ISCO 2014

3rd International Symposium on Combinatorial Optimization

5-7 March 2014, Lisbon, Portugal

Centro de Investigação Operacional

Contents

WELCOME

Welcome to the 3rd International Symposium on Combinatorial Optimization at the Radisson Blu Hotel, Lisboa, Portugal!

ISCO is a biannual symposium whose aim is to gather researchers from combinatorial optimization and other related fields of operations research.

It is intended to be a forum for the exchange of recent scientific developments and for the discussion of new trends.

We have received more than 160 submissions with a high standard quality, from a large variety of countries.

Of the 100 paper submissions submitted to the LNCS proceedings, nearly 40 were accepted.

The final program contains 108 talks (in 32 sessions) plus 3 plenaries by well known researchers in the field.

We wish all the participants an excellent conference! Enjoy!

All the best,

On behalf of the program chairs

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- Luís Gouveia and Ridha Mahjoub

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Guidelines for session chairs

Each session will be coordinated by a member of the Organizing Committee. The chair must:

- contact the speakers before the session to verify their presence;
- guarantee that each session begins and ends on time. In every parallel session, each speaker will be given 25 minutes, including questions. In every plenary session, the plenary speaker will be given 45 minutes, including questions;
- guarantee that the presentations follow the program schedule to allow participants to switch between sessions. In case of a missing speaker the given schedule should still be maintained;

Guidelines for speakers

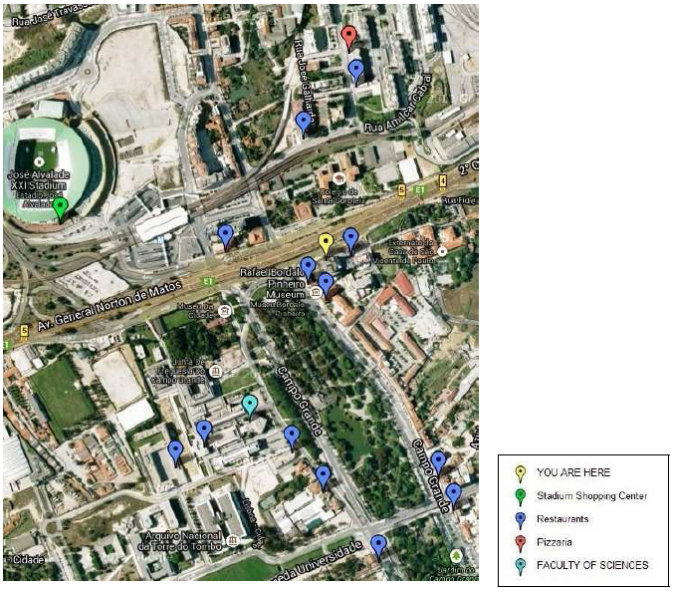
- All session rooms are equipped with DLP video projectors, a laptop, a flipchart and mineral waters for the speakers.
- As a safety measure, you may use your own laptop to ensure that the right software version will be used in your presentation and that no fonts and templates are lost. In this case,
  - you should not forget to bring the supply cord of your laptop;
  - you may need an adapter to connect your laptop to the local voltage - 220V - and wall plug type;
  - if your laptop is a MAC, you should also bring the required adapter for the external video output.
- Please try to arrive early at your own session before it begins in order to set up and test the connection to the projector.
- As an extra advice the speakers should keep a backup copy of their presentation on an USB pen (*e.g.*, the customized conference USB).
- The session code at the the header of each session (see the Quick Program) identifies the day, the period of the day and the room. For example, session WA-I takes place on Wednesday - W, on the first period - A, on room Miguel Ângelo I. Session FB-II takes place on Friday - F, on the second period - B, on room Miguel Ângelo II.

Registration desk

The registration desk will be located in the basement floor of the hotel, next to the conference rooms. It will be opened on Tuesday from 17:00 to 19:00. On Wednesday it will be opened at 7:30. The conference material consists of: a bag with your badge and attendance certificate, a fountain pen and notebook, a customized conference USB with the digital book of Abstracts and a map of Lisbon.

Lunches

Several restaurants are located around the hotel area (see the map below) where you can have lunch (and/or dinner) during the conference. This list also includes the restaurant at the hotel.



Coffee-breaks

There will be one coffee-break on the morning period and another in the afternoon period.

Social Events

On Wednesday, from 18:30 to 20:00, a Welcome Reception will be held at the hotel bar.

On Thursday, there will be a tour in Lisboa. The meeting point is the Hotel entrance. Buses leave at 17.00 and the tour ends near the restaurant of the Conference dinner. The dinner will be held in a Castle, Castelo de São Jorge, in the picturesque district of Alfama. After dinner, transportation back to Radisson Blu Hotel is available.

Special issues

Special issues of Lecture Notes in Computer Science

Accepted regular papers (with up to 12 pages) will be published by Springer-Verlag in the Lecture Notes in Computer Science (LNCS) series in a post-conference proceedings volume. For a paper to be included in this volume, it should be presented at the conference by one of the authors. The authors will have to prepare their camera-ready version until the 4th of April 2014.

Guest editors: Pierre Fouilhoux, Luís Gouveia, Ridha Mahjoub and Vangelis Paschos

Special issue of Discrete Optimization

A special issue of Discrete Optimization on "Combinatorial Optimization" will also be associated to ISCO2014. The deadline for submission is the 31st of July 2014.

Guest editors: Luís Gouveia, Andrea Lodi and Ridha Mahjoub

Wednesday

7:30 - 8:00	Registration
8:00 - 8:10	Opening Session
8:10 - 8:55	WP: Plenary Session
8:55 - 9:00	break
9:00 - 10:15	WA: Parallel Sessions
10:15 - 10:30	Coffee break
10:30 - 12:10	WB: Parallel Sessions
12:10 - 14:00	Lunch (on your own)
14:00 - 15:40	WC: Parallel Sessions
15:40 - 16:00	Coffee break
16:00 - 17:40	WD: Parallel Sessions
18:30 - 20:00	Welcome Reception

Thursday

8:30 - 9:15	TP: Plenary Session
9:15 - 9:30	break
9:30 - 10:45	TA: Parallel Sessions
10:45 - 11:00	Coffee break
11:00 - 12:15	TB: Parallel Sessions
12:15 - 14:00	Lunch (on your own)
14:00 - 15:40	TC: Parallel Sessions
15:40 - 16:00	Coffee break
17:00 - 19.00	Lisbon Tour
19:30	Conference dinner

Friday

9:30 - 10:15	FP: Plenary Session
10:15 - 10:30	Coffee break
10:30 - 12:10	FB: Parallel Sessions
12:10 - 14:00	Lunch (on your own)
10:15 - 10:30	break
14:00 - 15:15	FC: Parallel Sessions
15:15 - 15:30	Coffee break
15:30 - 16:45	FD: Parallel Sessions
17:00 - 17.30	Closing Session and Dissertation Award Prize

Quick Program

Wednesday, 5 March, 2014

7:30 - 8:00	Registration: Basement		
8:00 - 8:10	Opening Session: room Miguel Ângelo II + III		
8:10 - 8:55	**Session WP**: room Miguel Ângelo II + III **Martin Grötschel - Routing problems: Standard and unusual cases** Chair: Ridha Mahjoub		
8:55 - 9:00	break		
9:00 - 10:15	**Session WA-I** **Routing/Polyhedra** Chair: Pierre Pesneau	**Session WA-II** **Integer Linear Programming I** Chair: Maria Grazia Scutella	**Session WA-III** **Robust Optimization I** Chair: Ivana Ljubic
	Daniel Espinoza 2-parity inequalities for the traveling salesman problem: Separation and lifting	Paula Carroll Unit Commitment Models and Benchmark Problems	Jean-François Baffier Parametric Multiroute Flow and its Application to Robust Network with k Edge Failures
	Ibrahima Diarrassouba Separation of the CVRP Rounded Capacity Cut Inequalities: Complexity and Applications to Rooted Partition Inequalities	Carlos Casorrán-Amilburu Novel Formulations for Stackelberg Security Games	Marisa Resende Algorithms for the min-max regret robust shortest path problem in a finite multi-scenario model
	Maria Teresa Godinho On the Single Commodity Flow Formulation: Generalizing the Upper and Lower Flow Bounding Inequalities	Phuoc Hoang Le Generalized Minimum Spanning Tree Games	Ivana Ljubiic The Recoverable Robust Facility Location Problem
10:15 - 10:30	Coffee Break: Basement Atrium		
10:30 - 12:10	**Session WB-I** **Routing I** Chair: Annegret Wagler	**Session WB-II** **Integer Linear Programming II** Chair: Bernard Gendron	**Session WB-III** **Trees I** Chair: S. Raghavan
	Thibaut Barthelemy A multi-objective Recovering Beam Search and its application to the TSP with Profits	Hacene Ouzia Two New Reformulation Convexification Based Hierarchies for 0-1 MIPs	Naoyuki Kamiyama Packing Arborescences in Acyclic Temporal Networks
	Maria João Cortinhal Local search heuristics for residential waste collection problems	Ruslan Sadykov Combining dual price smoothing and piecewise linear penalty function stabilization in column generation: experimental results	Sandro Montanari Rectilinear Shortest Path and Rectilinear Minimum Spanning Tree with Neighborhoods
	Elyn Solano-Charris Heuristic Approaches for the Robust Vehicle Routing Problem	Agostinho Agra Valid inequalities for a MIP set with variable conflicts	Olga Oliveira Tree inference from a distance matrix
	Kadri Sylejmani Planning Trip Itinerary for Tourist Groups via a Tabu Search Algorithm	Bernard Gendron Reformulations by Discretization for Piecewise Linear Integer Multicommodity Network Flow Problems	S. Raghavan A Tight Extended Formulation for the Weighted Target Set Selection Problem on Trees
12:10 - 14:00	Lunch (on your own)		

Wednesday, 5 March, 2014

14:00 - 15:40	**Session WC-I** **Routing: Pick up and delivery** Chair: Juan José Salazar González	**Session WC-II** **Integer Linear Programming III** Chair: Maria Teresa Almeida	**Session WC-III** **Network Design I** Chair: Thibaut Lefebvre	**Session WC-IV** **Non-Linear Programming** Chair: Jon Lee
	Annegret Wagler On Resolving the Static Relocation Problem in Carsharing Systems	Graciela Nasini A tabu search heuristic for the Equitable Coloring Problem	Mateusz Zotkiewicz Fast algorithms for access network design	Pauline Sarrabezolles Colorful Linear Programming, Nash Eequilibrium and Pivots
	Agustin Montero An ILP-based heuristic for the VRP with pickups and deliveries	Noriyoshi Sukegawa Fractional programming formulation for the vertex coloring problem	Amal Benhamiche Optical Multi-Band Network Design problem : polyhedron and Branch-and-Cut	Long Trieu Active Set Methods with Reoptimization for Convex Quadratic Integer Programming
	Mario Ruthmair Modeling and Solving the One-to-One Multi-Commodity Pickup and Delivery Traveling Salesman Problem	Martin Fürer Approximating the k-Set Packing Problem by Local Improvements	Thibaut Lefebvre Network coding and multi-terminal flow problems	Geir Dahl Optimization and classes of completely positive matrices
	Juan José Salazar González Solving the one-commodity pickup-and-delivery single-vehicle routing problem with split demands	Maria Teresa Almeida Integer models for the triangle k-club problem		Jon Lee On global optimization with indefinite quadratics
15:40 - 16:00	Coffee break: Basement Atrium			
16:00 - 17:40	**Session WD-I** **Graphs I** Chair: Domingos Cardoso	**Session WD-II** **Integer Linear Programming IV** Chair: Pierre Fouilhoux	**Session WD-III** **Robust Optimization II** Chair: Sara Mattia	**Session WD-IV** **Scheduling I** Chair: Miguel Constantino
	Valeria Alejandra Leoni $\{k\}$-packing Functions of Graphs	Silvia Bianchi Study of identifying code polyhedra for some families of split graphs	Anna Ilyina Lagrangean Decomposition for Mean-Variance Combinatorial Optimization	Gulcin Ermis A branch and bound algorithm for scheduling chains with nonnegative timelags, arbitrary processing times and release times to minimize sum of completion times
	Toshimasa Ishii Subexponential Fixed-parameter Algroithms for Partial Vector Domination	Riccardo Dondi Fixed-Parameter Algorithms for Scaffold Filling	Martin Tieves A Modelling Framework for Multiple Sources of Data-Uncertainty in Combinatorial Optimization Problems	Paolo Serafini A time indexed model for Open Shop and Job Shop with three operations
	Karlis Freivalds Graph Compact Layout Algorithm	Yanina Lucarini Progress on identifying codes in cycles	Sara Mattia Robust shift scheduling in call centers	Imed Kacem Fully Polynomial Time Approximation Scheme for the Maximum Lateness Minimization on a Single Processor with a Fixed Operator or Machine Non-Availability Interval
	Sofia J. Pinheiro Spectral bounds for the k-regular induced subgraph problem	Pascale Bendotti An integer formulation based on common supersequences to solve the Permutation Problem using a Unit-Capacity Robot		
18:30 - 20:00	Welcome Reception : Hotel Atrium (groundfloor)			

Thursday, 6 March, 2014

8:30 - 9:15	**Session WP**: room Miguel Ângelo II + III **Matteo Fischetti - BRANCHstorming (brainstorming about tree search)** Chair: Giovanni Rinaldi		
9:15 - 9:30	break		
9:30 - 10:45	**Session TA-I** **Scheduling II** Chair: Luís Florêncio	**Session TA-II** **Integer Linear Programming V** Chair: Martine Labbè	**Session TA-III** **Trees II** Chair: Geir Dahl
	Ruben Hoeksma Decomposition Algorithm for the Single Machine Scheduling Polytope	Alessia Violin A Branch-and-Price for the Network Pricing Problem with Connected Toll Arcs	Borzou Rostami Improved Lower Bound for the Quadratic Minimum Spanning Tree Problem
	Vincent T'Kindt A constraint generation approach for the two-machine flow shop problem with jobs selection	Rafael Schouery The Envy-Free Pricing Problem and Unit-Demand Markets	Alexandre Salles Da Cunha Finding Totally Independent Spanning Trees with Linear Integer Programming
	Luís Florêncio A hybrid algorithm for the unrelated parallel machine scheduling problem with job splitting	Rui Zhang Engineering Diffusion on a Social Network at Minimum Cost	Markus Leitner A polyhedral study of the diameter constrained minimum spanning tree problem
10:45 - 11:00	Coffee Break: Basement Atrium		
11:00 - 12:15	**Session TB-I** **Rounting II** Chair: Angel Corberan	**Session TB-II** **Integer Linear Programming VI** Chair: Agostinho Agra	**Session TB-III** **Network Design II** Chair: Pedro Moura
	Ana Catarina Nunes The mixed capacitated arc routing problem with non-overlapping routes	Alexandre Freire An integer programming formulation for the Maximum k-Subset Intersection problem	Aurélien Questel Branch-and-Cut-and-Price using Stable Set polytope inequalities for the Capacitated-Ring-Star Problem
	Petrica Pop A novel approach for solving the Generalized Vehicle Routing Problem	Zacharie Ales An Extended Formulation for K-Partitioning	Julija Asmuss Adaptive Optimization of Bandwidth Resource Allocation for Virtual Networks
	Angel Corberan New results on the Generalized Directed Rural Postman Problem	Pedro Martins Mining biological networks using weighted cliques	Leonardo Taccari Maximum throughput network routing subject to fair flow allocation
12:15 - 14:00	Lunch (on your own)		
14:00 - 15:40	**Session TC-I** **Rounting III** Chair: Alain Quilliot	**Session TC-II** **Knapsack** Chair: Arie Koster	**Session TC-III** **Graphs II** Chair: Carlos Luz
	Pasquale Avella Cutting planes for Multi-Vehicle Inventory Routing Problems	Franklin Djeumou Fomeni A Cut-and-Branch Algorithm for the Quadratic Knapsack Problem	Mariana Escalante Lovász and Schrijver N_+-relaxation on web graphs
	Charlotte Vilhelmsen A Heuristic for the Tank Allocation Problem in Bulk Shipping	Michele Garraffa A hybrid heuristic approach based on a quadratic knapsack formulation for the Max-Mean Dispersion problem	Oliver Schaudt b-coloring is NP-hard on co-bipartite graphs and polytime solvable on tree-cographs
	Sophie Michel Planning of container transfers in a multimodal platform	Sagvan Saleh A fast large neighborhood search for disjunctively constrained knapsack problems	Carlos Luz A simplex like approach based on star sets for recognizing convex-QP adverse graphs
	Alain Quilliot Branch and Price for a Reliability Oriented DARP Model	Grit Claßen A Dynamic Program for the Multi-Band Robust Knapsack	
15:40 - 16:00	Coffee break: Basement Atrium		
17:00 - 19.00	Tour in Lisbon (meeting point at the hotel entrance)		
19:30	Dinner: Castelo S.Jorge - City Center		

