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MADRID 2021

34th Conference of the European Chapter on Combinatorial Optimization

Madrid (Spain) June 10-11 2021

CONFERENCE ABSTRACT BOOK

EURO THE ASSOCIATION OF EUROPEAN OPERATIONAL RESEARCH SOCIETIES

EWG ECCO COMBINATORIAL OPTIMIZATION

INSTITUTO de CIENCIAS SOCIALES COMPUTACIONALES

Universidad Rey Juan Carlos

Contents

Presentation

Dear Participant at the ECCO2021 conference,

ECCO (European Chapter on Combinatorial Optimization) is a working group of EURO (Association of European Operational Research Societies) that provides an excellent opportunity to discuss recent and important issues in Combinatorial Optimization and its applications.

The ECCO meetings are held on a regular basis (once a year during Spring) and nicely combine scientific work and the exchange of new ideas with an exciting environment. The 34th conference of the European Chapter on Combinatorial Optimization (ECCO 2021) is organized by the DSLAB Research Group of the Universidad Rey Juan Carlos (Madrid, Spain) on June 10–11, 2021. This online edition includes three plenary lectures and 63 oral communications with more than 140 attendees from 29 countries.

The ECCO annual meetings aim to bring together researchers in the field of Combinatorial Optimization to present their work, share experiences, and discuss recent advances in theory and applications. Topics of interest:

- theory and applications of combinatorial optimization,
- exact solution algorithms, approximation algorithms, heuristics, meta-heuristics and matheuristics for combinatorial optimization problems,
- integer optimization, global optimization, stochastic and robust integer optimization, multi-objective optimization, bilevel optimization, graph theory and network flows, quadratic assignment and knapsack optimization problems,
- application areas include facility in static and dynamic location problems, transit network design, carriers collaboration and other transportation problems, energy generation and distribution, transportation and distribution planning, and other fields.

A special issue of Discrete Applied Mathematics will be dedicated to contributions presented at the conference. All articles will be refereed according to the high standards of the journal. The Guest Editors will be Antonio Alonso-Ayuso, Laureano F. Escudero and Silvano Martello.

Antonio Alonso-Ayuso (chair of the Local Committee)
Laureano F. Escudero (co-chair of the Pogram Committee)
Silvano Martello (co-chair of the Pogram Committee)

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Chair: Silvano Martello . . . . . 1- GB Dantzig

17:40 - ECCO Board meeting

Chair: Silvano Martello . . . . . 1- GB Dantzig

18:10 - End of activities

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Sessions

TA1-P1 Plenary. Linear bilevel optimization: overview and recent results

Chairperson: Paolo Toth

Linear bilevel optimization: overview and recent results. M. Labbé

Martine Labbé, mlabbe@ulb.ac.be

A bilevel optimization problem consists of an optimization problem in which some of the constraints specify that a subset of variables must be an optimal solution to another optimization problem. This paradigm is particularly appropriate to model competition between agents, a leader, and a follower, acting sequentially. In this talk, I will focus on the simplest bilevel problems, those that are linear. I will present the main characteristics, properties, and algorithms for these problems. Then, I will discuss some recent results showing that these problems are already extremely challenging.

Keywords: Bilevel optimization.

TB1 Scheduling 1

Chairperson: Alan Soper

A fixed job schedule problem arising in train-unit assignment. V. Cacchiani, P. Toth

Valentina Cacchiani, valentina.cacchiani@unibo.it

Motivated by an application in railway systems, we study the following Fixed Job Schedule Problem. A set of fixed jobs, each with given start and end times, must be scheduled on a set of non-identical machines, each having a cost, and capable of executing one job at a time. Each job has a demand of resource, and each machine has a maximum resource capacity. Each job must be executed by a set of machines such that their overall capacity satisfies the job demand. In addition, a setup time must be respected between the execution of two jobs on the same machine. The goal is to determine the minimum cost schedule. In the railway context, fixed jobs correspond to timetabled train trips characterized by a demand of passenger seats, and machines to train-units that can possibly be combined to provide more available seats. In this work, we study two problem variants corresponding to two extreme cases: in the first one, exactly one machine is assigned to each job, while in the second one there is no limit on the number of machines assigned to each job. For these variants, we propose a heuristic algorithm, and test it on realistic instances of the train-unit assignment problem.

Keywords: Fixed job scheduling, Lower bound, Heuristic, Train-Unit Assignment.

Constraint programming-based solution approach for solving the lot streaming problem in flexible job shops. P. Yunusoglu, S. Topaloglu Yildiz

Pinar Yunusoglu, pinar.yunusoglu@bakircay.edu.tr

Constraint programming (CP) is an effective tool for solving constrained optimization problems. However, it is still being stuck at a solution due to the computational complexity of the highly constrained scheduling problems. Therefore, in this paper, we propose a CP-based solution approach to solve the lot streaming problem encountered in flexible job shops. In the proposed solution approach, the CP model is used as a local search to solve the neighborhoods. Moreover, to enhance the performance of the CP model, we develop efficient branching strategies based on different variable and value ordering heuristics. We extend the flexible job shop scheduling problem benchmark instances regarding the lot streaming problem. The computational study is carried out with different scenarios in real-world settings. The proposed CP-based solution approach tackles the computational complexity of the problem. The computational results show that the CP-based solution approach outperforms the novel CP model in medium- and large-size instances.

Keywords: Lot Streaming, Flexible Job Shop Scheduling, Constraint Programming, Branching Strategies.

Preemptive scheduling on two unrelated parallel machines. A. Soper, V. Strusevich

Alan Soper, A.J.Soper@gre.ac.uk

In this paper, for the problem of minimizing the makespan on two unrelated parallel machines we compare the quality of preemptive and non-preemptive schedules. It is known that there exists an optimal preemptive schedule with at most two preemptions. We show that the power of preemption, i.e., the ratio of the makespan computed for the best non-preemptive schedule to the makespan of the optimal preemptive schedule is at most 3/2. This result complements the only other known bound on the power of preemption for unrelated parallel machines which is 4 and tight in the limit of an infinite number of machines. We also show that the ratio of the makespan for the best schedule with at most one preemption to the makespan of the optimal preemptive schedule is at most 9/8. For both models, we present polynomial-time algorithms that find schedules of the required quality. These bounds match those previously known for the less general problem with two uniform machines. We have found one point of difference between the two cases: if an optimal preemptive schedule has exactly one preemption then the power of preemption is 4/3 if the two machines are uniform and remains 3/2 if they are unrelated.

Keywords: Unrelated parallel machines, preemptive scheduling, power of preemption.

TB2 Bioinformatics

Chairperson: Jacek Blazewicz

RNA World simulation using partial differential equations. J. Synak, A. Rybarczyk, J. Blazewicz

Jaroslaw Synak, jaroslaw.synak@cs.put.poznan.pl

One of the main questions in modern biology is how the life on Earth had actually started. One of the hypotheses explaining this is RNA World, which states that at the very beginning RNA molecules served both as enzymes and genetic information careers. However, even if this is true, there are a lot of questions to be answered, for example whether the population of such molecules could achieve stability and retain genetic information for many generations, which is necessary for the Darwinian evolution to start. We try to answer this question based on the parasite-replicase model, which divides RNA molecules into enzymes (replicases) capable of catalyzing replication and parasites, which can (contrary to their name) perform other important functions, for example storing the genetic information. Our main method is to model such system using partial differential equations and using computers – find general rules governing its evolution. Everything is modelled using methods adapted from chemistry – every type of molecule has a certain density, which can change according to possible chemical reactions.

Keywords: RNA World, simulation, partial differential equations, population dynamics.

A new overlap graph method for DNA sequence assembly. S. Swat, A. Laskowski, J. Badura, A. Świercz, W. Frohmberg, P. Wojciechowski, M. Kasprzak, J. Błażewicz

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Reconstruction de novo of a genome sequence is a great challenge, largely due to computational difficulties connected with processing millions of reads at once. ALGA is a new method realizing this process and is based on the overlap-layout-consensus approach. The approach consists of three phases: construction of the overlap graph, preparation of the graph for traversal and agreement of final sequences. It is generally viewed as more accurate than the so-called de Bruijn graph approach, but much more consuming in the sense of time and memory. Several new ideas were implemented in order to increase efficiency at each of the phases, including a number of heuristics designed to effectively simplify the overlap graph's structure during the second phase as well as during the graph creation. ALGA was tested on a few real data sets, including whole human genome, and the results were evaluated with the standard tool QUAST. In comparison to other assemblers, ALGA provides very good results according to metrics such as genome coverage fraction, length of resulting sequences and occurrences of misassemblies.

