithm produces better results than the CGA for all the problems considered, and it also reaches the best solution known in the literature with less computational effort in comparison to the state-of-the-art algorithms.

# Rescheduling strategies for a dynamic visit scheduling problem of a salesperson

Mualla Gonca Avci
Industrial Engineering, Dokuz Eylul University

Melisa Akkus
Industrial Engineering, Dokuz Eylul University

Aybuke Onar
Industrial Engineering, Dokuz Eylul University

This study focuses on a customer visit scheduling problem of a salesperson working in a public bus manufacturer in Türkiye. The salesperson visits the customers to obtain information about their future sales plans and to make sales contracts. The salesperson must visit each customer at least once in the planning horizon and can make multiple visits to a customer with a high priority. The salesperson develops monthly customer visit schedules by considering the customer priorities and predefined intercity tours. In the realization of the schedule, priority of a customer may change occasionally due to some events such as a rapid purchase decision notified by a private call. In this case, the schedule should be modified to visit such customers as soon as possible. In this study, we have developed a mathematical model for rescheduling and proposed alternative rescheduling strategies for the problem. In the computational study, we have generated a set of problem instances to test the performances of the proposed rescheduling strategies. We have compared the proposed strategies under a set of dynamic scenarios and developed managerial insights for the dynamic customer visit scheduling problem.

# A solvable case of the Path-TSP on Van der Veen distance matrices

Eranda Cela
Department of Discrete Mathematics, TU Graz

Vladimir Deineko
Warwick Business School

Gerhard Woeginger
RWTH Aachen

In the Path-TSP, the travelling salesman is looking for the shortest $(s,t)$-TSP-path, i.e. a path which starts at a given city $s$ and ends at another given city $t$, after visiting every city exactly once. In this work we present a polynomially solvable case of the Path-TSP, where the distance matrix of the cities is a Van der Veen matrix (as defined in [1],[2] below). We investigate the combinatorial structure of the optimal solutions and observe first that it can be characterized by means of certain forbidden patterns. This allows us to restrict the search for optimal solutions on the particular set $P$ of $(s,t)$-TSP-paths which do not contain the forbidden patterns. While the cardinality of $P$ is exponential in the number $n$ of cities, each path in $P$ can be obtained by patching together simply structured paths of four types, each of them being well amenable to dynamic programming. These specific dynamic programming procedures can be combined to efficiently optimize over $P$. To this end we distinguish three particular cases: (i) $(s,t) = (1,n)$, (ii) $s = 1$ and t is arbitrary and (iii) s and t are both arbitrary. In Case (i) we show that the Path-TSP can be equivalently transformed to a directed shortest path problem on an auxiliary graph with $O(n)$ vertices. The analysis of the two further case is incremental and builds upon optimal solutions of suitably chosen smaller instances of Case (i) by exploiting the fact that submatrices of a Van der Veen matrix are again Van der Veen matrices.

A straightforward analysis of the constructive steps leads to a dynamic programming algorithm with cubic time complexity for the general case. It takes a clever implementation and a careful analysis to obtain a quadratic algorithm. Thus a Van der Veen instance of the Path-TSP with $n$ cities can be solved in quadratic time. Obviously this result is best possible (as compared to the size of the input).

[1] V.G. Deineko, B. Klinz, A. Tiskin, and G.J. Woeginger (2014), Four-point conditions for the TSP: the complete classification. Discrete Optimization 14, 147-159.

[2] J.A.A. Van der Veen (1994), A new class of pyramidally solvable symmetric traveling salesman problems. SIAM Journal on Discrete Mathematics 7, 585-592.

# The time-consistent travelling salesman problem

Juan José Salazar González
Estadística e Investigación Operativa, Universidad de La Laguna
Daniel Díaz-Ríos
Universidad de La Laguna

The consistent travelling salesman problem looks for a minimum-cost set of Hamiltonian routes, one for every day of a given time period. When a customer requires service in several days, the service times on different days must differ by no more than a given threshold (for example, one hour). We analyze two variants of the problem, depending on whether the vehicle is allowed to wait or not at a customer location before its service starts. There are three mathematical models in the literature for the problem without waiting times, and this paper describes a new model appropriated to be solved with a branch-and-cut algorithm. The new model is a multi-commodity flow formulation on which Benders' Decomposition helps manage a large number of flow variables. There were no mathematical models in the literature for the variant with waiting times, and this paper adapts the four mathematical models to it. We analyze the computational results of the formulations on instances from the literature with up to 100 customers and three days.