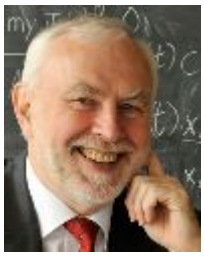
Friday, 7 March, 2014

9:30 - 10:15	**Session FP**: room Miguel Ângelo II + III **Michel Balinski - Judge: Don't Vote!** Chair: Luís Gouveia		
10:15 - 10:30	Coffee Break: Basement Atrium		
10:30 - 12:10	**Session FB-I** **Transportation Routing** Chair: Ana Paias	**Session FB-II** **Integer Linear Programming VII** Chair: Janny Leung	**Session FB-III** **Polyhedra** Chair: Mourad Baiou
	Claudio Contardo Resource-based cycle elimination applied to the vehicle routing problem	Alain Quilliot Linear Arrangement Problems and Interval Graphs	Stefano Coniglio On the exact separation of rank inequalities for the stable set problem
	Martin Kidd State space reduced dynamic programming for the aircraft sequencing problem with constrained position shifting	Brian Curcio Linear Ordering Problem with Penalties	Markus Sinnl On the Asymmetric Connected Facility Location Polytope
	Pedro Munari Using an interior point branch-price-and-cut method for solving variants of the vehicle routing problem	Mathieu Lacroix Circuit and bond polytopes in series-parallel graphs	Mourad Baiou The dominating set polytope via facility location
	Marta Mesquita MIP-based heuristics for driver rostering	Janny Leung On the Mixed Odd Hole Inequality	
12:10 - 14:00	Lunch (on your own)		
14:00 - 15:15	**Session FC-I** **Stochastic** Chair: Rüdiger Schultz	**Session FC-II** **Integer Linear Programming VIII** Chair: Conceição Fonseca	**Session FC-III** **Trees III** Chair: Bernard Fortz
	Yohanes Kristianto A Multi-period Bi-level Stochastic Programming with Decision Dependent Uncertainty in Supply Chains	Kamel Zeltni Multi-objective Cuckoo Search with Leader Selection Strategies	Olaf Maurer Integer Programming Formulations for the Node-Weighted Group Steiner Tree Problem
	Mario Brcic Proactive Reactive Scheduling in Resource Constrained Projects with Flexibility and Quality Robustness Requirements	Sara Veronica Rodriguez-Sanchez A mixed integer linear program for planning and scheduling the meat production in a pork supply chain	Cristina Requejo Formulations and heuristic methods for the Weight-Constrained Minimum Spanning Tree Problem
	Dennis Weyland The Computational Complexity of Stochastic Optimization	Ismaila Abderhamane Ndiaye Multicriteria pedestrian evacuation plan for natural disasters with safety and duration	Martim Moniz Mathematical programming models for Traffic Engineering in Ethernet networks implementing the Multiple Spanning Tree Protocol
15:15 - 15:30	Coffee break: Basement Atrium		
15:30 - 16:45	**Session FD-I** **Graphs III** Chair: Ioannis Milis	**Session FD-II** **Integer Linear Programming IX** Chair: José Valério de Carvalho	**Session FD-III** **Network Design III** Chair: Vangelis Paschos
	Gilles Simonin Coupled-tasks in presence of bipartite compatibilities graphs	Dimitri Thomopulos Modeling Two-Dimensional Guillotine Problems via Integer Programming	Eduardo Álvarez-Miranda Vulnerability Assessment of Spatial Networks: Models and Solutions
	Dang Phuong Nguyen Stochastic Graph Partitioning	Marco Bender Maximum Generalized Assignment with Convex Costs	Ruben Becker On Min-Cost Flows in Planar Graphs
	Paolo Detti Solving Graph Partitioning problems arising in tagless cache management	José Valério de Carvalho Multidimensional dual-feasible functions and fast lower bounds for the vector packing problem	Hovhannes Harutyunyan Approximation Algorithm for the Broadcast Time in k-path Graph
17:00 - 17.30	Closing Session: room Miguel Ângelo II + III		

Plenary Sessions

WP

Wednesday, 8:30 - 9:15
Room: Miguel Ângelo II + III
Plenary Talk
chair: Ridha Mahjoub



Routing problems: Standard and unusual cases

Martin Grötschel, *Züse Institute Berlin*,

Shortest path, Chinese postman and symmetric travelling salesman problems are combinatorial optimization problems with a rich theory. They have undergone extensive computational studies and can be viewed as "solved" for the majority of their practical applications. However, most routing problems are not so nicely structured. They often come with various combinations of side constraints such as capacity, depot and ordering constraints as well as time windows, with online or real-time requirements and possibly multiple objective functions. Such routing problems are notoriously difficult and a typical playground for heuristics. In the last 30 years my research group has covered a large variety of routing problems in public transport, logistics, general transportation, machine and emergency scheduling, etc. I plan to give a broad survey on these problems as well as on successful solution approaches, and I will concentrate on particular cases that we are currently working on. These include train scheduling (high-speed trains ICE in Germany with uncommon "regularity requirements") and a quite unusual routing problem where vehicles have to be routed "optimally" to catch trucks on the German Autobahn that try to avoid the payment of road tolls. Needless to say, that these inspection vehicles have to satisfy several nonstandard legal requirements.

TP

Thursday, 8:10 - 8:55
Room: Miguel Ângelo II + III
Plenary Talk
chair: Giovanni Rinaldi

BRANCHstorming (brainstorming about tree search)

Matteo Fischetti, *Padova University*,

Quoting from Wikipedia http://en.wikipedia.org/wiki/System_dynamics: "System Dynamics is an aspect of systems theory as a method for understanding the dynamic behavior of complex systems. The basis of the method is the recognition that the structure of any system - the many circular, interlocking, sometimes time-delayed relationships among its components - is often just as important in determining its behavior as the individual components themselves. Examples are chaos theory and social dynamics. It is also claimed that because there are often properties-of-the-whole which cannot be found among the properties-of-the-elements, in some cases the behavior of the whole cannot be explained in terms of the behavior of the parts."
No doubts that tree search is a very complex process with its own dynamics, that sometimes behaves as a chaotic system due to its high dependency on the initial conditions.
However, tree search is seldom studied as a whole by the Mathematical Programming community, perhaps because it is often perceived as a shame—we should be able to solve our problems at the root node, don't we? As a matter of fact, its main ingredients (e.g., cut generation and selection) are often studied in vitro—i.e., evaluated "at the root node"—and then just transplanted in the enumeration body with significant organ-rejection rates.
The study of the properties-of-the-whole of tree search is of course a long-term project. In this talk we will make a mandatory preliminary step by addressing a number of preconceptions about it.
We will start reviewing recent work on the role of erraticism in the design and validation of tree-search algorithms, thus addressing the prejudice that enumeration is a stable mechanism whose performance only depends on how clever we are in designing its single elements. We will then address a main source of erraticism in a branch-and-bound scheme, namely, the existence of multiple relaxation solutions. In particular, we will comment about the risk of overfitting due to the common practice of uncritically picking one such solution (or just few) for guiding the search.

FP

Friday, 9:30 - 10:15
Room: Miguel Ângelo II + III
Plenary Talk
chair: Luís Gouveia

Judge: Don't Vote!

Michel Balinski, *CNRS and Ecole Polytechnique Paris*,

This talk argues that the traditional methods of voting and judging contestants (e.g., figure skaters, movies, wines, beauty queens, political candidates) fail in both theory and practice and should be replaced by a new method, "majority judgment." Majority judgment best meets five essential properties: (1) It avoids the Condorcet and Arrow paradoxes, (2) it elicits honest voting, (3) it is meaningful (in the sense of measurement theory), (4) it resists manipulation, and (5) it heeds the majority's will.

References: Michel Balinski and Rida Laraki, 2010. Majority Judgment: Measuring, Ranking and Electing. Cambridge, MA and London: MIT Press.
–and– , 2013. "Judge: Don't vote!" To appear in Operations Research.

Parallel Sessions

Wednesday

WA-I

9:00 - 10:15
Room: Miguel Ângelo I

Routing/Polyhedra

Contributed session
chair: Pierre Pesneau

2-parity inequalities for the traveling salesman problem: Separation and lifting

Daniel Espinoza, *Universidad de Chile*, daespino@gmail.com
Co-author(s): William Cook, bico@uwaterloo.ca, University of Waterloo; Marcos Goycoolea, marcos.goycoolea@uai.cl, Universidad Adolfo Ibanez.

The effectiveness of IP methods for solving general instances of the traveling salesman problems, mainly rest on the ability of efficiently separating high-dimensional faces of the polyhedron induced by the set of feasible solutions. Although a large family of facet-defining inequalities are known for the TSP, very few of them can be separated in polynomial time. Some of the few exceptions are sub-tour inequalities, simple comb inequalities; and, when the support graph is planar, domino parities and (more generally) k parities. In this work, we improve the practical complexity of the separation of one and 2-parity inequalities, we also provide new insight in the lifting problem of the resulting inequalities, i.e. the problem of taking the resulting inequality (valid in the support graph) and transform it into a valid inequality for the complete graph.

Separation of the CVRP Rounded Capacity Cut Inequalities: Complexity and Applications to Rooted Partition Inequalities

Ibrahima Diarrassouba, *Laboratoire de Mathématiques Appliquées du Havre - Université du Havre*, diarrasi@univ-lehavre.fr

In this paper, we are interested in the separation problem of the so-called Rounded Capacity Cut Inequalities which are valid for the CVRP (Capacitated Vehicle Routing Problem) polytope. The Rounded Capacity Cut Inequalities, as well as their separation problem, are of particular interest for solving the CVRP, especially when dealing with Branch-and-Cut algorithms. To the best of our knowledge, it is not known in the litterature whether this separation problem is NP-Hard or polynomial, and several authors devised heuristic algorithms to separate them. In this paper, we study a generalization of the Rounded Capacity Cut Inequalities and show that these inequalities, as well as Rounded Capacity Cut Inequalities, can be separated in polynomial time. We give an ((n-1)E(n,m +n))-time separation procedure where E(n,m+n) can be bounded by O(n4). Then, we discuss applications of the above result to the separation problem of the so-called Rooted Partition Inequalities, a class of valid inequalities for the polytopes of the rooted Two Node-Disjoint and rooted Two Edge-Disjoint Hop-Constrained Network Design Problems.

On the Single Commodity Flow Formulation: Generalizing the Upper and Lower Flow Bounding Inequalities

Maria Teresa Godinho, *Polytechnic Institute of Beja*, mtgodinho@ipbeja.pt
Co-author(s): Luís Gouveia, legouveia@fc.ul.pt, University of Lisbon,Faculty of Sciences, DEIO, CIO; Thomas L. Magnanti, magnanti@mit.edu, Massachusetts Institute of Technology-Dep. of Electrical Engineering and Computer Science and Sloan School of Management; Pierre Pesneau, pierre.pesneau@math.u-bordeaux1.fr, University of Bordeaux.

The unit-demand Capacitated Vehicle Routing Problem (CVRP) is defined on a given directed graph $G = (V, A)$ with a node set $V = 1, ..., n$ and an arc set A with an integer weight (cost) ca associated with each arc a of A, as well as a given natural number Q. The problem seeks a minimum cost set of routes originating and terminating at the depot (we assume that node 1 is the depot) with each node in $V - 1$ visited exactly once and each route containing at most Q nodes (plus the depot). Many integer linear formulations for the unit-demand Capacitated Vehicle Routing Problem (CVRP) use besides the topological variables, xa, that indicate whether or not a given arc a is in the solution, an extra set of variables to model the capacity constraints. In this talk we address one of those formulations, the well-known single commodity flow formulation by Gavish and Graves. In particular, we show how to generalize the linking constraints proposed in the original model, introducing a new large class of upper bounding and lower bounding flow constraints. For several of them we show that they are facet defining for the CVRP under mild assumptions. Then, we show how to obtain sets of inequalities defined in the space defined by the xa variables, by using Hoffman's theorem. Finally, we relate the new inequalities to the multistar constraints that are known to be implied by the linear programming feasible set of the original formulation.

WA-II

9:00 - 10:15
Room: Miguel Ângelo II

Integer Linear Programming I

Contributed session
chair: Maria Grazia Scutella

Unit Commitment Models and Benchmark Problems

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With a significant amount of interest in unit commitment (UC) within engineering literature, it is important for the optimisation community to consider the UC problem as improvements in solutions and algorithmic performance are desired.
The UC problem can be stated as that of determining the combination of electricity generating units to commit or decommit, so as to meet the expected power demand and satisfy the operating constraints of the gen- erating units and of the electricity system as a whole. The UC problem is linked to the Economic Dispatch (ED) problem which seeks to determine the committed units' power production. The interlinked problems are solved so as to minimise costs and/or other factors.
Transmission system operators (TSOs) currently solve mixed integer (lin- ear) programming

(MILP) models on a day-ahead basis at an hourly level. That is, the units to commit and their power levels per hour are determined the day before demand is to be met. UC /ED MILP models include constraints for the estimated generator power availability, esti- mated demand production, estimated renewable production and additional operational constraints. A particular concern in Ireland is the integration of wind production into the electricity grid. TSOs have indicated a need to optimise models at smaller time-steps to increase the ability of the electricity grid to re- spond to uctuating availability of renewable power sources and demand reserves. This gives rise to more challenging UC problem instances.
A key concern to practitioners and researchers is the empirical perfor- mance of their algorithms on real world data sets. This paper explores an overview of the current state of unit commitment models and algo- rithms, and presents a standard test case and data format based on an Irish case study. This allows for a more accurate and complete compar- ison of unit commitment models and algorithms. A MILP model and results are given.