Keywords: Genome assembly de novo, heuristics.

Assembly free comparison of sequencing data. A. Laskowski, S. Swat, J. Badura, P. Wojciechowski, A. Swiercz, M. Kasprzak, J. Blazewicz

Artur Laskowski, artur.pi.laskowski@gmail.com

The aim if this work is calculating similarity of genomic data, which is a crucial task. We could use similarity measures to decide whether given data comes from the same species or not. Given that similarity is high enough, we could calculate the number of structural variants among a group of individuals from the same species. Those measurements should make us better understand of the evolution process. Additionally this should improve our understatement of how individuals from across the world mix with each other. Previously, analyses like that could only be performed with assembled data since state-of-the-art methods, ANI and Mash, are calculating the similarity of genomes. The assembling process is highly time-consuming, and for calculation of the human genome could take more than 12 hours. In this work, we would like to introduce the assembly-free process of comparing genomic data in the form of long-read sequences produced by NGS sequencers like Illumina. In contrast to state-of-the-art methods, our method could produce results within minutes.

Keywords: de-novo, assembly, algorithms.

TB3 TSP and its variants

Chairperson: Yuval Cohen

The Asymmetric Steiner Traveling Salesman Path Problem ASTSPP - open and closed tours' efficient determination in general digraphs. P. Richter

Peter Richter, peterhrichter@online.de

The ASTSPP has been unattended in the past despite its high practical importance for real-time navigation in digital traffic nets! We are given a graph G with asymmetric arc weights, start point s, target point t, and a subset $S \subseteq V(G)$. The objective is to find a shortest route from s to t in G visiting all nodes of S at least once. The proposed deterministic solution approach relies (a) on an Advanced Scan of Spanning Trees applied to approximate Steiner trees $T \subset G$ spanning S, (b) on a Tree Structure Adaption that overcomes "flaws" of T hampering good results and (c) on a Confined Complete Enumeration that rearranges the sequence of the last $n \leq 6$ stopovers of S, each time a new successor $x \in S$ has been found. The implemented algorithm shows a maximal sample standard deviation q-max $\leq$ 1,86 % and it remains real-time capable for $|S| < 150$. It complies with demands for using graphs that must not necessarily be complete (e.g. traffic maps), that have generally asymmetric arc weights, and that have not to comply with the triangle inequality. It satisfies the request to evenhandedly compute near-optimal round trips ($s = t$) as well general routes ($s \neq t$) without any special precaution.

Keywords: Asymmetric Steiner Traveling Salesman Path Problem.

IP formulations for equitable Traveling Salesman Problems. V.H. Nguyen, T.Q.T. Vo

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We consider several equitable versions of the Traveling Salesman Problem where the equity is based on the cost of the edges taken by the tour. One of these versions is the balanced traveling salesman problem defined by Larusic and Punnen (COR, vol. 38, pp 868-875 2010) where the objective is to minimize the difference between the maximum cost and the minimum cost of the edges in the tour. We also consider the OWA (ordered weighted averaging) TSP which favors tours with similar costs on the edges while assuring a degree of efficiency on the total cost. We propose MIP formulations for those problems where the equity constraints are formulated as linear constraints. Moreover, no additional integer variable is needed with respect to the IP formulation of the original TSP. We also present numerical experiments where, to our knowledge, optimal solutions for several instances of the balanced TSP are proved for the first time.

Keywords: Traveling salesman problem, Equity, Ordered weighted averaging, Mixed integer linear programming.

An improved penalty heuristic for the generalized assignment and the TSP. Y. Cohen, J. Reis, F. Pilati

Yuval Cohen, yuvalc@afeka.ac.il

This study examines several significant improvements to the penalty method suggested by Martello and Toth (1981) for the assignment problem. It is shown that these improvements reduce the possible effect of worst case scenarios. Based on the principles of the improved assignment, a heuristic procedure is proposed for solving the TSP. Again, it is shown that the effect of worst case scenario is greatly reduced by using this heuristic when compared to the Nearest Neighbor approach.

Keywords: Penalty, Assignment, TSP, Traveling Salesman, Myopic, Heuristic.

TC1 Scheduling 2

Chairperson: Grzegorz Pawlak

Scheduling data gathering in tree networks with limited memory. J. Berlińska

Joanna Berlińska, joanna.berlinska@amu.edu.pl

We analyze makespan minimization in a tree data gathering network with limited memory. The network consists of a set of worker nodes, a set of intermediate nodes and a single base station. Each of the worker nodes holds a dataset that has to be transferred to an appropriate intermediate node. The intermediate node processes the dataset and then sends it to the base station. At most one worker can communicate with a given intermediate node at a time, and at most one intermediate node can communicate with the base station at a time. A dataset occupies the intermediate node's memory buffer from the moment when it starts being received until the time when its transfer to the base station completes. The total size of datasets coexisting in the memory of an intermediate node can never exceed its buffer size. The scheduling problem is to minimize the total time of gathering the data. We show that this problem is strongly NP-hard even in the special case when there is only one intermediate node and the communication with the base station takes no time. Heuristic algorithms are proposed and tested by means of computational experiments.

Keywords: scheduling, data gathering networks, limited memory, heuristics.

Improving solution performance of the S-graph scheduling framework. O. Ősz, M. Hegyháti

Olivér Ősz, osz.oliver@sze.hu

The S-graph framework is a combinatorial approach for batch process scheduling. It utilizes a branch-and-bound algorithm to find the optimal schedule. While this determines the general frame of the search, there are several parts in the algorithm that can be carried out in many different ways: how to choose the next node of the search, what scheduling decisions should be made to branch out from a node, how to calculate the bound, and when to use what heuristic to find an incumbent solution. This study examines some of the possibilities regarding these options. One investigated approach uses a more complex bound calculation to obtain a tighter bound. Due to the tradeoff between the quality and computational need of the bound, this bounding function should not be used at every node, only at strategic points of the search, offering even more fine-tuning options. Another approach that was investigated is to guide the search by prioritizing assignment decisions over sequencing decisions. The effects of these improvement approaches were demonstrated by computational tests on literature problems and randomly generated instances.

Keywords: scheduling, combinatorial optimization, branch-and-bound.

Rescheduling jobs with a LIFO buffer. G. Nicosia, A. Pacifici, U. Pferschy, J. Resch, G. Righini

Ulrich Pferschy, ulrich.pferschy@uni-graz.at

Given an input sequence of jobs, we consider the possibility of rescheduling the jobs to improve an objective function. However, rescheduling is limited as follows: (a) jobs can only be postponed but not preponed and (b) when a job is taken out of the sequence, it is put on a buffer of limited capacity before being reinserted in its new position closer to the end of the sequence. The buffer is organized as a stack, i.e. jobs are stored with a Last-In-First-Out policy. This situation can occur in industrial processes where parts traverse several working stations with different processing times and thus different schedules are desirable for each of them. However, rescheduling may be constrained by the technical possibilities of manipulating parts from a conveyor belt. Four common objective functions are considered. For three of them, we construct dynamic programming algorithms running in polynomial time, while for the case of minimizing the weighted number of late jobs the problem is NP-hard. For that case we evaluate two ILP formulations. Then we develop a refined implementation of a pseudo-polynomial dynamic program and compare it to a combinatorial branch-and-bound approach.

Keywords: rescheduling, dynamic programming.

TC2 Integer Optimization

Chairperson: Adam Letchford

Projective cutting planes. D. Porumbel

Daniel Porumbel, daniel.porumbel@cnam.fr

The goal is to replace the separation sub-problem of the well-known Cutting-Planes method with the projection sub-problem: given any strictly interior point x inside a polytope P and an arbitrary direction d, perform a projection along $x \rightarrow d$ and determine the first-hit point $x + t^*d$ where P is "pierced". Imagine one "shooting" from x towards d: the first-hit point $x + t^*d$ is the point where the bullet hits (a wall/facet of) P. This sub-problem is difficult because P has a prohibitively large number of facets. Compared to Cutting-Planes, the main advantage of Projective Cutting-Planes is that it has a built-in functionality to generate a feasible inner solution $x + t^*d$ at each iteration. By selecting a sequence of points x and d, the feasible solutions $x + t^*d$ converge iteratively to an optimal solution opt(P).

The audience may choose between: - a robust optimization problem - a problem formulated using a Benders decomposition - the graph coloring problem expressed using a Column Generation model, where P is a dual.

This work is based on the paper [Daniel Porumbel, Projective Cutting-Planes, SIAM Journal on Optimization, 30(1): 1007-1032, 2020] and on a paper in revision.

Keywords: Cutting Planes, Separation subproblem, Projection subproblem.