# The Generalized Traveling Salesman Path Problem GTSPP – An impactful construction algorithm

Peter Richter
Development, O&S Consultancy

The GTSPP looks in asymmetric directed graphs, whose nodes are partially segmented into several classes S (services, clusters), for a shortest walk from a given start s to a given target t such that each class is visited at least once. The proposed construction method arises from the problem's decomposition into (a) Search for a Densest Set S of Service Locations (shortly Service Location Cloud Problem SLCP) containing at least one location each service such that the sum of the distances among these locations as well as to s and t is minimal and (b) the Asymmetric Steiner Traveling Salesman Path Problem ASTSPP that looks for a shortest s-t-walk through all these nodes S. A novel SLCP algorithm determines the service location cloud S and a novel ASTSPP algorithm builds and scans an approximate Steiner tree T(S) to get a shortest walk from s to t through S using a new meta-heuristic Advanced Scan of Spanning Trees ASST. During this scan another new meta-heuristic Tree Structure Adaption TSA tries to find proposals to change this tree T(S) afterwards to a mutated one T'(S) whose scan most probably provides a shorter walk. Tests on large high density digraphs reveal that the proposed deterministic algorithm gets near-optimal results with a sample standard deviation $q_{max} = 2.5\%$ in real-time.

# A scheduling problem with restricted work/days-off periods

Fabien Nießen
Computer Science, KU Leuven

Paul Paschmanns
University Bonn

The field of nurse rostering is a broad topic and involves many problems differing in complexity and structure. An easy formulation is used in the Days-On-Days-Off Scheduling Problem, which includes few constraints on the length of consecutive working and off-day periods. This problem was introduced in 2013 and claimed to be NP-hard. We proved that the decision version of this problem is indeed strongly NP-complete and succeeded in developing some algorithms for polynomial time subproblems. In this talk, we want to present the latest results and discuss the remaining open cases.

# Efficient constraint evaluation for the nurse rostering problem

Robin Tourlamain
Computer Science, KU Leuven

Pieter Smet
Computer Science, KU Leuven

Greet Vanden Berghe
Computer Science, KU Leuven

Local search algorithms are often used to generate solutions for numerous combinatorial optimisation problems. The effectiveness of such algorithms relies on their solution acceptance criterion, neighbourhood definitions, iteration speed, and other parameters. Our research focuses on the importance of efficient solution evaluation in local search algorithms, specifically in the context of the nurse rostering problem. Publications often overlook reporting this facet of their algorithms, even though it is integral to the reproducibility of the results. Indeed, as we will demonstrate, how one chooses to evaluate solutions is a highly consequential design decision and has a significant impact on the effectiveness of an algorithm. This is because the majority of computation time is spent evaluating new solutions, as calculating penalties for violated constraints is a complex task. Accelerating this process allows local search algorithms to perform more iterations, thereby improving solution quality.

In this talk we will introduce an efficient delta-evaluation method which reduces the number of necessary computations to a minimum. Re-using roster information from previous iterations enables us to safely ignore unaffected sections of the roster, and focus only on the modified part. Consequently, the worst-case performance of our method is equal to that of what is traditionally implemented, which evaluates the entire roster every time. Preliminary results indicate that this worst-case behaviour is a rare occurrence, as our method outperforms the traditional approach in terms of evaluation speed on every instance from the KaHo dataset [1].

[1] B. Bilgin, P. De Causmaecker, B. Rossie, G. Vanden Berghe (2012), Local search neighbourhoods for dealing with a novel nurse rostering model. Annals of Operations Research 194, 33–57.

# The Integrated Healthcare Timetabling Competition 2024

Pieter Smet
Computer Science, KU Leuven

Sara Ceschia
Polytechnic Department of Engineering and Architecture, University of Udine

Roberto Maria Rosati
Polytechnic Department of Engineering and Architecture, University of Udine

Andrea Schaerf
Polytechnic Department of Engineering and Architecture, University of Udine

Greet Vanden Berghe
Computer Science, KU Leuven

Eugenia Zanazzo
Polytechnic Department of Engineering and Architecture, University of Udine

Hospitals are notoriously complex systems that encompass a variety of decision and optimization problems. On their own, these problems are often already challenging from a combinatorial point of view. This complexity is compounded by the fact that, in practice, these problems cannot be addressed separately. Instead, realistic optimization problems in hospitals require different interdependent, constrained decisions to be taken at the same time, while optimizing complex objective functions. In this talk, we introduce the Integrated Healthcare Timetabling Competition 2024 which will begin in September 2024. Our goal is to stimulate research on the specifics of integrated scheduling problems in healthcare through a competition format that has proven successful in the past for other problem domains. The competition problem integrates three critical problems encountered in hospitals: surgical case planning, patient admission scheduling and nurse-to-room assignment. We describe each of these problems in detail, along with their interdependencies. Additionally, we discuss some practical aspects of the competition such as its rules and the provided support for participants.

# On SAT information content, its polynomial-time solvability and fixed code algorithms

Maciej Drozdowski
Institute of Computing Science, Poznan University of Technology

The amount of information in satisfiability problem (SAT) is considered. Search problems, such as SAT, information content can be measured as the information in string relations. SAT can be polynomial-time solvable when the solving algorithm holds an exponential amount of information. It is established that SAT Kolmogorov complexity is constant. It is also argued that the amount of information in SAT grows at least exponentially with the size of the input instance. The amount of information in SAT is compared with the amount of information in the fixed code algorithms and generated over runtime. For more information see `https://doi.org/10.48550/arXiv.2401.00947`.