Novel Formulations for Stackelberg Security Games

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Stackelberg Games confront contenders with opposed objectives sequentially. The Leader acts first and the Follower reacts to the Leader's strategy. The objective of the game is for the Leader to commit to a reward-maximizing strategy anticipating the Follower's best response.
In a Bayesian Stackelberg Game, which is NP-hard, the Leader faces one out of a group of Followers, otherwise the game is called a Single-type-of-Follower Stackelberg Game, which is polynomial (Conitzer and Sandholm, 2006). Moreover, games in which the respective strategies of the Leader and Follower consist in covering and attacking targets are called Stackelberg Security Games.
We present novel tight formulations for the Single-type-of-Follower Stackelberg Game and for the Single-type-of-Attacker Stackelberg Security Game, significantly improving the current formulations present in the literature (Paruchuri et al., 2008), (Kiekintveld et al., 2009). Further, we show that both formulations provide a complete linear description of the convex hull of the sets of feasible solutions of the corresponding problems and show that one formulation is the projection of the other on the appropriate space. The formulations presented for the Bayesian case improve the continuous relaxations of existing formulations. Computational experiments are carried out to compare our formulations with those in the literature.

Generalized Minimum Spanning Tree Games

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The minimum spanning tree game is a special class of cooperative games defined on a graph with a set of vertices and a set of edges, where each player owns a vertex. Solutions of the game represent ways to distribute the total cost of the minimum spanning tree among all the players. When the graph is partitioned into clusters, the generalized minimum spanning tree problem is to determine a minimum-cost tree including exactly one vertex from each

cluster. This paper introduces a new class of cooperative games called the generalized minimum spanning tree game and proposes a constraint generation algorithm to calculate a stable payoff distribution. The paper also presents some properties of this game and computational results with the proposed algorithm.

WA-III

9:00 - 10:15
Room: Miguel Ângelo III

Robust Optimization I

Contributed session
chair: Ivana Ljubic

Parametric Multiroute Flow and its Application to Robust Network with k Edge Failures

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In this work, we extend the definition of max-h-route flow to the case when the route number h can be non-integer. We show that a function taking the value h to the flow value is piecewise hyperbolic, and modify a parametric optimization technique, the ES algorithm, to find the function. The running time of the algorithm is $O(pmn)$, when p is a source-sink edge connectivity of our network, m is the number of links, and n is the number of nodes. We can use the result from that algorithm to solve two max-flow problems against k edge failures, referred to as max-k-robust flow and max-k-balanced flow. When h is optimally chosen from the function, we show that the max-h-route flow is an exact solution of both problems for graphs in a specific class. Our numerical experiments show that 98% of random graphs generated in the experiment are in that specific class. Given a parametric edge e, we also show that the function taking the capacity of e to the max-h-route flow value is linear piecewise. Hence we can apply our modified ES algorithm to find that function in $O(h^2mn)$ time.

Algorithms for the min-max regret robust shortest path problem in a finite multi-scenario model

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The robust shortest path problem is a well known problem that has been researched when interval data scenarios are considered over a given network with uncertain costs. In spite of this, such subject was not so extensively developed when the information is discrete. In this talk the minmax regret objective function on a finite multi-scenario model is adopted to solve the problem by minimizing the worst deviation cost with respect to the shortest path cost for all scenarios. Some properties of the optimum solutions regarding uniqueness, the presence of cycles and bounding of their costs are presented. As a consequence, three algorithmic strategies are devised, the first based on a labeling approach, the second on

a bounded ranking of loopless paths and the last supported on an hybrid version of the previous two, which allows to discard useless paths and spare computational effort. Some preprocessing techniques are also described, attempting to increase the methods' efficiency. The presented algorithms are tested on random networks and the computational results are analyzed.

The Recoverable Robust Facility Location Problem

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In many real-world applications, when modeling network and transporta- tion planning problems, one looks for solutions that should be robust for many different scenarios. For instance, when planning the location of medi- cal service facilities and the corresponding allocation of urban areas to them, decision makers should make decisions before knowing with complete cer- tainty potential location of facilities, or complete demographic characteristics of the surrounding areas. Such kind of uncertainty might arise in dynamic systems subject to geopolitical changes, natural disasters or eco- nomical crashes. In this work we are dealing with a facility location problem in which location and allocation policy is defined in two stages such that we are required to find a first-stage solution that should be robust against the possible realizations (scenarios) of the input data that are revealed in a second stage. The first-stage solution is expected to perform reasonably well, in terms of optimality and/or feasibility, for any possible realization of the uncertain parameters. This means that instead of looking for a solution that is robust against all possible scenarios without allowing any kind of recovery (which is the case for many classical robust optimization approaches) we want a solution robust enough so that it can be "recovered" promptly and at low cost in the second stage. For this novel problem we design a sophisticated algorithmic framework based on a Benders decomposition approach and complemented by several non-trivial enhancements, including dual lifting, branching priorities and zero-half cuts. Using two large sets of realistic instances we analyze in detail the characteristics of the proposed model and the obtained solutions as well as the effectiveness, behavior and limitations of the designed algorithm.

WB-I

10:30 - 12:10
Room: Miguel Ângelo I

Routing I

Contributed session
chair: Annegret Wagler

A multi-objective Recovering Beam Search and its application to the TSP with Profits

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A Beam Search procedure is a breadth-first Branch & Bound where, at each level of the

search tree, up to w nodes are kept only. That results in a meta-heuristic whose solving time is polynomial in the number of variables and w. Several authors chose Beam Search to solve single-objective problems, mostly scheduling-related ones, while only 2 articles address multi-objective optimization. In particular, there is no paradigm stating what a good node selection could be. In our Beam Search, we study five components (node evaluation, node selection, branching and two branching improvements). To design each one in a likely good way, a few theory and discussion are given. By means of experiments on the bi-objective TSP with Profits (BOTSPP), we show that they contribute to good results. The BOTSPP consists in finding cycles in a graph such that the sum of weights of the traversed edges is minimized while the sum of weights of the selected vertices is maximized.

Local search heuristics for residential waste collection problems

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This work addresses a residential waste collection problem, as a real world application of the sectoring arc routing problem. The aim is to assign the street services to the different vehicles, and then to determine the set of trips to be performed by each single vehicle such that all the required streets are serviced within a given objective. In this research work three objectives were taken into account: the total traveled time, the workload balance among the sectors, and the connectivity of each sector. The proposed solution methods were designed in order to favor the concentration of each vehicle service area in a geographical region.
One constructive heuristic and two local search heuristics based on hill climbing (HC) and on tabu search (TS) methods, are presented. Experiments with a set of benchmark based instances and with a set of real world based instances are performed.
Computational results show that the constructive heuristic is very fast but tends to produce solutions with very high imbalances, namely on the largest size instances.
The computational results also highlight the importance of considering the aforementioned criteria simultaneously on the evaluation of the solutions during the search process. In fact,if one criteria is considered then the quality of the solution increases for the criteria that is being considered but decreases, in some cases largely, for the other two criterion.
The results obtained with TS on the large instances are very promising, namely if compared with the best previous known results, making it worth to consider for other practical applications.

Heuristic Approaches for the Robust Vehicle Routing Problem

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In this article, the Robust Vehicle Routing Problem (RVRP) with uncertain traveling costs is studied. It covers a number of important applications in urban transportation and large scale bio-terrorism emergency. The uncertain data are defined as a bounded set of discrete scenarios associated to each arc of the transportation network. The objective is to determine a set of vehicle routes minimizing the worst total cost over all scenarios. A mixed integer linear program is proposed to model the problem. Then we adapt some classical VRP heuristics to the RVRP, such as Clarke and Wright, randomized Clarke and Wright,

Sequential Best Insertion, Parallel best insertion and the Pilot versions of the Best Insertion heuristics. In addition, a local search is developed to improve the obtained solutions and serve in a Greedy Randomized Adaptive Search Procedure (GRASP). Computational results are presented for both the mathematical formulation and the proposed heuristics.

Planning Trip Itinerary for Tourist Groups via a Tabu Search Algorithm

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Sightseeing trips are often done in groups, where tourists enjoy their trip in company with their relatives or friends. Therefore, in this paper, in order to model trips for tourist groups, we introduce a new problem, as an extension of the existing problem in the literature for a single tourist trips. The new problem extends the existing problem with two additional concepts. The first one is consideration of multiple tourists, where their individual preferences about Points of Interests (POIs) are taken into account, and the second one is the introduction of the concept of mutual social relationship between the different tourists. Further, we solve the introduced problem with a tabu search metaheuristic that uses two new operators for exploring the search space. The computational experiments show that the application of the new proposed operators yield to better itineraries for tourist groups.

WB-II

10:30 - 12:10
Room: Miguel Ângelo II

Integer Linear Programming II

Contributed session
chair: Bernard Gendron

Two New Reformulation Convexification Based Hierarchies for 0-1 MIPs

Hacène Ouzia, *Sorbonne Université, UPMC Univ.*, h.ouzia@gmail.com

Let n and m two nonnegative integers. Let X be the set of feasible solutions of a mixed integer linear problem with n binary variables and m continuous variables. Without lost of generality, we will assume that the set X is a subset of the hypercube. By hierarchy of relaxations (hierarchy for short) of the set X we mean a finite family of continuous relaxations indexed by an integer, called rank, such that : (i) the relaxation of rank 0 coincides with the continuous relaxation of X; (ii) for every integer d, the relaxation of rank d is always included in the relaxation of rank d-1 and (iii) the relaxation of rank n (the number of binary variables) coincides with the convex hull of the set X. We will say that an hierarchy A dominates another hierarchy B if, for avery integer d, the rank d relaxation of the hierarchy A is included in the rank d relaxation of the hierarchy B. An hierarchy A is said to be equivalent to an hierarchy B if A and B dominate each other. The hierarchies we will address in this work are all defined using four steps : reformulation, convexification, linearization and projection. The reformulation we will consider was introduced by Sherali and Adams (H. D. Sherali and W. P. Adams, 1990). The linearization step consists in replacing, using

new variables, the nonlinear terms appearing in the description of the set obtained after the reformulation (or convexification) step. Different linearizations are possible and, as proved by the author (M. Minoux and M. Ouzia, 2010), this gives rise to different hierarchies. The linear description obtained after the linearization step is called extended linear description. The projection step consists in projecting back the extended linear description onto the space of the original variables. In this work, first, we introduce two new hierarchies called RTC and RSC. These two hierarchies are obtained using two different convexification schemes : term convexification in the case of the RTC hierarchy and standard convexification in the case of the RSC hierarchy. Secondly, we compare the strength (see M. Minoux and H. Ouzia, 2010) of these two hierarchies. We will prove that : (i) the hierarchy RTC dominates the hierarchy RSC; (ii) the hierarchy RTC is equivalent to the RLT hierarchy of Sherali-Adams and (iii) the hierarchy RSC is dominated by the Lift-and-Project hierarchy (see M. Minous and H. Ouzia, 2010). Finally, for every rank d, we will characterize the projection of the rank d extended linear relaxation of both hierarchies. Part of these results will allow us, in some cases, to give an explicit characterization of RLT relaxations.

Combining dual price smoothing and piecewise linear penalty function stabilization in column generation: experimental results

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Column generation is a well-known method to solve large-scale combinatorial optimisation problems. However, its application in practice if often limited by convergence issues. To overcome this drawback, several stabilization techniques have been proposed. Probably, the most common techniques are 1) adding piecewise linear penalty functions to the dual objective and 2) dual price smoothing, which consists in pricing with a linear combination of the current dual solution and the best dual solution obtained earlier. Recently we proposed an automatic (parameter-less) variant of the dual price smoothing technique.
In this work, we experimentally compare efficiency of the two above mentioned stabilisation techniques on a wide range of problems, including machine scheduling, generalised assignment, lot sizing, capacitated vehicle routing, shift scheduling, and min-cost multi-commodity flow. We also show numerically that these techniques have a cumulative stabilization effect : our experimental results show that for most problems this combination outperforms the two techniques applied separately.

Valid inequalities for a MIP set with variable conflicts

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Strong valid inequalities have been intensively used as cuts (cutting planes) in solving mixed integer problems. One classical approach to generate these valid inequalities is to study the polyhedral structure of simple mixed integer sets which occur as relaxations of the feasible sets of those general problems.
In this study we consider a mixed integer set which results from the intersection of a simple mixed integer set defined for a single constraint, with the vertex packing set resulting from

a conflict graph. This set arises as a subproblem of more general mixed integer problems such as inventory routing and facility location problems. In this work we focus on deriving a variant of the well-known mixed integer rounding inequalities which are called conflict mixed integer rounding inequalities where the incompatibilities between binary variables are considered. In addition, we describe families of strong valid inequalities that consider the structure of simple mixed integer set and the vertex packing set simultaneously and discuss on separation problems associated to those valid inequalities. A computational experiment to test the effectiveness of those derived inequalities in improving the integrality gap of randomly generated instances of the single node fixed-charge set with conflicts on arcs is presented.

Reformulations by Discretization for Piecewise Linear Integer Multicommodity Network Flow Problems

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We consider the piecewise linear multicommodity network flow problem with the addition of a constraint specifying that the total flow on each arc must be an integer. This problem has applications in transportation and logistics, where total flows might represent vehicles or containers filled with different products. We introduce formulations that exploit this integrality constraint by adapting to our problem a technique known as discretization that has been used to derive mixed-integer programming models for several combinatorial optimization problems. We enhance the discretized models either by adding valid inequalities derived from cutset inequalities or by using flow disaggregation techniques. Since the size of the formulations derived from discretization and flow disaggregation rapidly increases with problem dimensions, we develop an efficient and effective Lagrangian relaxation method to compute lower and upper bounds. We perform computational results on a large set of randomly generated instances that allow us to compare the relative efficiency of the different modeling alternatives (flow disaggregation plus addition of cutset inequalities with or without discretization), when used within the Lagrangian relaxation approach.

WB-III

10:30 - 12:10
Room: Miguel Ângelo III

Trees I

Contributed session
chair: S. Raghavan

Packing Arborescences in Acyclic Temporal Networks

Naoyuki Kamiyama, *Kyushu University*, kamiyama@imi.kyushu-u.ac.jp

A temporal network is a directed graph in which each arc has a time label specifying the time at which its end-vertices communicate. An arborescence in a temporal network is said to be time-respecting, if the time labels on every directed path from the root in this arborescence are monotonically non-decreasing. In this paper, we consider the problem of packing time-respecting arborescences in a temporal network. Precisely speaking, we discuss an extension of Edmonds' arc-disjoint arborescences theorem in a temporal network. Unfortunately, it is known that a natural extension of Edmonds' arc-disjoint arborescences theorem in a

temporal network does not hold. In this paper, we first show that this extension does not hold, even if an input temporal network is acyclic. Next, we prove that if an input temporal network is acyclic and pre-flow, then this extension holds and we can find arc-disjoint time-respecting arborescences in polynomial time. Furthermore, we extend our main result to the problem of packing time-respecting partial arborescences.