Starter factorization of $\mathbb{K}_{2n}$. N. Hoang, Q. Hoang, M. Rosenfeld

Quan Hoang, quanhoang.pm@gmail.com

One-factorizations of the complete graph $\mathbb{K}_{2n}$ is a challenging, attractive topic in combinatorics and operations research. In this talk, we introduce a new one-factorization: starter one-factorizations, one-factorizations where every one-factor is a starter. We show that instances can be solved by graph coloring, finding maximum independent sets in graphs, set covering, counting, and binary ILP. As a collateral benefit, we identify many new HBTD(n)s (rainbow-colored hamiltonian balanced tournament designs) and provide evidence that most likely they exist for almost all sizes.

Keywords: starter, factorization, round-robin tournaments.

Strengthened clique-family Inequalities for the stable set polytope. A. Letchford, P. Ventura

Adam Letchford, a.n.letchford@lancaster.ac.uk

The stable set polytope is a fundamental object in combinatorial optimisation. Among the many valid inequalities that are known for it, the clique-family inequalities play an important role. Pecher and Wagler showed that the clique-family inequalities can be strengthened under certain conditions. We show that they can be strengthened even further, using a surprisingly simple mixed-integer rounding argument. Examples are given of new facet-defining inequalities that can be derived in this way.

Keywords: stable set problem, cutting planes, polyhedral combinatorics.

TC3 Natural Disaster Management

Chairperson: Laureano F. Escudero

Mass damping and stroke factors in optimum design of tuned mass dampers. M.F. Karapınar, G. Bekdaş, S.M. Nigdeli

Mehmet Fırat Karapınar, mehmetfiratkarapinar@gmail.com

There are various applications in order to reduce seismic effects occurring in buildings. One of these applications is to install tuned mass dampers in the structures. In this study, optimization of some parameters for tuned mass dampers has been carried out with metaheuristic algorithms and their effects on structures have been investigated. Single degree of freedom structures that have different period values had been determined and tuned mass dampers had been installed in these structures. Considering the mass, damping ratio and maximum displacement parameters of the aforementioned tuned mass dampers, time history analysis, the Jaya algorithm and the Matlab program have been used. As a result of the analysis, optimum tuned mass damper parameters have been determined for single degree of freedom structures. As the novel investigation of the study, several cases of mass, damping ratio limit and stroke capacity of TMD are investigated to show the performance of an optimum TMD under these limitations

Keywords: Tuned mass dampers, Jaya algorithm, optimization, Matlab.

Parameter optimization of tuned mass dampers via metaheuristic algorithms. O. Uzdil, T. Çoşgun, S.M. Nigdeli, G. Bekdaş

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Building-like structures should be taken under control to reduce vibrations under dynamic effects such as earthquakes, to extend the useful life of building elements and to achieve goals such as life safety and comfort. For this purpose, passive, semi-active and active control systems are used for structures. Among these systems, Tuned Mass Dampers (TMD), which are passive control devices, are generally used in high-rise buildings but are also preferred to protect artifacts in historical buildings. In this study, parameter optimization of mass dampers will be done by using various metaheuristic algorithms, and the performance of these algorithms will be compared. In the optimization methodology, time-domain analysis results are taken as objective function by considering the stroke limitation as a design constraint to find optimum design variables. As a result, the metaheuristic-based methods are effective to consider the real problem for multiple degrees of freedom system in the time-domain analysis as an advantage to classical methods.

Keywords: TMD, Metaheuristic Algorithms, Optimization.

Decomposition strategies in mixed 0-1 two-stage optimization: a case study for emergency response after earthquake disasters. A. Unzueta, I. Eguia Ribero, M.A. Garín

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Stochastic optimization problems of practical applications lead, in general, to some large scale models. The size of those models is linked to the number of scenarios that defines the scenario tree, which can be so large that decomposition strategies are required for problem solving in reasonable computing time. Methodologies such as Branch-and-Fix Coordination or Lagrangean Relaxation make use of these decomposition approaches, where independent scenario clusters are given. In this work, we present a technique to generate nested cluster submodel structures from the decomposition of a general two-stage stochastic mixed integer optimization model. These scenario cluster submodels can be embedded in different algorithmic schemes in order to make the chosen solution procedure more efficient. We will consider as a case study, a two-stage stochastic mixed 0-1 model that aims to make decisions that help to mitigate the complications of earthquake hazards, particularly in the area of Japan. Using it as a test bed, and with different algorithmic schemes, we provide some computational experience showing the effects of such a decomposition.

Keywords: Two stage mixed 0-1 optimization, Scenario Cluster Partitioning, Nested Decomposition.

TD1 Scheduling 3

Chairperson: Emanuele Tresoldi

Autonomous learning effects in resource-constrained project scheduling. A. Hill, J. Ticktin, T. Vossen

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It's commonly assumed that experience leads to efficiency, yet this is largely unaccounted for in resource-constrained project scheduling. We consider the case that selected activities can be completed within reduced time when scheduled after activities that result in learning of relevant skills. Using constraint programming, we computationally explore the effect of this autonomous learning on optimal makespan and problem difficulty across hundreds of thousands of scenarios. In this large-scale analysis, we evaluate the impact of multiple parameters such as project size, learning frequency, and learning intensity on PSPlib instances. Moreover, we compare different model formulations and lower bounding techniques with respect to their efficiencies.

Keywords: Project Scheduling, resource-constrained.

An exact approach for the personnel task rescheduling problem with task retiming. T. Borgonjon, B. Maenhout

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In this work, we study the personnel task rescheduling problem with task retiming. We assume a baseline personnel task schedule that is subject to different types of disruptions, occurring on a daily basis. This operational uncertainty is the result of three sources of variability, i.e. uncertainty of demand, uncertainty of capacity and uncertainty of arrival, which may render the baseline schedule infeasible. Therefore, the rescheduling of the originally constructed personnel schedule is necessary to compose an operational schedule. We propose a dedicated branch-and-price procedure to recover the personnel task schedule, which considers a wide range of recovery mechanisms to reassign the tasks to workers, allowing the retiming of tasks, to restore the feasibility. Different computational experiments are conducted to show the performance of the proposed branch-and-price thriving on different speed-up techniques and optimisation principles. We benchmark the proposed algorithm with other optimisation procedures and show the contribution of the algorithm design choices.

Keywords: scheduling, personnel task rescheduling, branch-and-price, task retiming.

Solution approaches for the Capacitated Scheduling Problem with Conflict Jobs. E. Tresoldi

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The Capacitated Scheduling Problem with Conflicts Jobs (CSPCJ) requires to find a feasible schedule, on a set of parallel identical machine without preemption, that maximizes the total weighted value of jobs completed before a common deadline. The schedule is subject to conflict constraints limiting the set of jobs that can be processed concurrently. In this work we present a new arc-flow inspired mathematical formulation and a three-step heuristic algorithm combining randomization, greedy construction and local search improvement for the CSPCJ. The effectiveness of our approaches is tested through extensive computational experiments. The results demonstrate that our formulation outperforms existing models proposed in the literature and that our simple heuristic algorithm is able to find very good solutions in limited computational time.

Keywords: Scheduling, Parallel Machines, Conflicts, Arc-flow.

TD2 Quadratic Assignment and Knapsack Optimization

Chairperson: Laura Galli

A quadratic assignment solver by graph pointer networks and reinforcement learning. X. Li, C. Han, T. GUO

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The Quadratic Assignment Problem (QAP) is one of the NP-hard combinatorial optimization problems and is known for its diverse applications in real life. The metaheuristics are prevalent solution methods for this problem. However, it is difficult to solve in the polynomial time even for small instances and different metaheuristics are applicable to different problems. In this paper, we propose a Graph Pointer Network(GPN) for the QAP using Reinforcement Learning. Our method introduces the Graph Neural Network to capture the relationship between each node based on the traditional Pointer Network. The trained network then outputs approximate solutions in feasible time, without the need to re-train for every new problem instance. We demonstrate the performance of our approach outperforms the previous learning-based methods on the benchmark instances of QAPLIB, a well-known library of QAP instances, and show that our model is able to generalize well: (i) from training on small graphs to testing on large graphs; (ii) from training on one type of random graphs to testing on another type of random graphs; and (iii) from training on random graphs to running on real-world graphs.

Keywords: Quadratic Assignment Problem,Graph Pointer Networks,Reinforcement Learning.