# Complexity of the uniqueness problem of a minimum vertex cover in a graph

Olivier Hudry
Télécom Paris

Given an undirected graph $G = (V, E)$, a vertex cover (VC) of $G$ is a subset $C$ of $V$ such that any edge of $G$ has at least one extremity in $C$. The optimization problem consisting in determining a minimum VC in $G$ is well-known to be NP-hard; more precisely, its decision problem is NP-complete. We consider the complexity of the following two decision problems: Name: Uniqueness of VC with bounded size (U-VCBS). Instance: a graph $G$; an integer $K$. Question: Is there a unique VC in $G$ of size less than or equal to $K$? and Name: Uniqueness of the minimum VC (U-MVC). Instance: a graph $G$. Question: Is there a unique minimum VC in $G$?

To study the complexity of U-VCBS and U-MVC, we consider two other uniqueness problems: Name: Uniqueness for satisfiability problem (U-SAT) Instance: a set $B$ of Boolean variables, a set of logical clauses defined on $B$ (i.e. containing variables of B or complementary variables of $B$) Question: is there a unique assignment function $f$ defined on $B$ such that each clause contains at least one element set to true by $f$? and the variant of U-SAT, noted U-1-in-3-SAT, in which each clause contains exactly three elements. The problems U-VCBS, U-MVC, U-SAT and U-1-in-3-SAT are not known to be in NP or in co-NP but U-SAT and U-1-in-3-SAT have the same complexity, in the sense that one transforms into the other according to polynomial transformations. These two problems are NP-hard and belong to the complexity class noted DP (or also BH2 in the Boolean hierarchy) which contains the decision problems that can be stated, in terms of languages, as the intersection of a language belonging to NP (corresponding here to the question "is there at least one assignment function..") and a language belonging to co-NP (corresponding here to the question "is there at most one assignment function..."). If $<$ denotes the polynomial transformation, we establish the following relationships:

- U-1-in-3-SAT $<$ U-VCBS
- U-VCBS $<$ U-SAT
- U-1-in-3-SAT $<$ U-MVC

We deduce from this that U-VCBS, U-SAT and U-1-in-3-SAT have the same complexity. As a consequence, U-VCBS is NP-hard and belongs to DP. For U-MVC, this involves that U-MVC is at least as difficult as U-SAT (in particular, U-MVC is NP-hard). Moreover, we show that U-MVC belongs to the class of decision problems that can be solved using an algorithm solving a NP-complete problem called a logarithmic number of times, thus providing an upper bound of the complexity of U-MVC

# The constrained bottleneck spanning tree problem with upgrades

Bryan Coulier
Computer Science, KU Leuven

Hatice Çalık
Computer Science, KU Leuven

Greet Vanden Berghe
Computer Science, KU Leuven

Upgrading the connections of an existing network is common in the context of telecommunication and electric grid networks. Constructing a new network from scratch is typically not a viable option due to resource constraints, especially for low-voltage grids. Moreover, if the underlying network structure necessitates a tree configuration, this results in a novel variant of the Constrained Bottleneck Spanning Tree Problem (CBST), which is referred to as the Constrained Bottleneck Spanning Tree Problem with Upgrades (CBSTU). This novel variant considers potential edge upgrades with a corresponding cost for each upgrade. There are only two existing polynomial-time algorithms that can tackle this problem after transforming the network into a CBST instance in linear time. Furthermore, a computational study highlights the strengths and weaknesses of these algorithms. By combining the strengths of these existing algorithms, a novel polynomial-time Edge Elimination (EE) algorithm is proposed. The EE algorithm builds on the strengths of both existing algorithms by combining progressive network reduction and binary search. Specifically, the EE algorithm identifies a subset of edges to remove during each iteration, thereby simplifying the network and reducing the overall complexity of the problem. Furthermore, the algorithm utilizes binary search in order to efficiently reach an optimal solution. Our new algorithm outperforms both previous algorithms in terms of computation speed and lays the foundation for future research into the CBSTU.

# Dedekind Numbers, counting monotone Boolean functions on a finite set: formula's and complexity issues.

Patrick De Causmaecker
Computer Science, KU Leuven

In March 2023, we were one of groups to independently compute the ninth Dedekind Number, i.e. the number of monotone Boolean functions on the subsets of a set of nine elements.

Throughout the 20th century, actually since the statement of the problem in 1897 by Richard Dedekind, computing these numbers has served as a test case for both the growth of mathematical understanding of combinatorial problems and the growth of computational power. In this talk we present the methods used in 2023 in relation with earlier achievements, and how these were implemented on today's supercomputers. We enter into the complexity properties of the used formula's and we explain how the current status of computing hardware and software impacts the possibilities and power of the proposed approaches. Consequently we generalise on some of the methods and discuss recent developments. We speculate how this, together with upcoming technology, will take us to the computation of the tenth number.