Rectilinear Shortest Path and Rectilinear Minimum Spanning Tree with Neighborhoods

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We study the geometric shortest path and the minimum spanning tree problem with neighborhoods in the L1 metric. In this setting, we are given a graph G = (R, E), where R = R1, ..., Rn is a set of polygonal regions in the plane. Placing a point pi inside each region Ri turns G into an edge-weighted graph Gp , p = p1, ..., pn, where the cost of an edge is the distance between the points. The Shortest Path Problem with Neighborhoods asks, for given Rs and Rt, to find a placement p such that the resulting shortest s-t path in Gp is smallest among all graphs Gp. The Minimum Spanning Tree Problem with Neighborhoods asks for a placement p such that the resulting minimum spanning tree of Gp has the smallest cost among all minimum spanning trees of all graphs Gp. We study these problems in the L1 metric, and show that the shortest path problem with neighborhoods is solvable in polynomial time, whereas the minimum spanning tree problem with neighborhoods is NP-hard, even if the neighborhood regions are segments.

Tree inference from a distance matrix

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In this work we deal with the problem of reconstructing the tree of a network by knowing only its set of terminal nodes and their pairwise distances, so that the reconstructed network has its total edge weight minimized. This problem has applications in several areas, namely the inference of phylogenetic trees and the inference of routing networks topology. Phylogenetic trees allow the understanding of the evolutionary history of species and can assist in the development of vaccines and the study of biodiversity. The knowledge of the routing network topology is the basis for network tomography algorithms and it is a key strategy to the development of more sophisticated and ambitious traffic control protocols and dynamic routing algorithms. We present mixed-integer linear programming models to the problem and discuss different solution procedures. The quality of the models are evaluated by using data both from the phylogenetics and the communication network areas. The results are compared with the results obtained with a model available in the literature used to solve the balanced minimum evolution problem. Extensive computational results show that the models are quite effective in finding integer feasible solutions, present small gap values, and solve higher size instances.

A Tight Extended Formulation for the Weighted Target Set Selection Problem on Trees

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The Target Set Selection (TSS) problem is a fundamental problem about the diffusion of influence in social networks. Starting with Kempe, Kleinberg, and Tardos (2003) it has been widely studied in the literature. The TSS problem has applications in many areas in economics, business, sociology and medicine including viral marketing and epidemiology. Its input is a graph, the social network, and each node has a threshold. The goal is to find a subset of nodes, the target set, that activates the whole network through the following activation process and has the smallest size. Initially all nodes are inactive. We select the target set and all nodes in it become active. After that, in each step, we update the state of nodes by the following rule: an inactive node becomes active if the number of its active neighbors at the end of the previous step is greater than or equal to its threshold. In our work, we consider the weighted version of the TSS problem (WTSS problem). The weights in the WTSS problem model the fact the cost or effort to activate different nodes can vary. The TSS problem is known to be NP-hard, and earlier work on the TSS problem has focused on approximation. Motivated by the desire to develop mathematical programming approaches to solve the WTSS problem, we focus on developing a strong formulation for the WTSS problem on trees. We present a tight and compact extended formulation for the WTSS problem on trees. In other words, we provide an extended linear programming formulation whose projection onto the space of the natural node selection variables is the convex hull of feasible target set vectors.

WC-I

14:00 - 15:40
Room: Miguel Ângelo I

Routing: Pick up and delivery

Contributed session
chair: Juan José Salazar González

On Resolving the Static Relocation Problem in Carsharing Systems

Annegret Wagler, *Université Blaise Pascal (Clermont-Ferrand II)*, wagler@isima.fr
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Carsharing is a modern way of car rental, attractive to customers who make only occasional use of a car on demand. In a carsharing system, a fleet of cars is distributed at specified stations in an urban area, customers can take a car at any time and station and return it at any time and station, provided that there is a car available at the start station and a free place at the final station. For operating such a system in a satisfactory way, the stations have to keep a good ratio between the total number of places and the number of cars in each station, in order to serve as many customer requests as possible. This leads to the problem of balancing the load of the stations, called Relocation Problem: an operator has to monitor

the load situations of the stations and to decide when and how to move cars from overfull stations to underfull ones. Balancing problems of this type occur for any car- or bikesharing system, but the scale of the instances, the time delay for prebookings and the possibility to move one or more vehicles in balancing steps differ. We consider an innovative carsharing system, where the cars are partly autonomous which allows to build convoys of cars, where each convoy is moved by only one driver. This setting is different from usual carsharing, but similar to bikesharing, where trucks can simultaneously load and move several bikes during the relocation process. In this paper, we address the Static Relocation Problem: the system has to be set into a certain state, outgoing from the current state, within a given time horizon. We model the Static Relocation Problem within the framework of a metric task system, where the tasks consist in moving cars out of overfull stations into underfull ones, and present two approaches to solve this problem. We propose a combinatorial algorithm that matches tasks to generate transport requests, subsequently solves a Pickup and Delivery Problem, and iteratively augments the transport requests and resulting tours. In order to obtain an exact solution, we interpret the Static Relocation Problem by means of flows in a time-expanded network. The two flows are coupled in this sense that the flow of cars is dependent from the flow of drivers (since cars can only be moved in convoys). We show that, in special cases, the combinatorial algorithm is an approximation algorithm. Our computational results show that it computes also in practice good solutions in a reasonable time and, thus, is suitable for practical situations.

An ILP-based heuristic for the VRP with pickups and deliveries

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We address the Vehicle Routing Problem with pickups and deliveries (VRPPD) with a heuristic approach. We consider the one-to-one problem (see, e.g. Berbeglia et al. (2007)) where a particular precedence must be satisfied by a pair of origin-destination clients. Formally, let G be an undirected complete graph, with 0, 1, . . . , 2n the set of vertices, where 0 represents the depot. Each edge has an associated positive distance and there is a precedence constraint between vertices i, n + i, for i = 1, . . . , n. The objective is to find a set of at most k routes covering each vertex exactly once at minimum total cost.
In this research, we consider the scheme proposed in De Franceschi et al. (2006) for the Distance Constrained Capacitated VRP, which has been successfully applied to other variants of the VRP (see, e.g., Toth and Tramontani (2008), Naji-Azimi et al. (2012)). Starting from a initial feasible solution, this scheme follows the destroy/repair paradigm where a set of vertices is removed from the routes and reinserted by solving heuristically an associated ILP formulation with an exponential number of variables, named Reallocation Model (RM). Given the RM has an exponential number of variables, the standard approach is to heuristically generate columns considering their reduced cost and solve the model by a general purpose ILP solver, such as CPLEX.
Our work presents a formulation of the RM that includes the precedence constraints to guarantee the feasibility of the solution. In contrast to the previous cases, the number of rows in the RM is not fixed a priori since precedence constraints have to be included in the formulation depending on the set of variables generated, and the formulation becomes a special case of the column-dependent-rows problem studied, e.g., in Muter et al. (2012). As a result, reduced costs can only be approximated using the current dual information with-

out solving auxiliary subproblems. Therefore, we study the computational behavior of the general scheme and propose some modifications in order to generate good quality variables for the RM. Based on preliminary results, the proposed scheme shows good potential to be applied in practice and a is good starting point to consider more complex versions of the VRPPD.

Modeling and Solving the One-to-One Multi-Commodity Pickup and Delivery Traveling Salesman Problem

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We address the one-to-one multi-commodity pickup and delivery traveling salesman problem (m-PDTSP) introduced by Hernandez-Perez and Salazar-Gonzalez in 2009. The m-PDTSP is a generalization of the TSP and arises in several transportation and logistics applications. We are given a complete directed graph with a node set consisting of start and end depot and a set of customers. For each arc a travel distance (or cost) is given. A set of commodities is defined, each one associated with a demand, a source and a destination node. The objective is to find a minimum-cost Hamiltonian path such that the vehicle starts and ends at the corresponding depot, the demand of each commodity is transported from its source to its destination, and the given vehicle capacity is not exceeded throughout the path.
A different problem variant, the many-to-many one-commodity pickup and delivery traveling salesman problem (1-PDTSP), just considers a single commodity and each node can be a source or target for units of this commodity, defined by a given positive or negative demand. We show that the m-PDTSP is equivalent to the 1-PDTSP with additional precedence constraints defined by the origin-destination pairs for each commodity and explore several models based on this equivalence. In particular, we consider a formulation based on a 3-dimensional layered graph that combines time and load together and achieves tight LP bounds, at the cost of a large model size.
Especially for tightly capacitated instances with a large number of commodities our branch-and-cut algorithms are able to outperform the approaches by Hernandez-Perez and Salazar-Gonzalez. Additionally, an adapted variant of our branch-and-cut algorithm for the uncapacitated m-PDTSP (sequential ordering problem) is able to solve to optimality several open instances from the TSPLIB.

Solving the one-commodity pickup-and-delivery single-vehicle routing problem with split demands

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We introduce a new pickup and delivery problem in which one product is transported between different customers with a single vehicle. As usual in the vehicle routing literature, the vehicle capacity and the customer demands are known. The novelty of our problem is that a customer can be served several times by the vehicle. In other words, the solution is a route that visit each location at least once. Still, to guarantee customer satisfaction, a maximum number of visits is required.
A flow-based formulation is given together with some inequalities to project out the flow variables. Also rounded inequalities are described to strengthen the linear programming relaxation.

Computational results illustrate the performance of a branch-and-cut implementation, showing that it is effective on benchmark instances.

WC-II

14:00 - 15:40
Room: Miguel Ângelo II

Integer Linear Programming III

Contributed session
chair: Maria Teresa Almeida

A tabu search heuristic for the Equitable Coloring Problem

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The Equitable Coloring Problem is a variant of the Graph Coloring Problem, where the sizes of two arbitrary color classes differ in at most one unit. This paper describes a new tabu search heuristic for the Equitable Coloring Problem. This algorithm is an adaptation of the dynamic TabuCol version of Galinier and Hao. Computational experiments are carried out in order to find the best combination of parameters involved in the tabu search heuristic, and to show its good performance over benchmark instances.

Fractional programming formulation for the vertex coloring problem

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We consider the vertex coloring problem (VCP) which is a well-known NP-hard combinatorial optimization problem with a large number of applications including scheduling, register allocation, and timetabling. In this problem, we are given a simple and undirected graph G = (V, E). The objective is to find an assignment of colors to V such that no two adjacent vertices share the same color and the number of used colors is minimized. Though a naive ILP formulation is known for years, there exists a great drawback resulting from the indistinguishability of colors. In this study, as an alternative, we devise a new formulation for VCP and verify the effectiveness through computational experiments using a MILP solver.

Approximating the k-Set Packing Problem by Local Improvements

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We study algorithms based on local improvements for the k-Set Packing problem. Sviridenko and Ward have given a polynomial-time local search algorithm improving the approximation ratio of the k-Set Packing problem from $\frac{k}{2} + \epsilon$ by Hurkens and Schrijver to $\frac{k+2}{3}$. Their algorithm looks for local improvements of $O(\log n)$ sets each of which intersects with at most 2 sets in the current solution, here n is the total number of sets. Cygan has shown that using local improvements of bounded pathwidth improves the performance guarantee

to $\frac{k+1}{3} + \epsilon$ for any $\epsilon > 0$.
In this paper, we achieve the approximation ratio $\frac{k+1}{3} + \epsilon$ for the k-Set Packing problem using a simple polynomial-time algorithm based on the method by Sviridenko and Ward. With the same approximation guarantee, our algorithm runs in time singly exponential in $\frac{1}{\epsilon^2}$, while the running time of Cygan's algorithm is doubly exponential in $\frac{1}{\epsilon}$. On the other hand, we construct an instance with locality gap $\frac{k+1}{3}$ for any algorithm using local improvements of size $O(n^{1/5})$. Thus, our approximation guarantee is optimal with respect to results achievable by algorithms based on local improvements.

Integer models for the triangle k-club problem

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The importance of clique-related models for applied studies in fields such as social network analysis, computational biology, and marketing has been noted by many authors in recent OR papers. The clique concept is a staple in the social network analysis literature since it represents a group of actors that are all pair-wise linked. However, it has long been recognized that the clique concept is too restrictive: in many contexts, to identify meaningful clusters, it is necessary to adopt approaches that generalize the clique concept. The triangle k-club structure we introduce in this talk aims to model a combination of an upper bound condition on the number of hops that may separate any pair of group members with a pattern condition that imposes that all group members must be embedded in at least one clique with three elements. Triangle k-clubs represent an interesting compromise between clique generalization and k-club restriction: while any pair of elements may be separated by up to k hops, every element must be embedded in at least one tightly knitted triplet. We propose integer linear models for the problem of finding the maximum cardinality triangle k-club of a graph, stated with different sets of variables. For the cases k=2 and k=3, we compare and test the models on a set of scale-free and uniform randomly generated graphs with up to 200 nodes. The comparison reveals that the models' dimensions are strongly influenced by the edge density and, for each edge density, by the structure of the graph. The computational performance of the models does not mirror the differences on their dimensions. For the scale-free graphs, a proven optimal solution was computed in every case in less than 3 minutes. With regard to the uniform graphs, 85% of the runs terminated with a proven optimal solution in less than 3 minutes and only about 9% of the runs hit the time limit of one hour.

WC-III

14:00 - 15:40
Room: Miguel Ângelo III

Network Design I

Contributed session
chair: Thibaut Lefebvre

Fast algorithms for access network design

Mateusz Zotkiewicz, *Warsaw University of Technology*, mzotkiew@tele.pw.edu.pl

In this work we face a problem of designing an access network. Consider a network consisting of a set of nodes N and a set of edges E. Also given are: a set of central nodes, which is a subset of N, a set of clients, which is also a subset of N, and a length for each edge of set E. Our task is to find a subset of E, such that for each client there exists a path that uses solely edges from the returned subset and connects the client to any central node. The returned subset should be of a minimal cost. The cost is understood as a sum of costs of activating edges, which are proportional to their lengths, and costs of wiring, which are proportional to lengths of utilized paths from clients to central nodes. We will call the problem the Access Network Design (AND) problem.

AND is very practical and can be used to model many important real-world challenges, for instance in telecommunications. Thus, it has been thoroughly studied, and it can be solved by many different algorithms that can be found in the literature. However, AND is not only stand-alone very important, but also can be seen as a subproblem of other more complicated, but also very practical, problems. Consider a problem of finding an optimal subset of locations for central nodes from a bigger set of all possible locations. We will call the problem Location Selection (LS) problem. Having a feasible solution to LS, understood as a subset of possible locations, we can grade the quality of the solution by solving AND. If we want to solve LS using a kind of heuristic approach, which evaluates a number of different solutions and selects the best one among the evaluated, we will need a fast algorithm capable of solving AND, but we neither require the algorithm to be exact nor it has to give any strict guarantees concerning the quality of a solution.

The simplest approach to this problem is a shortest path approach that selects for each client a shortest path to its nearest central point minimizing, in this way, the cost of wiring. The approach requires running a single instance of the Dijkstra's algorithm, and in the presented context can be considered as fast. On the other hand, an approach minimizing solely the cost of activating edges is much more difficult from the complexity viewpoint, as it requires solving the Steiner tree problem, thus it is unacceptable in the considered context.