A lifted-space dynamic programming algorithm for the Quadratic Knapsack Problem. F. Djeumou Fomeni

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The Quadratic Knapsack Problem (QKP) is a well-known combinatorial optimization problem which has many applications in finance, logistics, telecommunications, etc. The QKP is NP-hard in the strong sense and the existing state-of-the-art algorithms can only handle problems of small and moderate sizes. We will present a novel heuristic algorithm for the QKP that consists of implementing the well-known dynamic programming algorithm in the space of lifted variables of the QKP. We will present some computational results which show the potentials and capabilities of this new algorithm.

Keywords: knapsack problems, integer programming, dynamic programming, local search.

Lagrangian heuristics for the Quadratic Multiple Knapsack Problem. L. Galli, S. Martello, C. Rey, P. Toth

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The Quadratic Multiple Knapsack Problem (QMKP) generalizes, simultaneously, two well-known combinatorial optimization problems that have been intensively studied in the literature: the (single) Quadratic Knapsack Problem and the Multiple Knapsack Problem. Owing to its many practical applications, that range from project management to capital budgeting to product-distribution system design, as well as to its mathematical structure borrowing from well-studied combinatorial problems, the problem has received increasing attention in the literature over the last fifteen years, mostly concentrating on exponential-size formulations and meta-heuristic approaches. QMKP is strongly NP-hard and very difficult to solve in practice. We propose effective matheuristic algorithms, based on Lagrangian relaxation and on the optimal solution of Integer Linear Programming models. Computational results on small-size benchmark instances and on new randomly generated medium-size instances are reported. These results show the good performance of the proposed algorithms, which are able to determine, within reasonable computing times, either optimal or nearly optimal solutions.

Keywords: Quadratic Multiple Knapsack, Lagrangian Relaxation, Matheuristic.

TD3 Game Theory and Multicriteria Decision

Chairperson: Julia Sudhoff

Network connectivity game. D. Skorin-Kapov, J. Skorin-Kapov

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We investigate the cost allocation strategy associated with the problem of providing service/communication between all pairs of network nodes. There is a cost associated with each link and the communication between any pair of nodes can be delivered via paths connecting those nodes. The example of a cost efficient solution which could provide service for all node pairs is a (non-rooted) minimum cost spanning tree. The cost of such a solution should be distributed among users who might have conflicting interests. The objective of this paper is to formulate the above cost allocation problem as a cooperative game, to be referred to as a Network Connectivity (NC) game, and develop a stable and efficient cost allocation scheme. We formulate Network Connectivity (NC) game and construct an efficient cost allocation algorithm which finds some points in the core of the NC game. Finally, we discuss the Egalitarian Network Cost Allocation (ENCA) rule and demonstrate that it finds an additional core point.

Keywords: networks, cost allocation, cooperative games, mathematical programming.

On reward-penalty-selection games. T. Heller, S.O. Krumke

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The Set Cover Problem (SCP) is a well-known combinatorial problem and is strongly related to the Hitting Set Problem (HSP). We study a combination of both problems, the Reward-Penalty-Selection Problem (RPSP) in a game theoretic setting. Given a set of elements, a set of reward sets, and a set of penalty sets, we try to find a subset of elements such that as many reward sets as possible are covered and at the same time as few penalty sets as possible are hit. Given instances of the SCP and HSP, an instance of the RPSP can be constructed by taking the sets from SCP as reward sets, the elements from the HSP as penalty sets and the elements from the SCP and from the HSP as elements. Given the RPSP, we define a combinatorial cooperative game, where the participants are given by the elements of the RPSP. We prove that RPS games are convex, totally balanced and superadditive. The Shapley value can be computed in polynomial time. In addition to that, we provide a characterization of the core elements as a maximum flow in a network graph depending on the instance of the underlying RPSP. By using this characterization, a core element can be computed in polynomial time.

Keywords: Game Theory, Combinatorial Optimization, Cooperative Games, Core Elements.

Ordinal cost coefficients in matroid optimization. J. Sudhoff, K. Klamroth, M. Stiglmayr

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Bi-objective optimization problems on matroids are in general NP-hard and intractable, but if one of the objective functions is restricted to binary cost coefficients the problem becomes efficently solvable. A binary objective function often represents two categories and are thus a special case of ordinal coefficients that are in general non-additive. In this talk we consider ordinal objective functions with more than two categories. This leads to a new class of optimization problems, which we investigate especially with respect to their set of non-dominated outcome vectors. We present a transformation of an ordinal objective function to vector-valued objective functions with non-negative integer values. We show that all suggested models are efficiently solvable by a matroid intersection algorithm. Moreover, we discuss the application of this transformation to general combinatorial optimization problems with fixed cardinality and ordinal coefficients.

Keywords: matroid optimization, ordinal costs, matroid intersection, multi-objective reformulation.

TE1-P2 Plenary. Approximation of multiobjective optimization problems

Chairperson: Silvano Martello

Approximation of multiobjective optimization problems. M. Yannakakis

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When evaluating different solutions from a design space, it is often the case that more than one criteria come into play. The trade-off between the different criteria is captured by the so-called Pareto curve. The Pareto curve has typically an exponential number of points. However, it turns out that, under general conditions, there is a polynomially succinct curve that approximates the Pareto curve within any desired accuracy. This talk will discuss problems concerning the efficient computation of good approximate solutions for multiobjective problems. In the first part of the talk, we address the question of when an approximate Pareto curve can be computed in polynomial time. We discuss general conditions under which this is the case and relate the multiobjective approximation to the single objective case. In the second part of the talk, we address the problem of computing efficiently a good approximation of the trade-off curve using as few solutions (points) as possible. If we are to select only a limited number of solutions, how shall we pick them so that they represent as accurately as possible the spectrum of possibilities?

Keywords: Multiobjective Optimization.

FA1 Graphs and Networks 1

Chairperson: Marie Baratto

Disjoint shortest paths with congestion. S. Akhoondian Amiri

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In the k-Disjoint Paths Problem, a set of terminal pairs of vertices $\{(s_i, t_i)|1 \leq i \leq k\}$ is given and we are asked to find disjoint paths $P_1, \ldots, P_k$ such that each path P_i connects s_i to t_i. There are two main variations of this problem: shortest disjoint paths and disjoint paths with congestion; in the former, the aim is to make each P_i the shortest path and, in the latter, every vertex can tolerate a certain amount c of congestion. We introduce a more natural problem by mixing the two: k-disjoint shortest paths with congestion-c. This problem is more realistic in the sense that in practical networks we can tolerate certain congestion, moreover, routing along short paths is in priority. For this problem, we provide a simple algorithm to solve it in time $f(k)n^{O(k-c)}$ on DAGs. Our algorithm is based on the earlier algorithm of Amiri et al.[IPL 2019], but we significantly simplify their proof argument. We also discuss the hardness of the problem, achieving a better lower bound than the existing one in the previous work. We believe our simplified method of analysis can be helpful to deal with similar problems on general undirected graphs.

Keywords: Graph Algorithms, Disjoint Paths, Shortest Paths, Scheduling, Routing with Congestion, Acyclic Graphs.

An iterated local search heuristic for the problem of tree-depth decomposition of graphs. K. Sylejmani, A. Rexhepi, V. Rexhebeqaj, E. Meziu, B. Arifaj, B. Berisha

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We solve the problem of tree-depth decomposition of graphs, as defined in PACE 2020 challenge. In this problem, a connected undirected graph should be decomposed into a tree such that every edge that connects a pair of nodes in the graph constraints the decomposition of that pair of nodes into the tree in a such way that they maintain an ancestor-descendant relationship. The objective is to find a decomposition with the minimal tree depth. Our Iterated Local Search algorithm uses two alternating procedures, one that constructs a solution and the other one that partially destructs it. The construction procedure is a recursive algorithm that for a given list of nodes, sequentially, finds their best insertion position in the tree such that the tree depth remains minimal. The destruction procedure consists of several operators for node removal, such as: removing a subtree, removing a node (leaf, root, internal), removing all leaves, removing k top/bottom levels of nodes, and removing k nodes (from root/leaf) in a selected tree path. Further, with the aim of escaping from the local optima, our approach uses a perturbation mechanism after a given number of iterations without improvement.

Keywords: Iterated Local Search, Tree-depth decomposition, Graphs.

Selecting directed cycles: a polyhedral study. M. Baratto, Y. Crama

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The following ”cycle selection problem” is motivated by an application to kidney exchange problems. For a digraph G, a cycle selection is a subset of arcs of G forming a union of directed cycles. When the arcs are weighted, the Maximum Weighted Cycle Selection (MWCS) problem consists in finding a cycle selection of maximum total weight. We prove that MWCS is strongly NP-hard. Next, we focus on the cycle selection problem associated with a complete digraph. We provide four complete ILP formulations of the problem: a ”natural” one, featuring an exponential number of constraints which can be separated in polynomial time, and three extended ones. We investigate the relative strength of these formulations. We next concentrate on the natural formulation and on the description of the associated polytope. We prove that it is full-dimensional, and that all the inequalities used in the ILP formulation are facet defining. Furthermore, we describe three new classes of facet-defining inequalities. We also study the problem when we include an additional constraint on the cardinality of a cycle selection. Most of the results proved for the original case remain valid.