# A machine learning-based solution approach for solving the sustainable biomass supply chain network design problem

Pinar Yunusoglu
Industrial Engineering, İzmir Bakırçay University

Fehmi Burcin Ozsoydan
Industrial Engineering, Dokuz Eylul University

Bilge Bilgen
Industrial Engineering, Dokuz Eylul University

Sustainable supply chain management considers integrations of economic objectives and environmentally and socially responsible practices in each supply chain stage to minimize negative impacts on the environment and people. This study addresses a real-world sustainable biomass supply chain network design (BSCND) problem that handles strategic decisions (i.e., facility location) and tactical decisions (i.e., biomass sourcing and allocation, production planning, inventory management and the specific constraints related to BSCND problem) simultaneously. A machine learning-based solution approach based on a clustering methodology is developed to solve the BSCND problem. Initially, the k-means clustering algorithm is used to reduce the complexity of the problem. Later, an optimization model is solved to provide efficient operation and design of the supply chain. The proposed machine learning-based solution approach has achieved the optimal solution of the real-world BSCND problem in a reasonable computation time. Furthermore, the results of the computational experiments conducted on generated test instances indicate that the proposed machine learning-based solution approach is both effective and efficient in handling the computational complexity of the problem.

# Learning to branch with interpretable machine learning models

Nikolaos Sahinidis
Georgia Institute of Technology

Selin Bayramoglu
Industrial and Systems Engineering, Georgia Institute of Technology

George Nemhauser
Georgia Institute of Technology

Machine learning is being increasingly used in improving decisions made within branch-and-bound algorithms for solving mixed-integer programs (MIPs). A common trend of existing works in this area is the utilization of deep learning techniques. The construction of learning models based on these methods requires massive computations to construct the very large datasets that are required for training. Additionally, the deployment of these learning models becomes practical only in conjunction with manycore parallelization (GPUs) for the calculation of the learned functions themselves. In this work, we depart from common practice and build simple and interpretable machine learning models. We demonstrate this approach in the context of approximating strong branching scores, a costly expert branching rule. Our method selects important features for a given problem domain and produces statistically significant models for the MIPs studied. We compare our models with built-in branching rules of SCIP, a state-of-the-art solver, and existing ML-based branching rules. Just like existing ML-based branching rules, our approach solves significantly fewer linear programs on average than SCIP's default branching rule and results in faster solution of the MIPs tested. Compared to the state-of-the-art ML-based branching rule that utilizes a graph neural network (GNN) model, our model does not require a GPU for its deployment and involves fewer than 2% of the number of parameters of the GNN model. Due to its simplicity, our model is much easier to build and utilize in practice. We present extensive computational results on many problem classes to illustrate these findings

# Topology classification using a Multiple Kernel Learning approach with graphs and non-graphable data

Maciej Majchrzak
Poznan University of Technology
Piotr Lukasiak
Institute of Computing Science, Poznan University of Technology

In this study, the possibility of classifying topologies described by both graphable and non-graphable data using kernels was investigated. The focus was on 3D shape classification - especially CAD geometry models - using graph kernels coupled with Support Vector Classification.

Apart from the graphs describing the topology, each shape was also characterized by a number of parameters that cannot be depicted using graphs. A simple method was developed to incorporate these parameters into the classification process without any modification to the tools used in the aforementioned graph classification. In addition, the possibility of using Multiple Kernel Learning for this purpose was tested. The results show that supporting graph classification with additional data, even carried out in the simplest way, can noticeably improve classification quality. It also proved crucial to understand the meaning of data to avoid the overestimation of classification accuracy

# Approaches to the use of machine learning for medical problems

Piotr Lukasiak
Institute of Computing Science, Poznan University of Technology
Maciej Majchrzak
Poznan University of Technology

The ECBIG-MOSAIC project has established a unique form of collaboration that enables the application of artificial intelligence in conducting innovative research that integrates multidimensional biomedical and clinical data. The project lays the groundwork for the practical application of the latest scientific advancements in medicine, particularly in therapy, diagnosis, and disease prevention. As part of the project, the data collection and analysis process included civilization diseases selected based on national and international epidemiological, social, and economic conditions. These diseases include COVID-19, oncological diseases (such as thyroid cancer, lung cancer, and breast cancer), and cardiological diseases (such as premature coronary heart disease, resistant arterial hypertension, and atrial fibrillation). These activities could potentially help to identify the key processes involved in tumour development, which could lead to more personalized medical care for oncology and cardiovascular patients. The use of artificial intelligence in the diagnostic and therapeutic process could also be explored further.

AI is a technique used in medicine to analyze medical data using algorithms and statistical models. Its applications include predicting disease outcomes, diagnosing conditions, personalizing treatments, and enhancing patient care. By leveraging large datasets, machine learning can assist healthcare professionals in making informed decisions and improving overall health outcomes. In our research, we focused on head injuries and liver fibrosis.