In this work we introduce and evaluate a number of fast algorithms for AND in the context of solving LS using a heuristic, simulated annealing-like method. The evaluation answers a question to which extent the quality of solutions returned by algorithms for AND is important, and what is a desired relation between the quality of solutions and the complexity of algorithms. The presented work was supported by the Ministry of Science and Higher Education (Poland) under grant IP2012 065372.

Optical Multi-Band Network Design problem : polyhedron and Branch-and-Cut

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A major challenge for nowadays telecommunication actors is to propose solutions to manage the traffic growth, and ensure a smart use of network resources. This can be possible by overlapping the so-called multi-band OFDM (Orthogonal Frequency Division Multiplexing) technology on an optical fibre infrastructure. A better and more flexible use of the wavelength capacity is then enabled by dividing each wavelength channel into smaller subwavelengths or subbands. Moreover, since it is necessary to meet user demand, OFDM multi-band networks must present enough capacity to carry the traffic evolution. One of the best ways to ensure a smart use of this new network infrastructure, is to provide an accurate answer in terms of resource planning.
In this paper, we address the problem of designing a multilayer optical network, using multi-band OFDM technology. Given a physical layer, having a set of transmission nodes, interconnected by optical fibres, and a set of commodities. A set of modular capacities, referred to as OFDM subbands, may be installed between every pair of transmission nodes, so that the traffic can be routed. Every subband has a capacity and yields an installation cost, related to the optical devices that generate this subband. We then wish to determine a minimum cost assignment of the commodities to the subbands, so that every used subband is associated with a path in the physical layer. We will refer to this problem as the Optical Multi-Band Network Design (OMBND) problem. We propose here an integer linear programming formulation for the problem. We study the associated polyhedron and investigate the facial structure of the basic constraints of the formulation. We then derive new classes of valid inequalities and describe necessary conditions as well as sufficient conditions for these inequalities to define facets. Based on the provided polyhedral results, we devise a Branch-and-Cut algorithm. We carry on an experimental study to give an insight of the effectiveness of our approach. Several classes of instances are considered and we show a set of computational results for random and realistic instances, derived from SNDlib data. Finally, we manage to solve the problem for real networks and traffic matrices, provided by the french telecommunication operator Orange.

Network coding and multi-terminal flow problems

Thibaut Lefebvre, *Orange Labs*, thibaut.lefebvre1@gmail.com

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Given a telecommunication network with non-negative arc capacities, a special vertex called source, and a set of vertices called terminals, we want to send as much information as possible simultaneously from the source to each terminal. We compare the classical routing scheme modeled by the maximum concurrent flow problem and a network coding approach within a multicast network. Multicast protocols allow an intermediate node to replicate its input data towards several output interfaces, and network coding refers to the ability for an intermediate node to perform coding operations on its inputs (for example, bit-wise XOR or linear combinations) releasing a coded information flow on its outputs. It can be show that the maximum quantity of information that can be routed from the source to each terminal using multicast with network coding is the minimum over all terminals of the value

of a maximum flow between the source and the terminal. This means that we compare the maximum concurrent flow with the superposition of independent maximum flows, one for each terminal.

WC-IV

14:00 - 15:40
Room: Vieira da Silva

Non-Linear Programming

Contributed session
chair: Jon Lee

Colorful Linear Programming, Nash Eequilibrium and Pivots

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Let $S_1, ..., S_k$ be k sets of points in Q^d. The colorful linear programming problem, defined by Barany and Onn (Mathematics of Operations Research, 22 (1997), 550-567), aims at deciding whether there exists a T in the union of the S_i such that $|T \cap Si| \leq 1$ for $i = 1, ..., k$ and $0 \in conv(T)$. They proved in their paper that this problem is NP-complete when $k = d$. They leave as an open question the complexity status of the problem when $k = d + 1$. Contrary to the case $k = d$, this latter case still makes sense when the points are in a generic position. We solve the question by proving that this case is also NP-complete. The proof is inspired by the proof of the NP-completeness of the linear complementarity problem and uses some relationships between colorful linear programming and complementarity problems that we explicit. We also show that if $P = NP$, then there is an easy polynomial-time algorithm computing Nash equilibrium in bimatrix games using any polynomial-time algorithm solving the case with $k = d + 1$ and $|S_i| \leq 2$ for $i = 1, ..., d + 1$ as a subroutine. On our track, we found a new way to prove that a complementarity problem belongs to the PPAD class with the help of Sperner's lemma. We also show that we can adapt algorithms proposed by Barany and Onn for computing a feasible solution T in a special case and get what can be interpreted as a "Phase I" simplex method, without any projection or distance computation.

Active Set Methods with Reoptimization for Convex Quadratic Integer Programming

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We present a fast branch-and-bound algorithm for solving convex quadratic integer programs with few linear constraints. In each node, we solve the dual problem of the continuous relaxation using an infeasible active set method proposed by Kunisch and Rendl to get a lower bound; this active set algorithm is well suited for reoptimization. Our algorithm generalizes a branch-and-bound approach for unconstrained convex quadratic integer programming proposed by Buchheim, Caprara and Lodi to the presence of linear constraints. The main feature of the latter approach consists in a sophisticated preprocessing phase, leading to a fast enumeration of the branch-and-bound nodes. Experimental results for randomly generated instances are presented. The new approach significantly outperforms the MIQP solver of CPLEX 12.4 for instances with a small number of constraints.

Optimization and classes of completely positive matrices

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The convex cone CP_n of completely positive (CP) matrices is defined as the set of square matrices of order n that admit a factorization $A = BB^T$ where $B = [b_{ij}]$ is componentwise nonnegative. A number of combinatorial optimization problems can be modelled using CP_n, by letting variables be represented by completely positive matrices. An example of such a problem is that of minimizing a quadratic function over a polyhedron with the added constraint of the variables being binary (see [3] and references).
No efficient computational procedure is known for deciding if a given componentwise nonnegative and positive semidefinite matrix is completely positive. It is therefore natural to consider this question for subclasses obtained by restricting the matrices to have certain zero-nonzero patterns. Such a pattern may be represented by a graph on n vertices. In particular, characterizations of CP matrices are known for the following situations: (i) matrices of order at most 4, (ii) matrices whose graphs are triangle-free, and (iii) matrices whose graphs do not contain odd cycles of length greater than 3 (see [1]). In [4] a linear-time algorithm for reducing the problem to a matrix of smaller order is given, under some assumptions on the graph of the matrix. A different kind of restriction than on the zero-nonzero pattern, seen for example in [2], is to restrict the entries in B further, in this case to the set $\{0, 1\}$. A matrix satisfying $A = BB^T$ with $b_{ij} \in \{0, 1\}$ for all i, j, is called $\{0, 1\}$-completely positive. in [2] results are given for small matrices of order less than 4, and some larger matrices with special structure, for example tridiagonal matrices. In this talk, we will be concerned with certain convex subcones of CP_n that have "tractable" descriptions. A consequence of an algorithm in [4] is that complete positivity of a matrix whose graph is a tree can be verified in linear time, and for a given tree T we call this cone $CP_n(T)$. Similar results to [4] can be developed for the cone $CP_n^{\{0,1\}}(T)$, defined analogously to $CP_n(T)$ as a conical hull of $\{0, 1\}$-completely positive matrices. We present properties of these two cones and, for instance, an interesting connection to matching theory and matching polytopes is discussed. Finally, we discuss some optimization problems that can be formulated over the different sets mentioned above, and some computational issues.

On global optimization with indefinite quadratics

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We present an algorithmic framework for global optimization problems in which the nonconvexity is manifested as indefinite quadratic functions. Our solution approach consists of applying a spatial branch-and-bound algorithm, exploiting convexity as much as possible, not only convexity in given convex functions, but also extracted from the indefinite quadratics. A preprocessing stage is proposed to split the indefinite quadratics and rewrite them as a difference of convex quadratic functions, leading to a more efficient spatial branch-and-bound focused on the isolated non-convexity. We investigate several possibilities for splitting quadratics at the preprocessing stage, and prove the equivalence of some of them. Through computational experiments with different categories of test-beds, we analyze how the splitting strategies affect the performance of our algorithm, and find guidelines for choosing amongst them. Numerical comparisons with Couenne shows the competitiveness of our approach.

WD-I

16:00 - 17:40

Room: Miguel Ângelo I

Graphs I

Contributed session

chair: Domingos Cardoso

$\{k\}$-packing Functions of Graphs

Valeria Alejandra Leoni, *Unversidad Nacional de Rosario y CONICET*, v.aleo.ni@hotmail.com

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Given a a positive integer k and a graph G, a k-limited packing in G —defined by Gallant et al. in 2010— is a subset B of its vertex set such that each closed neighborhood has at most k vertices of B. In this paper we introduce the notion of a $\{k\}$-packing function of a graph, as a variation of a k-limited packing. Given a graph G, if f is a function that assigns a non-negative integer to the vertices of G, the weight of f is the sum of $f(v)$ over all the vertex set of G. If the closed neighborhood sum is at most k at every vertex, then f is called a $\{k\}$-*packing function* of G. For fixed positive integer k, we consider the problem $\{k\}$PF which deals with finding a $\{k\}$-packing function of maximum weight in a graph and introduce the study of its computational complexity. Firstly, we prove that $\{k\}$PF can be reduced linearly to the problem of finding a k-limited packing of maximum cardinality in a given graph (kLP). The reduction performed allows us to state that $\{k\}$PF is linear time solvable for the class of strongly chordal graphs which a subclass of chordal graphs that includes trees, block graphs and directed path graph. In addition, we present an $O(|V(G)| + |E(G)|)$ time algorithm to solve $\{k\}$PF on strongly chordal graphs. Finally, we use monadic second-order logic to prove that both problems are linear time solvable on graphs with clique-width bounded by a constant. The results in this paper enlarge the already known set of graph classes in which kLP is linear time solvable.

Subexponential Fixed-parameter Algroithms for Partial Vector Domination

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Given a graph $G = (V, E)$ of order n and an n-dimensional non-negative vector $\mathbf{d} = (d(1), d(2), \ldots, d(n))$, called demand vector, the vector domination (resp., total vector domination) is the problem of finding a minimum $S \subseteq V$ such that every vertex v in $V \setminus S$ (resp., in V) has at least $d(v)$ neighbors in S. The (total) vector domination is a generalization of many dominating set type problems, e.g., the dominating set problem, the k-tuple dominating set problem (this k is different from the solution size), and so on, and subexponential fixed-parameter algorithms with respect to solution size for apex-minor-free graphs (so for planar graphs) are known. In this paper, we consider maximization versions of the problems; that is, for a given integer k, the goal is to find an $S \subseteq V$ with size k that maximizes the total sum of satisfied demands. For these problems, we design subexponential fixed-parameter algorithms with respect to k for apex-minor-free graphs.

Graph Compact Layout Algorithm

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There exist many orthogonal graph drawing algorithms that minimize edge crossings or edge bends, however they produce unsatisfactory drawings in many practical cases. In this paper we present a grid-based algorithm for drawing orthogonal graphs with nodes of prescribed size. It distinguishes by creating pleasant and compact drawings in relatively small running time. The main idea is to minimize the total edge length that implicitly minimizes crossings and makes the drawing easy to comprehend. The algorithm is based on combining local and global improvements. Local improvements are moving each node to a new place and swapping of nodes. Global improvement is based on constrained quadratic programming approach that minimizes the total edge length while keeping node relative positions.

Spectral bounds for the k-regular induced subgraph problem

Sofia J. Pinheiro, *University of Aveiro*, spinheiro@ua.pt
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A maximum independent set, a maximum induced matching and a maximum clique is a maximum cardinality 0-regular, 1-regular and (w-1)-regular induced subgraph, respectively, were w denotes the clique number of the graph G. In Cardoso, Kaminski, and Lozin [J. Comb. Optim., 14, 455-463, 2007], it was proved that finding a maximum k-regular induced subgraph is NP-hard for any fixed value of k, so it is crucial to find upper bounds determined in polynomial time which are good approximations of the respective optimal solutions. In this talk we present some spectral upper bounds on the size of k-regular induced subgraph. These upper bounds are based on convex quadratic techniques and on adjacency, Laplacian and signless Laplacian spectrum. Finally we present some computational experiments comparing this spectral upper bounds.

WD-II

16:00 - 17:40
Room: Miguel Ângelo II

Integer Linear Programming IV

Contributed session
chair: Pierre Fouilhoux

Study of identifying code polyhedra for some families of split graphs

Silvia Bianchi, *Universidad Nacional de Rosario*, sbianchi@fceia.unr.edu.ar
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Many practical applications can be stated as set covering problems, among them newly emerging search problems for identifying codes in graphs. Given a graph, a node subset is dominating (resp. identifying) if its intersection with the closed neighborhoods of all nodes of the graph yields non-empty (resp. distinct) sets. An identifying code is a node subset which is dominating and identifying. Finding the minimum cardinality of an identifying code in a graph is challenging both from a theoretical and a computational point of view, even for

special graphs like bipartite graphs and split graphs. In a previous work, we presented a set covering formulation for the identifying code problem and defined the identifying code polyhedron. In this work we study identifying code polyhedra for some families of split graphs: graphs whose node set can be partitioned into a clique and a stable set. We study three regular families of split graphs with a clique and a stable set of the same size: thin and thick headless spiders and complete suns. We provide the according linear relaxations and discuss their combinatorial structure, based on the involved types of matrices. For thick headless spiders, we achieve a complete description of the identifying code polyhedron, and arrive at a profound conjecture on the polyhedra for thin spiders. It turned out that the linear relaxations for complete suns have a more complex structure involving different circulant matrices and, accordingly, more involved facets to describe the identifying code polyhedron. Based on polyhedral arguments, we found the exact value of minimum identifying codes for thin and thick headless spiders, and have a conjecture for complete suns. This demonstrates how polyhedral arguments can be applied to find minimum identifying codes for special graphs. We discuss further lines of research in order to apply similar techniques to obtain strong lower bounds stemming from linear relaxations of the identifying code polyhedron, enhanced by suitable cutting planes to be used in a B&C framework.

Fixed-Parameter Algorithms for Scaffold Filling

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In this paper we consider two combinatorial problems related to genome comparison. The two problems, starting from possibly incomplete genomes produced from sequencing data, aim to reconstruct the complete genomes by inserting a collection of missing genes. More precisely, in the first problem, called One-sided scaffold filling, we are given an incomplete genome B and a complete genome A, and we look for the insertion of missing genes into B with the goal of maximizing the common adjacencies between the resulting genome B' and A. In the second problem, called Two-sided scaffold filling, we are given two incomplete genomes A, B, and we look for the insertion of missing genes into both genomes so that the resulting genomes A' and B' have the same multi-set of genes, with the goal of maximizing the common adjacencies between A' and B'. While both problems are known to be NP-hard, their parameterized complexity when parameterized by the number of common adjacencies of the resulting genomes is still open. In this paper, we settle this open problem and we present fixed-parameter algorithms for the One-sided scaffold filling problem and the Two-sided scaffold filling problem. The two algorithms are both based on the application of the color-coding technique.