Keywords: Graphs, Integer Programming, Polyhedral Combinatorics,.

FA2 Heuristics 1

Chairperson: Cung Van-Dat

A comparative study of metaheuristic algorithms for structural engineering problems. S.M. Nigdeli, A. Alzarkan, G. Bekdaş

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The structural engineering problems include a high number of design constraints. In that case, these problems cannot be optimized via mathematical methods. For that reason, the best way to optimize is to provide an iterative optimization. the iterative optimization can be provided via metaheuristics, since these algorithms have a good convergence ability and efficiency in structural optimization. In this study, four metaheuristic methods such as jaya algorithm (JA), flower pollination (FPA), teaching-learning based optimization (TLBO) and artificial bee algorithm (ABC) were used to solve three structural engineering problem such as minimizing the cost of welded beam, cost optimization of reinforced concrete beam and weight optimization of 2-bar truss. Three algorithms JA, FPA and TLBO are quite better than the ABC in finding a minimum objective function.

Keywords: Optimization, Metaheuristic methods, Optimum design, Structural engineering.

Chaotic guided local search algorithm for solving optimization problems. A. Naanaa

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Chaos optimization algorithm (COA) can be an interesting alternative in a global optimization problem. Due to the non-repetition and ergodicity of chaos, it can explore the global search space at higher speeds than stochastic searches that depend on probabilities. To adjust the solution obtained by COA, guided local search algorithm (GLS) is integrated with COA to form a hybrid algorithm. The results show that the present algorithms significantly outperforms the existing methods in terms of convergence speed, numerical stability and a better optimal solution than other algorithms.

Keywords: Chaos theory; Guided local search; Metaheuristics; Combinatorial optimization; Hybrid methods.

Building Hyper-heuristic using crowdsouring. J. Badura, A. Laskowski, M. Antczak, S. Wasik

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Hyper-heuristic is a special program that aims to solve optimization problems independently from their search space. Instead, it uses a set of so-called low-level heuristics that are simple algorithms dedicated to solving a specific problem. I would like to use crowdsourcing to collect low-level heuristics. I designed a protocol that enables people to submit their low-level heuristics and implemented it on the Optil.io platform. The system was tested by collecting over a thousand low-level heuristics for a flowshop optimization problem. It is expected that those low-level heuristics form several clusters of similar approaches. I researched several ways of clustering algorithms so that I can choose a set of representative low-level heuristics that hyper-heuristic will use.

Keywords: Hyperheuristic, Crowdsourcing, Combinatorial Optimization.

FA3 Routing

Chairperson: Philipp Armbrust

A makespan minimizing dynamic spatial-temporal partitioning of the workspace in a multi-robot station. E. Åblad

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We study a station in an automotive manufacturing production line consisting of multiple robots, a workpiece, and a set of predefined tasks such as welding or inspection. The goal is to assign each task to a robot and to select one of the corresponding kinematic poses. We minimize the makespan of the multi-robot station; hence, both sequences and motions of the robots need to be computed. These two aspects are, traditionally, decoupled using the shortest path assumption: "let each robot use its shortest motion between poses". This, however, leads to poor solutions for some industrial instances. To find better solutions, we suggest a method preventing robot collisions by partitioning the robots' shared workspace into disjoint private zones. A dynamic sequence of such partitions, slightly overlapping in time, are used to allow for closely located tasks be assigned to different robots. We utilize vehicle routing formulations to model the robots' sequences, and a coarse time indexing together with set packing constraints to model the workspace partitioning. Our suggested method finds solutions with much lower makespan as compared to the traditional case of the shortest path assumption.

Keywords: Vehicle routing, set packing, motion planning, Generalized Voronoi diagram.

Euclidean approximation for Vehicle Routing Problems on road networks. T.H. Dang, A. Letchford, B. Boyaci

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Vehicle Routing Problems (VRPs) are an important and much-studied family of combinatorial optimisation problems. Most exact VRP algorithms assume that the instance is defined on a complete graph, and many heuristics assume that the instance is planar and Euclidean. In practice, of course, most VRPs are defined on road networks. It is sometimes possible to convert road-network instances into complete instances, by solving shortest-path problems. Sometimes, however, such a conversion is not possible. (This may be due to memory limitations, or to the nature of the objective and constraints.) In that case, one possible heuristic approach is to solve a modified version of the problem, in which true road distances are replaced with planar Euclidean distances. We conduct extensive computational experiments to explore the quality of this heuristic scheme. In particular, we create and solve 96 instances of the Steiner Travelling Salesman Problem and Capacitated VRP, using real road network data from twelve cities across the world. It turns out that the heuristic works rather well in most cases.

Keywords: vehicle routing problems, traveling salesman problem, road networks, combinatorial optimisation..

Analysing different operational scenarios for the Dial-a-Ride Problem. P. Armbrust, V. Pachatz, K. Maier, P. Hungerländer

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The Dial-a-Ride Problem (DARP) aims to find a set of minimal cost tours for a heterogeneous fleet of vehicles in order to satisfy a set of transport requests. Further restrictions, namely customer chosen time window sizes, pick-up and drop-off locations, and capacity constraints are generally customary. A common example arises in door-to-door transportation of people, especially elderly people or people with impaired mobility. In this work, we consider a dynamic-deterministic variant of the DARP for two Austrian mobility providers that focus on rural regions. As additional conditions, we take the transportation of people with impaired mobility, break times, and the capacity of wheelchairs into account. We consider a heuristically and an exact solution approach, namely a Large Neighborhood Search and a Mixed-Integer Linear Programming approach. In a computational study, we show different operator scenarios including minimizing overall driven kilometers, number of used vehicles, and number of unscheduled requests.

Keywords: Dial-a-Ride Problem, Large Neighborhood Search, Vehicle Routing.

FB1 Graphs and Networks 2

Chairperson: Phillippe Samer

Petri nets comparison based on graphlets. B. Szawulak, P. Formanowicz

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Graphlets represents an interesting approach to graph comparison based on distribution of small nonisomorphic structures (graphlets) inside two compared graphs. Graphlet Degree Distribution Agreement (GDDA) is a metric that was created for comparison of large graphs for which standard approaches are not efficient. Unfortunately, for graph characterized as low edge density structures GDDA was reported to become too sensitive. Because models created by use of Petri nets usually represent structures with total number of nodes up to a few hundreds, while original graphs have a few thousands vertices, they might be subjected to this problem. We have proposed new graphlets for biparted directed environment of Petri nets and performed tests based on GDDA metric to evaluate their usefulness .

Keywords: Petri nets, Graph comparison, Graphlets.

On trees with double domination number equal to double edge-vertex domination number. B. Şahin, A. Şahin

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An edge e dominates a vertex v, if e is incident to v or e is incident to a vertex which is adjacent to v. A subset $D \subseteq E$ is an edge-vertex dominating set (in simple, ev-dominating set) of a graph G, if every vertex of G is ev-dominated by at least one edge of D. The minimum cardinality of an ev-dominating set is called ev-domination number and denoted by $\gamma ev(G)$. In this paper, we study double edge-vertex domination where a subset $D \subseteq E$ is a double edge-vertex dominating set (in simple, double ev-dominating set) of G, if every vertex of $V(G)$ is ev-dominated by at east two edges of D. The double ev-domination number of a graph G is denoted by $\gamma dev(G)$ and it is equal to the minimum cardinality of a double ev-dominating set. We first show that determining the double ev-domination number of bipartite graphs is NP-complete. Moreover, we show that $\gamma dev(T) \leq \gamma d(T)$ for a tree T and we characterize the trees attaining the equality $\gamma dev(T) = \gamma d(T)$.

Keywords: Domination, double domination, double edge-vertex domination.