Machine learning algorithms are increasingly being used in the context of head injuries to improve patient outcomes and guide clinical decisions. These algorithms analyze various factors to predict prognosis, risk stratification, and early detection of complications. Their application holds promise for personalized medicine and innovative protocols. With the help of acquired medical imaging data, a range of machine learning methods were applied to create classifiers that can assist radiologists in categorizing and determining the relevance of injuries. The results obtained have the potential to speed up the treatment of patients who require immediate medical attention. Machine learning algorithms are also widely used in assessing and managing liver fibrosis and steatosis. They aid in diagnosis, staging, predicting disease progression, assessing treatment response, and risk stratification. These algorithms enhance patient care and contribute to personalized medicine. Data obtained from more than 100 patients were characterized by a set of broad-spectrum laboratory tests. Based on the learning set, an attempt was made to identify individuals who should be referred for detailed

medical tests related to liver fibrosis and steatosis. The computational studies carried out and rules generated on the basis of various machine learning models make it possible to automate the diagnostic process.

# Bounds on the number of non-equivalent colorings of a graph

Valentin Dusollier
Algorithms Lab, Computer Science, UMONS

Alain Hertz
Polytechnique Montreal and GERAD

Hadrien Mélot
Algorithms Lab, Computer Science, UMONS

We will focus on bounds on the number of non-equivalent colorings of a graph, also known as the graphical Bell number. This number counts the possible partitions of a set with some constraints given by the graph structure. We give both lower and upper bounds for graphs with fixed order and size, as well as those with fixed order and diameter.

# Interaction graphs as a way to discover multiplexes in nucleic acid structures.

Michal Zurkowski
Institute of Computing Science, Poznan University of Technology
Marta Szachniuk
Institute of Computing Science, Poznan University of Technology
Tomasz Żok
Institute of Computing Science, Poznan University of Technology

The scientific community is showing interest in nucleic acid structures containing quadruplexes and connected motifs. One of them is multiplexes which are also found together with quadruplexes. The presented algorithm will allow for the identification of those motifs and will fill another part of the knowledge that is not yet properly analyzed or gathered in databases. It will be the first method in the world dedicated to the search and identification of n-tads in nucleic acid structures. It detects quadruplex interactions with neighboring external nucleotides, which allows for the automatic identification of n-tads of any rank (tetrad, pentad, hexad) with possible future applications for a search of n-taplexes. Initial preprocessing is done with the ElTetrado tool which identifies and provides structural information about quadruplexes in the structure. Each quadruplex is analyzed individually and its nucleotides are used as starting points in the identification of the n-tads. We use their potential structural non-canonical connections as well as their geometrical 3D properties. The potential nucleotide's slope, distance, and height differences cannot deviate too much compared to the current tetrad which the candidate would be incorporated into. All geometrical cutoff parameters were obtained from the extensive analysis of the actual structures containing those motifs.

# New methodology for Hypergraph Clustering

Francisco Temprano Garcia
Stats and OR, Universidad de Sevilla

Stefano Benati
School of International Studies, University of Trento

Justo Puerto
Estadistica e I.O., Universidad de Sevilla

This talk deals with the problem of partining set of nodes into highly connected subsets over hypergraphs. Due to the lack of universal consensus and developed theory in literature, we must come up with a formal definition aim of the problem, in order to propose new optimization models to solve it. A hypergraph is known to be a generalization of a graph that allows us to represent a huge amount of real-life interactions between elements of a data sample that the classic and original networks can not. Once we formally define the problem, we develop a large list of functions able to measure the goodness of the node set subdivision. Next, we compare all these methods by using of mathematical programming and extensive computational experiments. Thus, we can conclude which methods describe better the properties of partition structures and which ones perform better, since multiple compact formulations and column generation algorithms are developed to solve the partitioning hypergraph problem. Finally, we have applied all methods to Eurobarometer data, showing the applicability of the introduced methodology.

# Extremal chemical graphs for the arithmetic-geometric Index

Alain Hertz
Polytechnique Montreal and GERAD

Sébastien Bonte
Algorithms Lab, Computer Science, UMONS

Gauvain Devillez
Algorithms Lab, Computer Science, UMONS

Valentin Dusollier
Algorithms Lab, Computer Science, UMONS

Hadrien Mélot
Algorithms Lab, Computer Science, UMONS

David Schindl
Economie d'entreprise, HEG Genève, HES-SO University of Applied Sciences and Arts Western Switzerland

A graph invariant is a property (typically numerical) which is preserved by isomorphism. Graph invariants play an increasingly important role in chemistry. Molecular structures are represented by graphs whose invariants constitute a kind of numerical descriptor of these structures and can therefore help to predict the behavior of chemical compounds. The arithmetic-geometric index is a newly proposed degree-based graph invariant in mathematical chemistry. We give a sharp upper bound on the value of this invariant for connected chemical graphs of given order and size and characterize the connected chemical graphs that reach the bound. We also prove that the removal of the constraint that extremal chemical graphs must be connected does not allow to increase the upper bound.