Progress on identifying codes in cycles

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Identifying codes have a wide range of applications. The concept of identifying code was introduced in 1998 by M.G. Karpovsky et al. in *On a new class of codes for identifying*

vertices in graphs. Here the authors give a first application for fault diagnosis in multiprocessor systems. Consider a network of processors modeled as an undirected graph. Some of the processors (which are part of the identifying code) are able to test when a neighbouring processor (or themselves) are faulty; if this is the case, they enter a special state. If some of the testing processors have detected an error, it is possible to identify exactly the faulty processor: it is the one whose identifying set is equal to the set of processors which have detected the error. In the case of networks of thousands of processors, it is extremely useful to minimize the set of testing processors. The problem of determining the minimum identifying code in a graph is NP-complete (see I. Charon et al. in *Minimizing the size of an identifying or locatingdominating code in a graph is NP-hard* (2003).) and this problem has been studied on some particular classes of graphs.

In this work we study the problem of identifying codes in cycles. In particular, we consider r-identifying codes in cycles C_n where $gcd(2r+1, n) = 1$, n odd and $n \geq 8r+3$, that are the much of the unknown cases in S. Gravier et al. in *Identifying codes of cycles* (2006). In the work done by Gravier et al., the r-identifying number of a cycle C_n ($m_r(C_n)$) was studied and the estimation $\frac{n+1}{2} + \frac{gcd(2r+1,n)-1}{2} \leq m_r(C_n) \leq \frac{n+1}{2} + r$ was obtained. As it shows, when $gcd(2r+1, n) = 1$ the upper and the lower bound differ in r so the bounds may not be tight for large values of r.

In this contribution, we state that the difference between the bounds is at most one and we identify the cases for which the lower and the upper bounds are attained.

We have obtained an r-identifying code of minimum size for all the unknown instances that we study.

In addition we answered the question stated in the paper of Gravier et al. on the number of nodes that are needed to add to a minimum transversal in order to obtain and r-identifying code. Indeed, when $n = k(2r+1) + p$ and $2 \leq p \leq 2r-1$ the same transversal corresponds to an r-identifying code. Actually if T is a transversal and $|T| = \frac{n+1}{2}$ then T is enough to r-cover all the nodes of C_n and then the r-identifying code number equals $\frac{n+1}{2}$.

In the case $p = 1$ or $p = 2r$ the transversal does not r-cover the nodes in C_n. In both cases we manage to identify and r-identifying code of minimum cardinality and proved that the r-identifying code number equals $\frac{n+1}{2} + 1$.

Moreover, starting with any given minimum transversal $T = \{u + i(2r+1) : i \text{ even}, 0 \leq i \leq k(2r+1)+p-1\}$ where $u \in V(C_n)$, and adding $\frac{k}{2}$ nodes of the form $\{(u+r)+i(2r+1) : i \text{ even }, 0 \leq i \leq k-2\}$ when $p = 1$, we obtain an r-identifying code of size $\frac{n+1+k}{2}$. If $p = 2r$ and we add $\frac{k-1}{2}$ nodes of the form $\{(u+r-1)+i(2r+1) : i \text{ odd }, 1 \leq i \leq k-2\}$ we get an r-identifying code of size $\frac{n+k}{2}$. In both cases the identifying codes are not minimum.

An integer formulation based on common supersequences to solve the Permutation Problem using a Unit-Capacity Robot

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Given a finite sequence S over an alphabet, a sequence S' is a supersequence of S if we can delete some characters in S' such that the remaining sequence is equal to S. Given a finite set R of sequences, a common supersequence of R is a sequence which is a supersequence of every sequences of R.

In this article, using a graph model introduced in [Bendotti et al 2013], we give a necessary

and sufficient condition for the PPCR to be feasible (i.e. to posses a solution). We then show that solving a special case of PPCR instances directly reduces to find a shortest common supersequence in a particular sequence set. We propose an integer formulation based on this reduction to solve general case instances. Using this formulation we present some experimental results where large instances coming from the nuclear fuel renewal problem are solved to optimality. In order to produce a solution for non-feasible PPCR instances, we introduce some locations for PPCR instances where a piece can be temporarily hold if required. We show that these locations correspond to Steiner nodes in the graph model and we then extend the integer formulation for the resulting Steiner PPCR.

WD-III

16:00 - 17:40
Room: Miguel Ângelo III

Robust Optimization II

Contributed session
chair: Sara Mattia

Lagrangean Decomposition for Mean-Variance Combinatorial Optimization

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We address robust versions of combinatorial optimization problems, focusing on the uncorrelated ellipsoidal uncertainty case, which corresponds to so-called mean-variance optimization. We present a branch and bound-algorithm for such problems that uses lower bounds obtained from Lagrangean decomposition. This approach allows to separate the uncertainty aspect in the objective function from the combinatorial structure of the feasible set. We devise a combinatorial algorithm for solving the unrestricted binary subproblem efficiently, while the underlying combinatorial optimization problem can be addressed by any black box-solver. An experimental evaluation shows that our approach clearly outperforms other methods for mean-variance optimization when applied to robust shortest path problems and to risk-averse capital budgeting problems arising in portfolio optimization.

A Modelling Framework for Multiple Sources of Data-Uncertainty in Combinatorial Optimization Problems

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The huge success of mathematical programming in practical applications is driven by the idea of abstracting real life problems into mathematical optimization models. Hence, an integral element of (combinatorial) optimization is data quality and significance. The data quality is subject to many influences, ranging from measurement errors to model abstractions leading to approximation errors. Dealing with these influences, to which we refer as data-uncertainty, is the aim of robust-optimization.
In the context of combinatorial optimization, the robustness concept proposed by Bertsimas and Sim, see The Price of Robustness, Oper. Res. 2004, the so called Γ-robustness is one commonly accepted technique. In this work, we develop an extension to their scheme,

allowing to embed Bertsimas and Sim's model of uncertainty into a more general setting with multiple influences of data-uncertainty. This means, we show how relations beyond a one-to-one mapping between random-events and coefficients of the constraint matrix can be expressed, naturally expanding the idea of Γ-robustness. In the modeling framework, each coefficient of the constraint matrix is potentially influenced by two (or more) random-events, jointly determining the realized coefficient. In practical scenarios, this situation occurs, for example, in telecommunication networks where the amount of traffic issued by a communication request is given by the product of the (uncertain) amount of content multiplied with an (uncertain) compression rate, see Coudert, Koster, Phan, and Tieves: Robust Redundancy Elimination for Energy-Aware Routing, in IEEE GreenCom 2013. Respecting this special structure allows for a more detailed model of the underlying (previously hidden) uncertainty, practically leading to solutions with a smaller price of robustness, i.e., lower rate of over-protection.
On the example of the knapsack problem, the proposed extended scheme is motivated and evaluated. We compare the non robust knapsack problem to the Γ-robust one and to the case where each weight is determined by the product of two random events. Our work concludes with a short discussion about further generalizations within the range of the extended scheme, explaining benefits and drawbacks of models including an even more detailed description of uncertainties.

Robust shift scheduling in call centers

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We propose a robust optimization model for shift scheduling in call centers. The model is designed to react to the deviations that often occur between the planned staffing levels and the actual number of employees that would be necessary to guarantee the desired level of service. Different perturbation patterns are considered giving rise to different uncertainty sets, and the corresponding algorithmic implications are discussed. A case study from an Italian Public Agency is finally presented, which shows how the proposed methodology improves the quality of the schedules. Interestingly, although the methodology is fairly sophisticated, it perfectly fits in a quite common managers current practice.

WD-IV

15:30 - 16:45
Room: Vieira da Silva

Scheduling I

Contributed session
chair: Miguel Constantino

A branch and bound algorithm for scheduling chains with nonnegative timelags, arbitrary processing times and release times to minimize sum of completion times

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We consider the scheduling problem with nonnegative timelags. In the problem, tasks with arbitrary processing times are scheduled on a single machine to minimize the sum of completion times. A task is not allowed to be scheduled before its release time and it also has to meet the precedence constraints. The precedence graph is in the form of chains where each task has at most one immediate predecessor and one immediate successor. Time delays are possible depending on the alternative scheduling options. Time delays are formally defined by nonnegative timelags. Accordingly, if two tasks having a precedence relation are to be successively scheduled on the machine, start time of the succeeding task is delayed such that it cannot be earlier than the timelag passed after the completion time of the preceding task. We study the case where timelag is the same for all tasks. We propose a branch and bound algorithm to solve the problem. An easier case of the problem where the release time constraint is dropped is known to be NP-hard. In the scheduling problem we considered, the timelags might not be eliminated by sorting the tasks in alternative orders since the objective function is highly sensitive to the completion time of a task in any position. The relation between the values of the timelag, processing time and release time of the candidate task should be analyzed to compute the completion time of a task at any position. Due to the variability of these parameters, the computation of the objective function becomes costly. In the branch and bound algorithm, we use a constructive algorithm to determine the upper bounds. This algorithm iteratively updates the precedence graph and the earliest start times of the candidate tasks to be scheduled with respect to release time and timelag constraints and applies a selection strategy by also checking the processing times of the candidate tasks. To find the lower bounds, we use a similar algorithm by relaxing the timelag constraints. The branching scheme we use considers only the candidate tasks from different chains, which eliminates the feasibility check. Since only one task with the highest priority degree in a chain can be scheduled, number of successor nodes of any node in the tree is smaller than or equal to the total number of chains. We employ best first search and classical pruning strategy to explore the solution space. We analyzed the performance of the proposed branch and bound algorithm and preliminary experiments show that the results are promising.

A time indexed model for Open Shop and Job Shop with three operations

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We propose a time indexed model for the Open Shop problem. For a given time horizon T, n jobs, m machines and q operations in total, there are n T constraints to forbid simultaneous

execution of two operations of the same job, other m T constraints to forbid simultaneous execution of two operations of the same machine and q assignment constraints for the operations. The number of columns is q T. Each column corresponds to scheduling an operation at a particular time and consists of a block of ones for the job constraints and another block of ones for the machine constraints. Each group of constraints is totally unimodular. Although this property is clearly lost when all constraints are present, yet the integrality gap is not large. The best way to tackle the problem with objective the maximum completion time is to find the best time horizon by binary search. The total time objective presents some problem since it is not known in advance which operation of a job is the last one. A similar model is also presented for the Job Shop problem with at most three operations. The only difference with the previous model is that the columns corresponding to the first operations of each job have a block of ones starting from time zero up to the operation completion time and the columns corresponding to the third operations of each job have a block of ones starting from the beginning of an operation up to the time horizon. In this way the job constraints compel the operations to be carried out in the exact sequence. Since in the Job Shop the last operations are explicitly known it is quite easy to take care of total time objectives. We think that this model could be also fruitfully used for Job Shop problems with a larger number of operations by scheduling in turn, in a local search fashion, groups of three operations at a time, taking care of how the other operations have been already scheduled.

Fully Polynomial Time Approximation Scheme for the Maximum Lateness Minimization on a Single Processor with a Fixed Operator or Machine Non-Availability Interval

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In this paper we consider the single machine scheduling problem with one non-availability interval to minimize the maximum lateness where jobs have positive tails. Two cases are considered. In the first one, the non-availability interval is due to the machine maintenance. In the second case, the non-availibility interval is related to the operator who is organizing the execution of jobs on the machine. The contribution of this paper consists in an improved FPTAS for the maintenance non-availability interval case and the elaboration of the first FPTAS for the operator non-availability interval case. The two FPTAS are strongly polynomial.

Thursday

TA-I

9:30 - 10:45
Room: Miguel Ângelo I

Scheduling II

Contributed session
chair: Luís Florêncio

Decomposition Algorithm for the Single Machine Scheduling Polytope

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Given an n-vector p of processing times of jobs, the single machine scheduling polytope C arises as the convex hull of completion times of jobs when these are scheduled without idle time on a single machine. Given a point $x \in C$, Carathéodory's theorem implies that x can be written as convex combination of at most n vertices of C. We show that this convex combination can be computed from x and p in time $O(n^2)$, which is linear in the naive encoding of the output. We obtain this result using essentially two ingredients. First, we build on the fact that the scheduling polytope is a zonotope. Therefore, all of its faces are centrally symmetric. Second, instead of C, we consider the polytope Q of half times and its barycentric subdivision. We show that the subpolytopes of this barycentric subdivison of Q have a simple, linear description. The final decomposition algorithm is in fact an implementation of an algorithm proposed by Grötschel, Lovász, and Schrijver applied to one of these subpolytopes.

A constraint generation approach for the two-machine flow shop problem with jobs selection

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We consider a job selection problem in a two-stage flow shop. The objective is to select the best job subset with a given cardinality to minimize the makespan. This problem is known to be ordinary NP- hard and the current state of the state of the art algorithms can solve instances with up to 3000 jobs. We introduce a constraint generation approach to the integer linear programming (ILP) formulation of the problem according to which the constraints associated with nearly all potential critical paths are relaxed and then only the ones violated by the relaxed solution are sequentially reinstated. This approach yields a new solution algorithm capable of solving problems with up to 100000 jobs or more.

A hybrid algorithm for the unrelated parallel machine scheduling problem with job splitting

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In this presentation, the unrelated parallel machine scheduling problem with job splitting

and sequence independent setup times is addressed, using a recently proposed framework, SearchCol, short for "Metaheuristic search by Column Generation". The problem consists in finding a scheduling plan for a set of independent jobs on a set of unrelated parallel machines, considering jobs and machines release dates, sequence independent setup times and the job splitting property, with due date related objectives. A machine schedule decomposition using the Dantzig-Wolfe technique is applied to a mixed integer programming model, to be solved using the hybrid approach entitled SearchCol and its diverse features. Problem specific heuristics are presented to use in the different components of the algorithm, namely Column Generation and Perturbations, to add as constraints in the restricted master problem. To evaluate the effectiveness of the model and the proposed algorithm and heuristics, computational tests are performed and their solutions analysed for a set of test instances.

TA-II

9:30 - 10:45
Room: Miguel Ângelo II

Integer Linear Programming V

Contributed session
chair: Martine Labbè

A Branch-and-Price for the Network Pricing Problem with Connected Toll Arcs

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Consider a network where there are two types of arcs: a subset of arcs is owned by a company imposing tolls for using them, and a subset of remaining arcs which are toll-free. Furthermore, toll arcs are connected such that they constitute a single path, as it occurs for instance in a highway network. The company is willing to maximise the revenue from tolls, whilst users seek for their minimum cost path between their origin and destination. This problem has been proposed in a bilevel programming framework by Heilporn et Al. (2010), and proved to be strongly $\mathcal{NP}$-hard.
In Fortz et Al. (2013) we proposed a Dantzig-Wolfe reformulation for this problem, and showed that the linear relaxation is stronger than the formulation proposed by Heilporn et Al. (2010) and easily solvable.
In this work we extend this framework: more advanced techniques have been included in our column generation algorithm, as initialisation alternatives, stabilisation of dual variables values and early stopping criteria. Furthermore, we propose a full Branch-and-Price scheme to solve the integer problem, with an ad-hoc branching algorithm using pseudo-costs to guide the choices. Finally some rounding heuristics have been investigated to improve the primal bound during the branching. We are currently extending the framework to a branch-and-cut-and-price, including some efficient valid inequalities from the literature. Numerical experiments have been run under the SCIP framework.