From fixed cardinality stable sets to conflict-free spanning trees. P. Samer, D. Haugland

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Given a graph $G = (V, E)$ and a set of conflicting edge pairs $C \subseteq E \times E$, a conflict-free spanning tree in G is a set of edges T inducing a spanning tree in G, such that for each $(e, f) \in C$, at most one of the edges e and f is in T. The existing work on Lagrangean algorithms to the NP-hard problem of finding minimum spanning trees under conflict constraints is limited to the most basic approach: using relaxations with the integrality property, and computing bounds with a standard subgradient algorithm. We have recently initiated the combinatorial and polyhedral study of fixed cardinality stable sets, which motivates a new formulation for conflict-free spanning trees based on Lagrangean Decomposition. By optimizing over the forest polytope of G and the fixed cardinality stable set polytope of the conflict graph $H = (E, C)$ in the subproblems, we are able to derive stronger Lagrangean bounds (equivalent to dualizing exponentially-many subtour elimination constraints), while limiting the number of multipliers in the dual problem to $|E|$. This naturally leads to more sophisticated dual algorithms, requiring the fewest iterations possible, such as customized dual ascent, and the volume algorithm.

Keywords: Lagrangean decomposition, fixed cardinality, stable sets, spanning trees, conflict constraints, integer programming, combinatorial optimization.

FB2 Heuristics 2

Chairperson: Silvia Pagani

A new algorithm for the Balanced and Fair Reviewer Assignment Problem. A.N. Medakene, K. Bouanane

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In academic conferences, the assignment of papers to reviewers can be formulated as a CO problem, named the Reviewer Assignment Problem (RAP). Given the matching degrees between reviewers and papers, we aim to find an assignment that maximizes the total matching degree such that the coverage and fairness constraints for each paper and balanced load constraint for each reviewer must be satisfied. As the fairness and load balance constraints are often neglected in existing works, we define the Balanced & Fair Reviewer Assignment Problem, BF-RAP, as a variant of RAP. It was shown in a previous work that BF-RAP can be reduced to Max m-ECP when we aim to find an equitable m-coloring in a defined graph such that the total performance of the partition is maximum. Where performance is defined for pairs of nonadjacent vertices. We present a new algorithm that aims to solve BF-RAP by finding an equitable m-coloring with maximum performance in the corresponding graph. After constructing an initial m-coloring with maximum performance, the algorithm aims to balance the color classes by moving vertices from overloaded to underloaded classes while minimizing the cost of such moves.

Keywords: Reviewer Assignment Problem, Fairness constraints, Load balance constraints, Equitable Coloring Problem., .

The balanced maximally diverse grouping problem with attribute values. A. Schulz

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The balanced maximally diverse grouping problem with attribute values (BMDGPAV) is a variant of the well-known maximally diverse grouping problem (MDGP) which assigns items to groups such that the sum of absolute differences of all item pairs assigned to the same group is maximized. In the BMDGPAV absolute differences are absolute differences of the attribute values of the corresponding items. This is a realistic setting for example in the assignment of students to courses according to their academic achievements. Moreover, BMDGPAV searches for a best-balanced solution amongst all solutions with maximal sum of intra-group differences (i.e. optimal solutions of the corresponding MDGP instance). We present theoretical insights as well as solution approaches and a computational study for the BMDGPAV.

Keywords: Computational Complexity, Mixed-Integer Programming.

Discrete tomography helps finite geometries: The power sum polynomial. S. Pagani, S. Pianta

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Discrete tomography aims to recover the interior of an object, represented as a density function, from its projections along given directions. Discrete tomography is an interdisciplinary topic, with connections to several areas of Mathematics. Usually, there is more than one function which agrees with a given set of projections. Ambiguities are due to functions having null projections along the considered directions, called ghosts. The algebraic description of all solutions of a tomographic problem, obtained by adding a suitable ghost to a solution, suggests a way of dealing with the subsets of the projective plane PG(2,q) related to a given polynomial. In the finite geometry context, a homogeneous polynomial of degree q-1, called power sum polynomial, may be associated to a subset of PG(2,q). It is hard in general to classify all the subsets related to the same power sum polynomial. After having established the connections between the two areas, we will introduce the geometric counterparts to the tomographic function sum and ghosts, and will show some recent results in the classification of the subsets of PG(2,q) sharing the same power sum polynomial. Joint work with S. Pianta.

Keywords: Discrete tomography, ghost, multiset sum, power sum polynomial, projective plane.

FB3 Cutting and Packing

Chairperson: María Sierra-Paradinas

Algorithms generating V-shaped sequences and their applications. W. Skowrońska, S. Gawiejnowicz

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Optimal schedules for some scheduling problems with fixed processing times have the property, called V-shape property, such that jobs are scheduled in non-increasing and non-decreasing order with respect to processing times before and after the job with the smallest processing time, respectively. There are also known scheduling problems with variable processing times, where the property is defined not with respect to processing times but with respect some other problem parameters, e.g. job deterioration rates. Sequences corresponding to such schedules are called V-shaped sequences and are studied in various contexts.

In the talk, first we summarize known properties of the V-shaped sequences. Next, we show how the sequences can be generated by a known non-recursive algorithm and a new recursive algorithm. Finally, we show how to apply the algorithms to solving of some scheduling problems with variable time-dependent job processing times. We illustrate our presentation with results of numerical experiments with implementations of discussed algorithms in Python 3.8.

Keywords: V-shaped sequences, algorithms, scheduling.

Algorithm portfolios for Strip Packing Problem. K. Piechowiak, M. Drozdowski, E. Sanlaville

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Selection of fast algorithm portfolios for 2D packing problem is considered. The 2D packing problem analyzed here consists in placing rectangles on a strip of a given width for minimum strip length. While solving combinatorial optimization problems longer runtimes increase chances of obtaining higher quality solutions. This means that solution quality vs runtime trade-off exists. Given some limited runtime a method is needed to provide the best solution possible. Usually a single algorithm outperforming all other methods under all possible conditions does not exist. Therefore, algorithm portfolios can reliably provide high quality solutions in the limited runtime. We propose a method choosing algorithm portfolios on the basis of the algorithm performance on a set of training instances. The portfolios cover the instances with the best solutions which could be obtained in the given runtime, subject to the minimum overall computational cost of the selected algorithms. We demonstrate that our method is capable of porting solution quality from the training datasets to the validation datasets.

Keywords: Heuristics, runtime-quality trade-off, 2D packing, algorithm selection problem, algorithm portfolios.

An exact model for a slitting problem in the steel industry. M. Sierra-Paradinas, Ó. Sóto-Sánchez, A. Alonso-Ayuso, F.J. Martin-Campo, M. Gallego

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From an economic point of view, the steel industry plays an important role and, when it comes to responding to new challenges, innovation is a crucial factor. This paper proposes a mathematical methodology to solve the slitting problem in a steel company located in Europe. A major challenge here is defining a slitting plan to fulfil all the requirements of the customers, as well as ongoing operational constraints and customer demands. The company looks for a reduction of the leftovers generated in the process, while maximising the overall accuracy of the orders. These leftovers may be used in the future if they are able to respond to specific requirements, or otherwise they are considered as scrap. This paper introduces a novel mixed integer linear optimisation model to respond to a specific slitting problem. The model is validated with real data and it outperforms the results obtained by the company: by adjusting the orders that are to be served, by reducing the amount of scrap and by using the retails for future orders. Furthermore, the model is solved in only a few minutes, while the company needs several hours to prepare the scheduling in the current operating process.

Keywords: Cutting, Steel industry, Mixed integer linear optimisation.

FC1 Graphs and Networks 3

Chairperson: Mustafa Pinar

Problems of searching for certain subsets of transitions as an essential stage in an analysis of models of complex biological systems. K. Gutowska, P. Formanowicz

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A systems approach based on Petri nets is increasingly used to model and analyze complex biological phenomena whose complete analysis is extremely difficult. Therefore, it is imperative to find component processes that have the most significant impact on an entire system's behavior. Such an approach is particularly useful in searching for therapeutic targets and may facilitate the development of new, more effective therapies. Searching for the mentioned, crucial component processes is associated with finding subsets of a set of transitions with a certain minimal cardinality, which are included in a sufficiently large number of t-invariant supports (t-invariants correspond to subprocesses occurring in the modeled system that do not change its state). Elements of these subsets correspond to elementary processes that appear in many subprocesses, thus they may be crucial for the functioning of the entire system. It also seems important to consider subsets of transitions that are not related to other subprocesses. Therefore, we consider the combinatorial problems of an occurrence and non-occurrence of certain subsets of transitions in t-invariant supports.

Keywords: Combinatorial problems, Searching for subsets, Analysis of Petri net-based models, Subsets of transitions in t-invariant supports.