# An rVNS metaheuristic to optimize airport ground-handling: a focus on catering operations assignment.

Alexandre Dupaquis
APO, IRIT TOULOUSE

Ronan Guivarch
IRIT, INP Toulouse

Sandrine Mouysset
IRIT, INP Toulouse

Daniel Ruiz
IRIT, INP Toulouse

Vincent Charvillat
IRIT, INP Toulouse

Frédéric Bouilhaguet
IRIT, INP Toulouse

As processing power grows and discoveries are made, previously difficult problems surrounding airport management become solvable. Specifically, automatizing ground-handling operations to reach yet unmatched efficiency through optimization. We are interested in the catering problem, a blend of vehicle routing problems and scheduling problems, which can be categorized as a simultaneous supply & delivery problem. The MTCVRSPTW-MB (Multi-Trip Capacitated Vehicle Routing and Scheduling Problem with Time Windows and Meal Breaks) is extended to a heterogeneous fleet of trucks and drivers, with qualifications and different load patterns. We introduce a greedy heuristic to solve a relaxed version of the problem, as a baseline. Then, we implement a cooperative rVNS-based metaheuristic. We compare our algorithms on multiple real-life instances at San Francisco International Airport. Our computational study shows the effectiveness of each approach and brings out the strength of our metaheuristic. Our algorithms will help ground handlers specialized in catering operations, to speed up the decision-making process of assigning hundreds of tasks every day. In particular, we show the multiple extra benefits of the metaheuristic approach, including minimizing fuel consumption and allowing dynamic task re-assignment.

# A complete algorithm for the truck driver scheduling problem?

Niels De Walsche
Computer Science, KU Leuven

Greet Vanden Berghe
Computer Science, KU Leuven

Pieter Smet
Computer Science, KU Leuven

In recent years, there has been an increased focus on employee wellbeing. This is especially relevant for truck drivers, who are often on the road for long periods of time. In an effort to ensure safe and sustainable working conditions for such drivers, the EU introduced a set of hours-of-service regulations, adherence to which results in a problem known as the truck driver scheduling problem [1]. It is crucial for companies to ensure that their drivers are compliant with these regulations, as non-compliance can lead to fines and other penalties. When this scheduling problem is combined with the vehicle routing problem, it becomes the Vehicle Routing and Truck Driver Scheduling Problem (VRTDSP). Here the goal is to find routes for the trucks and feasible schedules for the drivers that minimize the number of drivers used and the total distance traveled. Our proposed truck driver scheduling algorithm is based on the multilabel method introduced by Goel [1]. We have made several improvements compared to the original method, such as a better labeling strategy that finds more feasible schedules and a more effective pruning strategy that reduces the number of schedules that must be checked for feasibility. The algorithm has been tested on the VRTDSP instances introduced by Goel [1] and is able to deliver results that are better than the current state-of-the-art heuristic algorithm for the problem. However, although our algorithm is able to deliver improved results, it is not yet clear if it is complete. Due to the intersection of personnel scheduling and vehicle routing, the problem not only becomes very computationally challenging but also unintuitive for human planners. While we have not yet found any counterexamples, this makes it very difficult to determine whether the algorithm is overlooking/failing to find any potential feasible solutions. With this talk we want to invite experienced and theoretical perspectives to help determine if the algorithm is complete or to find holes in the method.

[1] A. Goel (2009), Vehicle scheduling and routing with drivers' working hours. Transportation Science 43(1), 17-26.

# A mathematical programming-based heuristic for the perishable inventory routing problem with product substitution

Mustafa Avci
Industrial Engineering, Izmir Bakircay University
Mualla Gonca Avci
Industrial Engineering, Dokuz Eylul University

The inventory routing problem (IRP) integrates inventory management and vehicle routing decisions. The IRP typically arises in vendor managed inventory systems, where a supplier monitors the inventory levels of a set of retailers and makes the replenishment decisions for each of them. In this study, we address an IRP with multiple perishable products and product substitution option. Each product is assumed to have a fixed shelf-life, and demand of some products can be fulfilled by using a set of substitutable products. We develop a mixed integer linear programming formulation for the problem and propose a matheuristic solution approach to obtain high-quality solutions in reasonable computation times. The matheuristic is applied to a set of randomly generated problem instances. The performance of the developed algorithm is evaluated according to the computational results.

# The strategic assembly line feeding problem

Hannah Verplancke
Ghent University

Veronique Limère
Business Informatics and Operations Management, Ghent University

El-Houssaine Aghezzaf
Industrial Management, Ghent University

Emmanouil Thanos
Computer Science, KU Leuven

The Assembly Line Feeding Problem (ALFP) aims at efficiently transferring all required parts from the warehouse to the assembly line. Recently, the rapid raise of the numbers of required parts, resulting from the increasing demand for customised products, imposes great difficulties upon solving the ALFP.