The Envy-Free Pricing Problem and Unit-Demand Markets

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A common problem faced in economics is to decide the pricing of products or services of a company, since poorly chosen prices might lead to low profit. One important model for this is the unit-demand envy-free pricing problem, where one considers that every consumer buys the item that maximizes his own profit, and the goal is to find a pricing of the items that maximizes the expected profit of the seller. This problem is NP-hard and unlikely to be in APX, but it is still interesting to be solved in practice. So, we present four new MIP formulations for it and experimentally compare them to a previous one due to Shioda, Tunçel, and Myklebust. We describe three models to generate different random instances for general unit-demand auctions, that we designed for the computational experiments. Each model has a nice economic interpretation. Our results show that our MIP formulations are a great improvement both for solving the problem to optimality or in order to obtain solutions with small gap.

Engineering Diffusion on a Social Network at Minimum Cost

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We consider the following marketing problem that arises on a social network. Let $G = (V, E)$ denote a social network, where V is the set of individuals, and E are the connections between them. Each node i has a hurdle b_i and d_{ij} denotes how much node j influences node i if node j adopts (or purchases) the product. Additionally, an extra incentive/inducement p_i (which could be viewed as a coupon or discount) could be given to node i to encourage it to adopt the product. In this setting node i adopts the product if the sum of the influences its neighbors have on it and the inducement it is given are greater than its hurdle, $\sum_{j \in a(i)} d_{ij} + p_i \geq b_i$ where $a(i)$ denotes the set of adjacent nodes of node i. The goal in the Least Cost Influence Problem (LCIP) is to determine the minimum amount of inducements that need to be paid out, while ensuring that the entire population (i.e., V) adopts the product. In this paper we focus on the case where all neighbors have equal influence: i.e., $d_{ij} = d_i$. We propose a strong MIP formulation for the LCIP. For tree networks, we show that the constraint matrix is TUM, thus providing integer solutions for the LCIP on tree networks. We then design and implement a branch-and-cut method for general networks. We discuss our computational experience with this branch-and-cut approach.

TA-III

9:30 - 10:45

Room: Miguel Ângelo III

Trees II

Contributed session

chair: Geir Dahl

Improved Lower Bound for the Quadratic Minimum Spanning Tree Problem

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The Minimum Spanning Tree Problem (MSTP) is one of the most typical and well-known problems of combinatorial optimization which seeks a subgraph spanning all vertices of a given connected graph whose edge-cost is minimum. The Quadratic Minimum Spanning Tree Problem (QMSTP) is a variant of the MST whose cost does not only depend on single edge-cost but also on the interaction cost between every pair of edges. In this paper we review different strategies found in the literature to compute a lower bound for the QMSTP and propose a lower bound based on a new mixed 0-1 linear formulation. We first show that the proposed model dominates other formulations in terms of continuous relaxation, and then develop an efficient Lagrangian relaxation to drive a tight lower bound for the problem. Computational experiences demonstrate the strength of our bound in comparison with the other approaches.

Finding Totally Independent Spanning Trees with Linear Integer Programming

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Two spanning trees of an undirected graph are totally independent if they are edge disjoint and if the unique paths that connect any pair of vertices in these trees are also node disjoint. Accordingly, $K \geq 2$ spanning trees are totally independent if they are pairwise totally independent. The problem of finding K totally independent spanning trees (KTIST) or proving that no such trees do exist is NP-Complete. We investigate KTIST and an optimization problem which consists of finding K totally independent spanning trees with the minimum possible number of central nodes. Both problems have applications in the design of interconnection networks. We propose an integer programming formulation, valid inequalities and a Branch-and-cut algorithm to solve them. We also present an experimental evaluation of such an algorithm.

A polyhedral study of the diameter constrained minimum spanning tree problem

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We consider the diameter constrained minimum spanning tree problem (DMSTP) on a graph. Given an edge-weighted undirected graph, the objective is to find a minimum-weight

spanning tree such that the number of edges on the path between any two nodes does not exceed a given diameter D. Several integer programming models as well as exact and heuristic solution approaches for the DMSTP have been discussed in the literature. The current state-of-the-art approach has been proposed by Gouveia, Simonetti and Uchoa in 2011 who used properties of centers in graphs and reformulated the DMSTP as a Steiner tree problem on a layered graph. The authors showed that the layered graph approach outperformed all previous integer programming based approaches both in theory and practice. Surprisingly not much is known, however, with respect to the polyhedral structure of the DMSTP. In this work, we aim to close this gap by studying formulations in the natural space of variables, i.e, in the space of undirected edge design variables. We introduce new classes of facet-defining inequalities that are based on so-called jump inequalities. Finally, preliminary results from computational experiments are given.

TB-I

11:00 - 12:15
Room: Miguel Ângelo I

Rounting II

Contributed session
chair: Angel Corberan

The mixed capacitated arc routing problem with non-overlapping routes

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Real world applications for vehicle collection or delivery along streets usually lead to arc routing problems, with additional and complicating constraints. In this paper we focus on arc routing with an additional constraint to identify vehicle service routes with a limited number of shared nodes, i.e. vehicle service routes with a limited number of intersections. This constraint results in solutions that are better shaped for real application purposes.
We propose a new problem, the bounded overlapping MCARP (BCARP), which is defined as the mixed capacitated arc routing problem (MCARP) with an additional constraint imposing an upper bound on the number of nodes that are common to different routes. The best feasible upper bound is obtained from a modified MCARP in which the minimization criteria is given by the overlapping of the routes.
We show how to compute this bound by solving a simpler problem. To obtain feasible solutions for the bigger instances a heuristic for the BCARP is also proposed. Computational results over two sets of well known benchmark instances show that the BCARP model produces better shaped solutions (more compact, and with few intersections of routes) than the MCARP model, with only a small increase in total traveled time.

A novel approach for solving the Generalized Vehicle Routing Problem

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The generalized vehicle routing problem (GVRP) was introduced by Ghiani et al. (2000) and belongs to the class of generalized network design problems, known as well as generalized combinatorial optimization problems Pop (2012). Characteristic for this class of problems is the fact that it generalizes in a natural way many network design problems by considering a related problem on a clustered graph (i.e. graph where the nodes are replaced by node sets), where the original problem's feasibility constraints are expressed in terms of the clusters instead of individual nodes.
Variable Neighborhood Search (VNS) is quite a recent metaheuristic used for solving optimization problems based on a systematic change of the neighborhoods structures within the search in order to avoid local optima.
In this paper, we propose a VNS based heuristic for solving the generalized vehicle routing problem (GVRP) that uses different neighborhood structures which are adapted for the problem. Our VNS algorithm applies 8 types of neighborhoods, each of them focusing on different aspects and properties of the solutions to the GVRP. We divided these neighborhoods into two classes depending if they operate on a single route or if they consider more than one route simultaneously. All the considered neighborhoods are defined at the level of the global graph. The neighborhoods from the first class are obtained by moving one or more clusters from one position in the global route to another position in the same route and are called intra-route neighborhoods. We considered in our VNS three such neighborhoods: Two-opt neighborhood, Three-opt neighborhood and Or-opt neighborhood. The moves defined within the intra-route neighborhoods are used in order to reduce the overall distance. The other class, called inter-route neighborhoods work with two global routes. They are used in order to reduce the overall distance and in some cases they can reduce as well the number of vehicles. We considered in our VNS five such neighborhoods: 1-0 Exchange neighborhood, 1-1 Exchange neighborhood, 1-2 Exchange neighborhood, Relocate neighborhood and Cross-exchange neighborhood. For each candidate solution provided by any of the mentioned neighborhoods, we apply the local-global procedure in order to find the best collection of routes (w.r.t. cost minimization) visiting the clusters according to the given sequences.
Computational results for an often used collection of benchmark instances show that our proposed heuristic delivered competitive results compared with the existing state-of-the-art algorithms for GVRP .

New results on the Generalized Directed Rural Postman Problem

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Let $G = (V, A)$ be a directed graph with set of vertices V and set of arcs A, and let $c_{ij} \geq 0$ be the cost associated with the traversal of arc $(i, j) \in A$. Given a family of arc subsets $H = H_1, ..., H_L$, the Generalized Directed Rural Postman Problem (GDRPP) consists of

finding a minimum cost tour starting and ending at the depot (vertex 1) and traversing at least one arc from each subset $H_i, i = 1, ..., L$. These subsets H_i do not need to be disjoint nor induce connected subgraphs. This problem, without considering the presence of a depot, was introduced by Drexl (2007) in his PhD thesis. He proposed a formulation for the problem and a branch-and-cut algorithm producing good computational results. A more recent version of his work was published in Drexl (2013). However, it was Shuttleworth, Golden, Smith, and Wasil (2008) who presented this problem in the context of constructing routes for meter reading, calling it the Close Enough Traveling Salesman Problem. In this application, a vehicle with a receiver travels through a series of neighborhoods. If the vehicle gets closer than a certain distance to a meter (customer), the receiver is able to record the gas, water, or electricity consumption. Therefore, the vehicle does not need to traverse every street, but only a few of them in order to get close enough to each meter. The set of streets from which a certain meter i can be read define the set H_i. In their work, Shuttleworth et al. proposed four heuristics to solve eight real-life instances with an average of 900 customers and 9000 streets each. More recently, Hà, Bostel, Langevin, and Rousseau (2013) studied the problem, which they call the Close Enough Arc Routing Problem, and propose a new formulation, which they compare with a previous one introduced in Hà et *al.* (2012) and the one by Drexl (2007, 2013). Moreover, they propose a branch-and-cut algorithm providing very good computational results on large-size instances. In this work, we present a new mathematical formulation for the GDRPP and study the associated polyhedron of solutions. We also describe several new families of valid inequalities that are used in a new branch-and-cut algorithm. Finally, we compare the performance of our algorithm with that of the branch-and-cut by Hà et *al.* (2013). From the results obtained, we can conclude that our algorithm is, to our knowledge, the best existing exact method to solve this problem.

TB-II

11:00 - 12:15
Room: Miguel Ângelo II

Integer Linear Programming VI

Contributed session
chair: Agostinho Agra

An integer programming formulation for the Maximum k-Subset Intersection problem

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In this paper, we study the maximum k-subset intersection (MkSI) problem. Given an integer k, a ground set U and a collection S of subsets of U, the MkSI problem is to select k distinct subsets S1, S2, ..., Sk in S whose intersection size is maximum. The MkSI problem is NP-hard and hard to approximate. Some applications of the MkSI problem can be found in the literature and, to the best of our knowledge, no exact method was proposed to solve this problem. In this work, we introduce a very effective preprocessing procedure to reduce the size of the input, introduce a GRASP heuristic which was able to nd solutions very close to be optimal ones, propose an integer programming formulation for the problem and present computational experiments made with instances that come from an application.

An Extended Formulation for K-Partitioning

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We consider the K-partitioning problem: given a graph of n nodes with valued edges, we have to partition the nodes in exactly K clusters so that the sum of all edge weights with both end points in a common cluster is minimized. We present a formulation for this problem with edge variables and representative variables, and extend this formulation with additional variables. Facet defining inequalities studied in a previous work naturally extend to the new formulation, namely: the two-partition inequalities and the two-chorded cycles inequalities. We generalize a class of valid inequalities based on the pigeonhole principle, that we call the generalized dependent set inequalities. A computational study illustrates the efficiency of the new formulation and of the new class of valid inequalities.

Mining biological networks using weighted cliques

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A network/graph provides an abstract representation, establishing the relationships among a set of elements. It helps organizing the information and provides an overall view of the underlying system. These structures are being used in a large number of areas and scientific domains, namely in Sociology, Financial Markets, Marketing, Engineering, Chemistry, Biology, among others, contributing for knowledge progress and deeper understanding of hidden underlying information. A clique is a complete subgraph, revealing a strongly related group of nodes (elements). If each edge of the graph has an associated weight, for instance, representing a correlation coefficient among the two nodes it links, then the weight of a clique is the sum of the weights of all of its edges. In this case, a clique with the maximum total weight may reveal relevant information about the entire structure, providing an alternative relevant tool for mining the network/graph. In this work, we discuss formulations for maximum edge-weight clique problems on sparse graphs, exploring new discretized models. We also discuss their applicability on some real-world environments, namely on networks of interacting pathways and gene co-expression networks. In effect, these compact formulations are very attractive to use within an integer linear programming package. This can be particularly useful for researchers from other areas that may which to find maximum weight cliques in their own graphs.

TB-III

11:00 - 12:15
Room: Miguel Ângelo III

Network Design II

Contributed session
chair: Pedro Moura

Branch-and-Cut-and-Price using Stable Set polytope inequalities for the Capacitated-Ring-Star Problem

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Given a graph G = (V,E,A), V is the set of nodes which is partitioned into the set of depots N, the set of customers U and the set of Steiner nodes W. A ring-star is a bounded elementary cycle going through one depot v in N along with a subset of arc (i,j) in A where i is a client and j is a node of the cycle. The Capacitated Ring-Star Problem (CRSP) consists in finding a subset of ring-stars of minimal cost such that every edge belongs to a limited number of cycles.
We propose a set partitionning formulation for this problem together with a column generation technique. We study the auxiliary problem and show that a classical algorithmic approach would not lead to an efficient pricing procedure. We propose to use a Branch-and-Cut algorithm based on a previous work to solve the auxiliary problem.
We then strengthen our formulation with additional inequalities, including the well-known clique and odd-cycle inequalities. These inequalities are known to be very efficient, meanwhile, their dual costs are hard to be taken into account in the auxiliary problem. For that reason, there have been very few attempts to incorporate these inequalities in a Branch-and-Price algorithm. We present a method that allows to handle such inequalities using a Branch-and-Cut algorithm to solve the auxiliary problem. We also propose some reduction operations over the polytope associated with the master problem in order to speed up the separation algorithms. Finally, we present an efficient Branch-and-Cut-and-Price algorithm CRSP.

Adaptive Optimization of Bandwidth Resource Allocation for Virtual Networks

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Let the topology of a substrate network be described by a weighted directed graph G = (V,E,C), defined by a set V of nodes and a set E of links with finite capacities given by a function C. We consider multiple virtual networks constructed correspondingly to graph G for carrying different kinds of traffic, i.e. with different performance objectives and QoS mechanisms and with different source-destination pairs. Given that bandwidth values for each virtual link are assigned by the substrate network. The goal of the substrate network is to optimize the aggregate utility of all virtual networks, but each virtual network runs independently accordingly to its own distributed protocol that maximizes its own performance objective. Taking into account the complexity of the resource allocation problem under such combined conditions, we consider sub-problems which solutions allow us to obtain dy-

namically adaptive bandwidth allocation approximate optimization mechanisms. First, we consider optimization problems at a smaller timescale for the performance objective of each virtual network under specific constraints. Second, we evaluate how satisfied each virtual network is with its allocated bandwidth. We suppose that the substrate network periodically reassigns bandwidth shares. Therefore finally we determine how much bandwidth each virtual network should obtain from the substrate network on each link. On virtual network level we adapt the shortest path algorithm. Decision making of the substrate network on link level is based on fuzzy rules and uses satisfaction indicators described with fuzzy values. We propose also a special algorithm of bandwidth resource reallocation on the whole network level and describe a practical realization of the proposed approach by means of Coloured Petri Nets (CPN) using CPN Tools with specially designed bandwidth adaptation module. The support of the ESF project 2013/0024/1DP/1.1.1.2.0/13/$APIA/VIAA$/045 is kindly announced.