Graph realization on sequences of degree sets. P. Wawrzyniak, P. Formanowicz

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The classical graph realization is a decision problem checking if a finite sequence of positive numbers can construct a graph, where degrees of nodes match the input sequence. This problem is related to many real problems, such as the design of reliable networks or analysis of biological networks. One such problem is testing the ability of molecular graphs construction basing on mass spectrometry data. As a model of chemical compounds, the molecular graphs bring some changes to the classical realization problem. In this case, the graph is a model of a single molecule, so we limit only to the connected graphs. The bonds in a chemical compound can be single or multiple, so we have to consider both graphs and multigraphs. Finally, the vertices represent the atoms, and the vertices' degrees match the valency of the atom. Because not each atom has a single valency, we cannot limit it to the single value in the input sequence. The described modification brings us to the definition of a new problem is, i.e., sequence of sets of positive integers S=(D1, . . . , Dn) graphic? Sequence S is called graphic when there exists such graph G, whose vertices v1, . . . , vn have degrees from sets D1, . . . , Dn.

Keywords: graphical sequences, molecular graphs.

The Quantile Matching Problem and point cloud registration. S. Chretien, O. Ekin Karasan, E. Oguz, M. Pinar

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Inspired from a problem in computer vision we introduce the quantile matching problem on a bipartite graph, the two parts of which represent two point clouds. The goal is to achieve an optimal registration of a point cloud with another point cloud. The problem is posed as the problem of computing a (perfect when possible) matching, which maximizes the α-quantile of affinity weights between the nodes of the graph. We prove that the problem is polynomially solvable in bipartite and non-bipartite graphs. Numerical illustrations are given. Implementations of the proposed algorithms in Python are described along with computational results with synthetic as well as real data from a computer vision application.

Keywords: Computer Vision; Point Cloud Registration ; Quantile; Matching; Bipartite Graphs; Graph Algorithms.

FC2 Heuristics 3

Chairperson: María Araceli Garín

CO2 minimization of reinforced concrete columns via teaching-learning-based optimization . G.B. Bekdaş, S.M. Nigdeli, A.E. Kayabekir

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The design of reinforced concrete (RC) members involves definition of cross-section dimensions and amount of the required reinforcement to ensure regulations that propose rules to provide safety for maximum strength, ductility, and usability. These rules are defined as design constraints in optimum design and these constraints are depending on the final design. This situation makes the problem nonlinear one. In that case, metaheuristics can handle these problems by providing iteratively defined random design variables. The general objective for the problem is the cost, but environmental factors are also important. In that case, the CO2 emission in production can be handled as the objective function. In the present study, an optimization methodology for RC columns considering slenderness effects is proposed for the minimization of CO2 emission. In the optimum design, classroom-inspired metaheuristic algorithm is used to provide the optimum design. As conclusion, the results compared with the cost minimization results show that cost and CO2 emission minimization factors are oppositely related. In future research, multi-objective optimization that uses both objectives is proposed.

Keywords: CO2, metaheuristic, teaching-learning-based optimization, reinforced concrete.

Two metaheuristics for the maximum network flow. M. Pavone, F. Zito, A.G. Spampinato

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Finding the maximum flow in (large) networks is one of the most interesting problems in Graph Theory, which finds application in many challenging areas, such as image segmentation, bipartite matching, and gene function prediction. Although there exit many traditional techniques to solve maximum flow problem (e.g., the Ford-Fulkerson algorithm), these may fail on high density and strongly connected networks. Furthermore, the Ford-Fulkerson algorithm might not terminate if it is allowed the arcs capacities to take irrational values. Thus, two metaheuristics were developed (IA - Immune Algorithm, and ACO - Ant Colony Optimization) with the aim to find approximate solutions (close to optimum) in shortest time. Both metaheuristics were compared to the Ford-Fulkerson algorithm to prove their efficiency and reliability.

Keywords: Metaheuristics, combinatorial optimization, maximum flow, immune algorithms.

Line identification in smart grids by 0-1 optimization. L. Aranburu, A. Unzueta, M.A. Garín, J.I. Modroño Herrán, A.A. Amezua

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An important problem faced by electric power distribution system operators is to know the actual location of all their assets with certainty in order to properly manage the network and provide the best possible service to their customers. In this work, we present a procedure for identifying which meters are connected to which low voltage feeders or distribution lines in smart grids. It is based on the formulation of the problem as a 0-1 optimization model with as many variables as the number of meters to be identified in the different feeders, and a number of constraints proportional to the points in time considered from the data. Given the large size of the problem in practice, its resolution through the use of conventional optimization software becomes unfeasible. Based on this approach, and making use of a stronger reformulation of the relaxation of the problem and some analytics on the data, an iterative procedure that allows recovering the integer solution of the initial model in an efficient way is developed. A computational experience has been carried out on a set of anonymized real data, obtaining results that support the efficiency of the proposed procedure.

Keywords: connectivity model, 0-1 optimization, iterative algorithm.

FC3 Logistics, Transportation and Distribution Planning 1

Chairperson: Gebrail Bekdaş

Single-track railways systems. G. Pawlak

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Rail transport systems are considered one of the most reliable transport systems for various reasons. Therefore, single-track railways are built and used in many regions of the world. The preset study, motivated by practical examples, takes into consideration currently tested single-track railway models from task scheduling point of view. Several models and practical solutions to the problem of scheduling tasks on a single-track railway line have been presented. Moreover, it was shown that it can be indeed effective to use this type of line, taking into account its natural limitations. From theoretical perspective, this approach leads to the analysis of numerous models and cases taking into account different criteria functions, and thus different ways of solving them out. Carrying out such an analysis both from modeling real systems and suggesting appropriately effective algorithmic solutions point of view, gives tangible benefits to users of such railway lines. Consequently, the present paper collects results of recent research efforts in this area and presents its relevant results.

Keywords: railways, scheduling, algorithms, complexity, models.

Robustness due to mass uncertainty for optimization of active control system via jaya algorithm. S. Ulusoy, S.M. Nigdeli, G. Bekdaş

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Unwanted vibrations or high amplitudes occur in the structures with the effect of seismic excitation such as earthquakes. These vibrations and amplitudes have destructive effects on the structure as well as reducing the comfort of the structure. For this reason, it is an important task of structural engineers to make the structure more stable at the time of an earthquake by adding different control systems. In this study, an active tendon control system with Proportional Integral Derivative (PID) controller is used in a single degree of freedom system (SDOF). The parameters of the PID controller are determined by the Jaya Algorithm (JA), which is one of the metaheuristic algorithms. The optimum parameters are calculated as a result of 10000 iterations. Then, these parameters have been investigated for the effect of the active tendons on the structure when the mass of the structure increases by 5, 10, 15 and 20 % due to the change of live loads. As a result, the optimum results are an effective approach to find the optimum parameters of active tendon-controlled structures under seismic excitation.

Keywords: Robustness, Optimization, Active Structural System, Metaheuristics.

A graph neural network based approach for Airport Gate Assignment Problem. N.E.H. Sayah Ben Aissa, A.N. Medakene, K. Bouanane, M.L. Kherfi

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In this study, we tackle the problem of assigning n flights to m gates, called Airport Gate Assignment Problem (AGAP). We study the case in which flights can be assigned to gates such that constraints on flight and gate sizes as well as conditions on flights' arrival and departure times are considered. The maximization of the robustness and the total preference for flight-gate assignment are taken into account. We define a novel graph formulation for AGAP as a weighted m-coloring problem and equivalently as a graph clustering task. This allows to apply a clustering based Graph Neural Network (GNN) method as a powerful tool that addresses graph representations with deep learning algorithms. The proposed algorithm aims to find an efficient clustering of vertices in the constructed graph and thus an optimal assignment of flights under the aforementioned constraints. To reach our goal, some modifications on the GNN algorithm are performed, where the total weight in the graph formulation is integrated in the loss function of the original algorithm. This permits to enhance the learning process of the model and obtain an acceptable solution with regard to our objectives.

Keywords: Airport Gate Assignment Problem, Graph Coloring, Graph Neural Network, Graph Clustering.

FD1 Graphs and Networks 4

Chairperson: Alain Hertz

On the edge dimension and fractional edge dimension of graphs. E. Yi

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Kelenc et al. [Discrete Appl. Math. 251 (2018) 204-220] introduced the notion of edge dimension, a variant of metric dimension. Assuming that some vertices are equipped with landmarks (or sensors), the question is the minimum number of such landmarks needed in order for a robot to know its location from the landmarks at all times as the robot moves from edge to edge. The edge dimension of a graph G is the minimum cardinality of a subset of vertices of G such that every edge of G is uniquely determined by its vector of distances to the chosen vertices.

In this talk, we obtain some general results on edge dimension and initiate the study of fractional edge dimension. We show that the set of edge metric coordinates does not uniquely determine a graph and that edge dimension is not a monotone parameter on subgraph inclusion. We examine the relation between planarity and the graphs with edge dimension two. We also compare fractional metric dimension and fractional edge dimension, among others.