Previous research mainly focused on the tactical decisions of the ALFP, such as the assignment of parts to vehicles and part feeding policies. However, tactical decisions must be taken with the strategic framework already in place. Strategic decisions are taken when a new production site is constructed and may not be frequently modified. Therefore, they critically affect the performance of the production facility in the long term.

In this work, we focus on the strategic ALFP decisions both dealing with the facility lay-out and the selection of adequate transport vehicles. Although they have been studied independently, academic studies rarely consider integrated approaches to combine them in one optimization model.

We propose a mixed-integer optimization model which assigns parts to feeding policies, locates preparation areas and assigns vehicles to each specific flow. The line feeding policies require preparation areas as well as space at the border of line and compete for the limited available space. Vehicle types and preparation areas induce investment and operating costs which must also be optimized. Some instances will be generated, and the results will be discussed.

# When does solving just-in-time scheduling problem with non-restrictive due date guarantee solution to the CON problem with same performances?

Ameur Soukhal
LIFAT, University of Tours

Nguyen Huyng-Tuong
Industrial University of Ho Chi Minh City

This study addresses the scheduling of n independent jobs on a single machine to minimize total weighted earliness and tardiness penalties. This entails completing the jobs as closely as possible to their due date. Known as Just-In-Time (JIT) scheduling problems, they have relevance to numerous industrial applications. One classical JIT problem is the model introduced by Kanet in 1981, wherein all jobs share a common due date. Such a model corresponds, for example, to an assembly system where the components of a product should be ready simultaneously, or when it involves an order from a customer that must be delivered by a predetermined date.

The earliness (and tardiness) of each job corresponds to the time elapsed from its early (or late) completion until its due date. Primarily, two families of JIT scheduling problems on a single machine are examined: - JIT with an unrestricted common due date, denoted unres: when the common due date is greater than the sum of processing times. - JIT with a controllable common due date, denoted CON "Constant Flow Allowance": the common due date is a decision variable with an associated cost.

Initially focusing on unres scheduling problems, some cases are proven to be polynomial: the symmetric case (where the earliness penalty of a job is identical to its tardiness penalty) and the case where processing times are identical. For the general case and under certain conditions on the earliness penalties, it is demonstrated that the unres JIT scheduling problem admits a PTAS (Polynomial Time Approximation Scheme).

Motivated by the investigation of the the existence of a strong link between these two families of JIT problems (unres vs CON), we have demonstrated through polynomial reductions how optimal solutions or approximation schemes (FPTAS and PTAS) for CON can be derived from solving the unres problems.

# Randomized strategyproof mechanisms with best of both worlds fairness and efficiency

Bo Chen
Warwick Business School, University of Warwick

Ankang Sun
University of Warwick

We study the problem of mechanism design for allocating a set of indivisible items among agents with private preferences on items. We are interested in such a mechanism that is strategyproof (where agents' best strategy is to report their true preferences) and is expected to ensure fairness and efficiency to a certain degree. We first present an impossibility result that a deterministic mechanism does not exist that is strategyproof, fair and efficient for allocating indivisible chores. We then utilize randomness to overcome the strong impossibility. For allocating indivisible chores, we propose a randomized mechanism that is strategyproof in expectation as well as ex-ante and ex-post (best of both worlds) fair and efficient. For allocating mixed items, where an item can be a good (i.e., with a positive utility) for one agent but a chore (i.e., a with negative utility) for another, we propose a randomized mechanism that is strategyproof in expectation with best of both worlds fairness and efficiency when there are two agents.

# Minimal and fair presence times for single-day sports tournaments with multiple fields

Lisa Garcia Tercero
Business Informatics and Operations Management, Ghent University

Dries Goossens
Business Informatics and Operations Management, Ghent University

David Van Bulck
Business Informatics and Operations Management, Ghent University

In this work, we study an amateur single round-robin tournament where all games take place at one location and a limited number of fields is available. Moreover, each team needs a resting time of at least one time slot between every two games they play. This setting regularly occurs in practice, and fairness regarding the resting times is a frequently studied topic since differences in resting times may affect the outcome of the games. Sometimes having more resting time is perceived as desirable, yet in amateur tournament environments teams prefer to play their games in quick succession so they can return home without delay. Therefore, we generate schedules minimizing presence times, defined for each team as the total number of time slots they are present, assuming they arrive right before their first game and leave immediately after their last game. We focus on creating schedules that are both efficient (by minimizing the total presence time) and fair (by minimizing the maximum presence time). The proposed heuristic is based on the circle method for asynchronous tournaments and adapted for tournaments with multiple fields. When enough fields are available and the number of teams is odd, the heuristic finds a schedule with an absolute performance guarantee equal to 1, meaning both the total and the maximum presences time of this schedule are 1 higher than the optimal presence times.