Keywords: metric dimension, edge dimension, fractional metric dimension, fractional edge dimension.

Decomposing graphs into interval colorable subgraphs and no-wait multi-stage schedules. C.J. Casselgren, A.S. Asratian, P. Petrosyan

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A graph G interval colorable if it has a proper edge coloring with colors 1,2,3,... such that the colors of the edges incident to every vertex of G form an interval of integers. Not all graphs are interval colorable; in fact, quite few families have been proved to admit interval colorings.

We introduce and investigate a new notion, the interval coloring thickness of a graph G, which is the minimum number of interval colorable edge-disjoint subgraphs of G whose union is G. Our investigation is motivated by scheduling problems with compactness requirements, in particular, problems whose solution may consist of several schedules, but where each schedule must not contain any waiting periods or idle times for all involved parties. We prove that every connected properly 3-edge colorable graph with maximum degree 3 is interval colorable, and using this result, we deduce an upper bound on the interval coloring thickness of a general graph. We demonstrate that this upper bound can be improved in the case when G is bipartite, planar or complete multipartite.

Keywords: edge coloring, interval edge coloring, compact scheduling, timetabling.

On the average number of colors in the non-equivalent colorings of a graph. G. Devillez, A. Hertz, H. Mélot, S. Bonte, P. Hauweele

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A coloring of a graph is an assignment of colors to its vertices such that adjacent vertices have different colors. Two colorings are equivalent if they induce the same partition of the vertex set into color classes. Let $\overline{(G)}$ be the average number of colors in the non-equivalent colorings of a graph G. We give properties and state open problems of this recently defined graph invariant.

Keywords: Graph coloring, Average number of colors, Graphical Bell numbers.

FD2 Location

Friday, June 11, 14:45, 2- LV Kantorovich

Chairperson: Maria Merino

Optimization of the ultimate shear and lateral-torsional buckling capacities of a plate girder with respect to the cross-sectional parameters using metaheuristic algorithms. C. Cakiroglu, G.B. Bekdaş

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Lateral torsional buckling and shear buckling are two of the most important structural behaviors that should be assiduously analyzed. One of the most recent incidents where lateral-torsional buckling was initiated due to insufficient bracing of plate girders was observed in Edmonton, Alberta, Canada during the replacement of bridge girders. The main goal of the current study is to acquire information about the effects of additional parameters such as the warping constant and the St. Venant's torsion constant on the lateral-torsional buckling load and the ultimate shear strength. To this end, the critical buckling moment and ultimate shear strength of a plate girder are optimized by changing various cross-sectional parameters. The results of this study clarify the effects of the warping constant and St. Venant's torsion constant on the structural performance of a plate girder. The visualization of the results was used to identify the ranges of these geometric parameters most favorable to the structural performance. The optimization of the cross-sectional dimensions was carried out using novel meta-heuristic optimization algorithms such as the harmony search algorithm.

Keywords: Optimization, harmony search, lateral torsional buckling, tension field theory.

An improved exact algorithm for a territory design problem with p-center-based dispersion minimization. R. Ríos, M.G. Sandoval Esquivel, J.A. Díaz

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Territory design deals with the discrete assignment of geographical units into territories subject to planning criteria. In this talk, we present an exact solution method based on an integer programming model with the objective of minimizing a p-center dispersion measure. The solution approach is an iterative algorithm that makes use of auxiliary covering-based models that help validate if, for given values of the objective function of the original problem, it is possible to find feasible solutions with at most p territories. This change allows testing various candidate distance values as lower bounds on the optimal solution of the original problem. These lower bounds are iteratively improved through a cut-generation scheme. Empirical tests on instances with up to 300 basic units reveal that the proposed algorithm performs significantly faster than the best-known exact solution method for this problem.

Keywords: Districting; p-Center Problem; Exact algorithm; Cut generation.

A two stage stochastic optimization model for ambulance location-allocation under coverage equity and response time efficiency. I. Gago, U. Aldasoro, J. Ceberio, M. Merino

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Emergency Medical Services are essential to health systems as their effective management can improve the prognosis of patients. Nevertheless, due to the complex nature of these systems, designing an optimized distribution of resources is a challenging task. Using mathematical modelling and optimization, the problems of locating or sizing the ambulance fleet can be resolved in a more efficient way. We have considered a pilot case in the Basque Public Emergency Medical Service. The related region has five major urban areas which cover half of the emergencies, while the rural area, with sparse population, accounts for very few emergencies. Since a minimum coverage level should be guaranteed in all areas, components of fairness will be added to the proposed model. To that end, a pure 0-1 two stage stochastic optimization model has been proposed, taking into consideration two types of decisions: tactical ones, for stations location and operational ones, where assignments of ambulances to emergencies are optimized. The main contribution of this model relies on the ability to cover emergencies in an equitable manner, at three level response time thresholds, via a multi-objective function.

Keywords: Healthcare facility location and relocation, Emergency Medical Services, Stochastic optimization, Effectiveness and Equity, Modelling.

FD3 Logistics, Transportation and Distribution Planning 2

Chairperson: M. Grazia Speranza

Crew rostering for toll enforcement – efficiency and employee friendliness. E. Swarat

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We present an optimization approach on the enforcement of the truck toll on German motorways. It is partly conducted by spot-checks of mobile control inspectors. In a research and development project with the control agency, we consider the task to optimize the mobile control tours for the inspectors. In addition, feasible rosters need to be generated. We tackle the problem by a standard multi-commodity flow model with some extensions in order to incorporate the control tours.

The major task is to find a compromise between quality and quantity of controls as well as providing fair roster schedules for the inspectors such that the acceptance of the optimized schedules can be increased. We will consider how to distribute undesirable duties in a fair fashion among the inspectors and how uneven duty sequences can be penalized by soft constraints. We will present computational results for real-world instances indicating that employee-friendly rosters can be achieved with almost no loss of control quality. And the influence of employee-related aspects on the solvability is evaluated.

Keywords: Crew Rostering, Large Scale Integer Programming, OR in practice.

Freight car network optimization and train scheduling. S. Frisch

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The Rail Cargo Austria (RCA) transports 113 million tons per year through the Austrian railway network. This requires many resources and cost-efficient strategies. The problem of obtaining a schedule for freight cars is typically solved in two steps. First, the Freight Car Routing Problem (FCRP) aims to ship all freight cars from their origins to their destinations while satisfying line and shunting yard capacities. After the freight car flows through the network are fixed, the Freight Train Scheduling Problem (FTSP) is solved by determining optimal departure and arrival times while travel time restrictions are satisfied. In this work, we develop an integrated mathematical model that solves the FCRP, the FTSP and additionally constructs an optimal routing matrix due to RCA's demands. While neither, solving the FCRP, solving the FTSP nor constructing a routing matrix is a novel idea, solving the combination of all three components in an integrated approach is. Additionally, we provide an extensive computational study based on real world instances derived from RCA. We consider utilization of trains, waiting times, shunting processes, and the effects of different routing strategies.

Keywords: Freight Car Routing, Network Optimization, Train Scheduling, Integer Linear Programing.

Efficient loading and unloading operations via a booking system. M.G. Speranza, A. Mor, J. Viegas

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

Keywords: Freight distribution, Routing, Traveling Salesman Problem.

FE1-P3 Plenary. On dynamic multiple allocation capacitated hub location expansion planning under uncertainty

Chairperson: Antonio Alonso-Ayuso

On dynamic multiple allocation capacitated hub location expansion planning under uncertainty. L.F. Escudero

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This work focuses on a stochastic mixed-integer linear optimization modeling framework and a matheuristic approach for solving the multistage capacitated allocation hub location network expansion planning under uncertainty. The strategic decisions are the hub location in a network and their initial capacity dimensioning as well as its expansion along a time horizon. Two types of uncertain parameters are considered namely, strategic and operational ones. The strategic uncertainty is stagewise-dependent. The operational uncertainty is stage-dependent, both being captured by a finite set of scenarios. Given the dimensions of the instances in real-life applications (due to the large-scale hub network dimensions and the cardinality of the joint strategic multistage operational two-stage scenario trees to properly represent the inherent uncertainty, it is unrealistic to seek the optimal solution. So, a sort of matheuristics should be looked for. The so-named SFR3 matheuristic decomposition algorithm is introduced for Scenario variables Fixing and constraints and binary variables' integrality iteratively Randomized Relaxation Reduction, where several strategies are considered. The performance of the overall approach is computationally assessed by using stochastic-based perturbed well-known CAB data.

Keywords: hub network location, stochastic optimization, multistage network expansion planning, strategic and tactical uncertainties, fix-and-randomized-relaxation-reduction matheuristic..

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