# Improved p-center problem solutions

Alfredo Marín
Departamento de Estadística e Investigación Operativa, University of Murcia

The design of a new method based on a property of the solutions of the p-center problem allows us to obtain better solutions for a well-known family of benchmark instances. An algorithm based on the iterated application of this property in several different ways and (i) quickly finds better solutions, (ii) in a time period that is small, compared to the methods in the literature that gave rise to the best previously known results, gives much better solutions and (iii) in some cases obtains optimal solutions below this time limit.

# Charging ahead: Optimal location of wireless power transfer systems to electrify urban roads

Thomas Byrne
Department of Management Science, University of Strathclyde
Yudai Honma
Institute of Industrial Science, The University of Tokyo

Many experts agree that the electrification of the transportation sector will be vital in our efforts to stem climate change. Indeed, if all cars on the road became electric, we could cut almost one-fifth of global emissions. To this end, the UK government, among others, has announced a ban on the sale of new petrol and diesel cars after 2035. However, currently, fewer than 1% of cars on UK roads are powered entirely by electricity, with similar statistics in most other countries.

The two widely accepted chief barriers to switching to an electric vehicle (EV) for private, commercial, and public transport are cost and "range anxiety". Fortunately, a recently-developed technology solves both: a wireless power transfer system (WPTS) on which vehicles can charge while in motion. By directly and efficiently receiving power while moving along an "electric road", battery size as well as dedicated charging time and space can be saved. This revolutionary technology is being widely heralded as the future of transport. However, it is of little value if not effectively implemented. The question of what to electrify remains (the WPTS is prohibitively expensive) and it is this challenge to which this talk rises.

Just this year, a new mixed-integer programming model was proposed to determine the optimal location of WPTSs in order to maximise total feasible demand flow on a transport network. This flow-capturing model for WPTS locations focused on long-distance trips on expressways, considering the installation of WPTS as continuous variables (and observed that WPTS has a strong potential as an electric vehicle power supply system in terms of coverage and economic rationality).

An alternative focus which has high demand for such a charging infrastructure is in urban environments. Given the slower speeds travelled upon city streets (often with stationary traffic) and reduced area compared to expressways, this represents an application with lower investment cost and likely higher utilisation.

It is from here that we take our inspiration; we will design and implement optimisation models to identify optimal segments of an existing urban transport network to electrify, taking into account the population continuously distributed around and the behaviours and characteristics of users of the transport infrastructure. The goal, as before, is to maximise the number of EV users of the road network. In order to design such a robust network model, we exploit the grid-like structures found naturally in most urban environments and utilise geometric

results to quantify the benefit of electrifying select edges, all while incorporating route uncertainty.

43% of people do not think the UK will ever be ready for the electric revolution. This work will help to transform, for the UK and other countries like it, the necessary choice into a feasible and affordable one.

# New results about the stochastic single-allocation hub location problem

Inmaculada Espejo
Estadística e I.O, Universidad de Cádiz

Alfredo Marín
Departamento de Estadística e Investigación Operativa, University of Murcia

Juan Manuel Muñoz-Ocaña
Estadística e I.O, Universidad de Cádiz

Raúl Páez
Estadística e I.O, Universidad de Cádiz

Antonio Manuel Rodriguez-Chia
Estadística e I.O, Universidad de Cádiz

This work presents a single-allocation hub location problem with uncertainty that affects the amount of product sent between origins and destinations, the transportation costs and the capacities of the hubs. This uncertainty is modelled by a set of different scenarios occurring with a given probability only after the hubs are selected. In order to minimize the expected overall costs of the system, two decisions have to be made: (i) the location of the hubs (this location does not change in the scenarios), and (ii) the allocation of each origin/destination to one of these hubs. A mixed integer programming formulation and some valid inequalities are provided for the introduced problem.

# Maximum covering network design for improving health care access

Felix Rauh
Operations Research and Statistics Research Group (ORSTAT), KU Leuven

Jannik Matuschke
KU Leuven

Hande Yaman
Operations Research and Statistics Research Group (ORSTAT), KU Leuven

We tackle a problem that arises when improving health care access in areas that are prone to disruptions that are caused, for example, by recurring floods. A given budget can be used both for building new hospitals as well as improving the network design by making weak links in the network resilient to floods. The objective is to maximize the number of households that can reach a hospital via a flood-resilient access of a maximum distance of, e.g., five kilometers.

First, we show that the problem on trees allows for an optimal solution approach via dynamic programming that is pseudo-polynomial in the given budget. Another class of graphs that are of interest are graphs that have cut vertices (also called articulation points), thus allowing for non-trivial block-cut tree decompositions (where each block is a maximal biconnected component). Motivated by the DP on trees, we introduce an exact approach that uses primal and dual bounds on the blocks to create fast heuristic as well as optimal solutions.

We present the computational benefits of the approach via preliminary results of an extensive computational study that compares it, among others, with a branch and cut approach that uses the idea of length-bounded cuts.

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