Maximum throughput network routing subject to fair flow allocation

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We investigate a bilevel network routing problem where, given a directed graph with a capacity for each arc and a set of elastic traffic demands specied by the corresponding origin-destination pairs, the network operator has to select a single path for each pair so as to maximize the total throughput while assuming that the flows are allocated over the chosen paths according to a fairness principle. We consider max-min fair flow allocation as well as maximum bottleneck. After presenting two complexity results, we discuss MILP formulations for the two problem versions, describe a Branch-and-Price algorithm and report some computational results.

TC-I

14:00 - 15:40
Room: Miguel Ângelo I

Rounting III

Contributed session
chair: Alain Quilliot

Cutting planes for Multi-Vehicle Inventory Routing Problems

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The Inventory Routing Problem (IRP) involves the distribution of one or more products from a supplier to a set of customers over a discrete planning horizon. Each customer has a known demand to be met in each period and can hold a limited amount of stock. The product is shipped through a distribution network by a fleet of vehicles of limited capacity. The version treated here, the so-called Vendor Managed Inventory Routing Problem (VMIRP) is the Inventory Routing problem arising when replenishment policies are decided by the sup-

plier. We consider two replenishment policies, both assuming that a stock upper bound is given for each customer. The first is known as Order-up (OU): if a customer is visited in a period, then the amount shipped to a client must bring the stock level up to the upper bound. The latter is called Maximum Level (ML): the stock level in each period cannot cannot exceed the upper bound.
The objective is to find replenishment decisions minimizing the sum of the storage and of the distribution costs. VMIRP contains two important subproblems: a lot-sizing problem for each client and a classical routing problem. In a recent paper we introduced reformulations of VMIRP-OU and VMIRP-ML derived from the single-item lot-sizing substructure and presented computational experience on single-vehicle benchmark instances.
Here we address Vendor Managed Inventory Routing Problems with multiple vehicles, introducing some cutting plane families derived from the relations between the lot-sizing and the routing substructures, based on the capacity of the vehicle and on the OU and ML replenishment policies. The cutting planes have been embedded into a Branch-and-Cut framework to demonstrate their effectiveness. Computational results on benchmark instances with a single product and multiple vehicles are presented.

A Heuristic for the Tank Allocation Problem in Bulk Shipping

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Many bulk ships have multiple tanks and can thereby carry multiple inhomogeneous products at a time. A major challenge when operating such ships is how to best allocate cargoes to available tanks while taking tank capacity, safety restrictions, ship stability and strength as well as other operational constraints into account. The complexity of the allocation problem varies with the number of tanks and the number and type of different products transported at the same time, and the problem of finding a feasible solution has been shown to be *NP-Complete*.
The Tank Allocation Problem (TAP) as described above is an operational planning problem but it also arises as a subproblem in tactical planning when routing bulk ship fleets. For each considered route, the TAP must be solved to assess route feasibility with respect to stowage. If the routing problem is solved in a way that requires assessment of numerous routes, as for instance in column generation and local search based methods, the solution time for the entire procedure will only be acceptable if the TAP can be solved efficiently.
We consider the TAP from a tactical perspective where the main objective is to quickly assess feasibility of a given ship route. We have developed a randomised heuristic for efficiently finding feasible allocations and computational results show that it can solve 99% of the considered instances within 0.5 seconds and all of them if allowed longer time. The heuristic is designed to work as an efficient subproblem solver and in such a setting with running times below e.g. 5 seconds, the heuristic clearly outperforms an earlier method by consistently solving more instances and effectively cutting 84% of the average running time. Furthermore, we have combined our heuristic with a modified version of the earlier method to derive a hybrid method that can efficiently solve all instances. Compared to the earlier method, this hybrid method cuts 93% of the average running times and consistently solves more instances than the other method within any given time limit.

Planning of container transfers in a multimodal platform

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Merchant shipping plays a central role in the global economy, with almost 90% of all international trade being done through naval shipping. In Europe, container ports from the northern range, such as Rotterdam, Antwerp, Hamburg, and Le Havre, are gateways to same hinterland, where intermodal container transshipments take place. Although their activities are somehow complementary, each of these ports is in concurrence with the others. To be competitive, a container port must have an optimized usage of its resources. We introduce a new tactical model for operations planning in a multimodal container platform, where a set of container terminals is cooperating. Our model considers two main resources for each terminal. The first one is hosting space, where container vehicles are immobilized while they are handled. Hosting space is divided into handling zones, for example: berths, or sets of railways. The second is container handling capacity, provided by groups of container cranes which can load and unload containers directly from the vehicles, for example: quay cranes or rail mounted gantry cranes. The set of vehicles contains vessels, feeders, trains and trucks, whose containers will be handled in one of the terminals during the planning horizon. For each vehicle, there is notably a time window, and a list of possible handling zones. Moreover, our model distinguishes container batches. A container batch is defined as a set of containers unloaded from a vehicle and loaded to another. For each container batch, we take into account the following handling operations: unloading, storage, loading and transfer between terminals. The objective is to minimize vehicles weighted tardiness. This problem polynomially reduces to a single processor scheduling problem, in which weighted tardiness is minimized. As the reduction is pseudo-polynomial, our problem is NP-hard in the strong sense, even for 1 container terminal, 1 handling zone, 1 crane, and each vehicle carrying 1 container batch.
We introduce a mixed binary linear program. This program contains a set of linking constraints: on hosting space, handling capacity, and on container batch operations. It has local constraints for each vehicle, notably on the loading and unloading operations of its container batches. We then propose an extended formulation, obtained by Dantzig-Wolfe decomposition, and a branch-and-price-and-cut algorithm. As the master problem is mainly a multi-dimensional knapsack problem, separation heuristics for lifted cover inequalities are used. We developed an instance generator and used it to show that our mixed binary linear program is tractable for realistic instances of reasonable size. We will compare the direct resolution of our model with the branch-and-price-and-cut algorithm over a large set of instances. We will consider a horizon of one week, two container terminals, four modes of transportation, and a traffic between 500 000 and 1 000 000 containers per year..

Branch and Price for a Reliability Oriented DARP Model

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We deal here with a static decisional model related to the monitoring of a DARP (Dial and Ride) model which involves, on a closed industrial site, small electrical autonomous vehicles. Because of technological issues, we focus on reliability, and propose a model which assign requests to vehicles while minimizing Load/Unload transactions. We study this model through both a Branch/Price approach, which provides us with benchmarks, and insertion based heuristics, well-fitted to dynamic contexts.

TC-II

14:00 - 15:40
Room: Miguel Ângelo II

Knapsack

Contributed session
chair: Arie Koster

A Cut-and-Branch Algorithm for the Quadratic Knapsack Problem

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The Quadratic Knapsack Problem (QKP) is a much-studied combinatorial optimisation problem, with many practical applications. We present a new exact algorithm for the QKP. The algorithm is of "cut-and-branch" type, in which a cutting-plane phase is followed by a branch-and-bound phase. The cutting-plane phase is much more sophisticated than those previously proposed in the literature, incorporating several classes of cutting planes, an effective primal heuristic, and several rules for eliminating both variables and constraints. Our computational results show that the algorithm is capable of solving instances of the QKP that cannot be solved by other methods.

A hybrid heuristic approach based on a quadratic knapsack formulation for the Max-Mean Dispersion problem

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The paper deals with the Max-Mean Dispersion Problem (Max-MeanDP) belonging to the general category of clustering problems. In Max-MeanDP, N is a set of elements with cardinality n and D a matrix whose components $d_{i,j}$ indicate distance/proximity between items i and j ($i, j \in N$). The aim of Max-MeanDP is to find a subset $M \subset N$ such that the expression $\frac{\sum_{i,j \in M} d_{i,j}}{|M|}$ is maximized. This problem has a real importance in fields like

architectural space planning and analysis of social networks. A two-phase hybrid heuristic procedure is proposed for Max-MeanDP that repeatedly solves a 0/1 quadratic knapsack formulation of a related Max-Sum dispersion problem within a matheuristic framework. In Phase 1, a set of candidate values of m is selected and corresponding feasible solutions are computed making use of a decision tree in order to seek promising intervals. In Phase 2, an enhancement procedure based on a Local Branching scheme is performed for each solution computed at the previous step. Computational results, performed on literature instances, show that the proposed procedure outperforms the state-of-the-art approaches.

A fast large neighborhood search for disjunctively constrained knapsack problems

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In this paper a fast large neighborhood search-based heuristic is proposed for solving the Disjunctively Constrained Knapsack Problem (DCKP). The proposed method combines a two-phase procedure and a large neighborhood search. First, a two-phase procedure is applied in order to construct a starting feasible solution of the DCKP. Its first phase serves to determine a feasible solution by combining two complementary problems: the weighted independent set problem and the classical binary knapsack problem. Its second phase uses a descent method trying to improve the current solution by applying both degrading and re-optimizing strategies. Second, a large neighborhood search is used for diversifying the search space. Finally, the performance of the proposed method is computationally analyzed on a set of benchmark instances for the literature and its results are compared to those reached by both Cplex solver and more recent algorithms in the literature. Several improved solutions have been obtained within small average runtime.

A Dynamic Program for the Multi-Band Robust Knapsack

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A generalization of the classical knapsack problem is the Gamma-robust knapsack problem which takes data uncertainty in the weights into account. In this problem, the weights of at most Gamma many items can deviate in an item specific range. A solution is feasible if the knapsack capacity is not exceeded for any realization of the weights. Just as for the classical knapsack, there exists a pseudo-polynomial algorithm in the form of a dynamic program for the Gamma-robust knapsack problem.
In this work, we investigate a further generalization, the multi-band robust knapsack problem. In this concept, the deviation range is partitioned into several deviation intervals, so-called bands, and the total number of realizations in each band is bounded by one parameter per band. We present an exact dynamic programming algorithm based on a dynamic program for the classical knapsack problem which has a complexity linear in the number of items but the knapsack capacity occurs with a power of the number of bands. Since in many applications the knapsack capacity is larger than the number of items, we develop an algorithm with a complexity linear in the capacity by restricting the domains of the dual variables in the robust counterpart of the multi-band robust knapsack problem. We show

that at most the number of items many values for each dual variable are possible in an optimal solution. This leads to a dynamic program with complexity linear in the capacity. To the best of our knowledge, this is the first pseudo-polynomial algorithm with linear complexity in the capacity for this problem.
Moreover, we improve the performance of our algorithm in practice and investigate it in case of two bands in a computational study using randomly generated instances of various sizes. The results demonstrate a clear benefit of the algorithm with a complexity linear in the capacity compared to the first algorithm. Additionally, the results show the effectiveness of the improvements and that our improved algorithm clearly outperforms CPLEX solving a compact reformulation.

TC-III

14:00 - 15:40
Room: Miguel Ângelo III

Graphs II

Contributed session
chair: Carlos Luz

Lovász and Schrijver N_+-relaxation on web graphs

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In this contribution we continue the study of the Lovász-Schrijver SDP-operator applied to the edge relaxation of the stable set polytope of a graph. The problem of obtaining a combinatorial characterization of graphs for which the SDP-operator generates the stable set polytope in one step has been open since 1990. In an earlier publication, we named these graphs N_+-perfect. In the current work, we prove that the only imperfect web graphs that are N_+-perfect are the odd-cycles and their complements. This result adds evidence for the validity of the conjecture stating that the only graphs which are N_+-perfect are those whose stable set polytope is described by inequalities with near-bipartite support.
Finally, it was also important to identify minimally N_+-imperfect structures in the webs. In fact, we have found a minimally N_+-imperfect rank-perfect web graph which is not near-perfect. This shows some advance in order to characterize N_+-perfect rank-perfect graphs and also a line for our future research.

b-coloring is NP-hard on co-bipartite graphs and polytime solvable on tree-cographs

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A b-coloring of a graph is a proper coloring such that every color class contains a vertex that is adjacent to all other color classes. The b-chromatic number of a graph G, denoted by $\chi_b(G)$, is the maximum number t such that G admits a b-coloring with t colors. A graph G is called b-continuous if it admits a b-coloring with t colors, for every $t = \chi(G), \ldots, \chi_b(G)$, and b-monotonic if $\chi_b(H_1) \geq \chi_b(H_2)$ for every induced subgraph H_1 of G, and every induced

subgraph H_2 of H_1.
We investigate the b-chromatic number of graphs with stability number two. These are exactly the complements of triangle-free graphs, thus including all complements of bipartite graphs. The main results of this work are the following:
- We characterize the b-colorings of a graph with stability number two in terms of matchings with no augmenting paths of length one or three. We derive that graphs with stability number two are b-continuous and b-monotonic.
- We prove that it is NP-complete to decide whether the b-chromatic number of a co-bipartite graph is at most a given threshold.
- We describe a polynomial time dynamic programming algorithm to compute the b-chromatic number of co-trees.
- Extending several previous results, we show that there is a polynomial time dynamic programming algorithm for computing the b-chromatic number of tree-cographs. Moreover, we show that tree-cographs are b-continuous and b-monotonic.

A simplex like approach based on star sets for recognizing convex-QP adverse graphs

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A graph G with convex-QP stability number (or simply a convex-QP graph) is a graph for which the stability number is equal to the optimal value of a convex quadratic program, say $P(G)$. This class of graphs was introduced in Luz [Oper. Res. Lett., 18 (1995), pp. 139–145] and subsequently studied in Luz and Cardoso [Ann. Oper. Res., 81 (1998), pp. 307–319] and in Cardoso [J. Global Optim., 19 (2001), pp. 291–306]. There are polynomial-time procedures to recognize convex-QP graphs, except when the graph G is adverse (that is, it is a non complete graph, without isolated vertices, such that the least eigenvalue of its adjacency matrix and the optimal value of $P(G)$ are both integer and none of them changes when the neighborhood of any vertex of G is deleted). This talk reports on a simplex-like algorithm for the recognition of convex-QP adverse graphs, which follows from a characterization of convex-QP graphs based on star sets associated to the least eigenvalue of its adjacency matrix. .

Friday

FB-I

10:30 - 12:10
Room: Miguel Ângelo I

Transportation Routing

Contributed session
chair: Ana Paias

Resource-based cycle elimination applied to the vehicle routing problem

Claudio Contardo, *ESG UQAM*, ccontard@gmail.com
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State-of-the-art solvers for many classes of vehicle routing problems are based on the solution of ad-hoc set-partitioning or set-covering formulations and solved by column generation. The pricing sub-problem used to to generate feasible routes of negative reduced costs is the ESPPRC, which is NP-hard. The computational complexity of solving the ESPPRC can be avoided if, instead of generating feasible routes, routes with cycles (i.e., that visit a subset of customers more than once) are allowed. The resulting problem is known as the SPPRC, which is weakly NP-hard, and solvable in pseudo-polynomial time by dynamic programming. Unfortunately, the lower bounds associated to this route relaxation are usually much weaker than those associated to the ESPPRC, so researchers have focused their attention in the last years in finding a good compromise between the quality of the lower bounds and the computational complexity needed to achieve them. The most remarkable refinement introduced in the last years is the ng-route relaxation proposed by Baldacci et al. (2011) used to allow cycles only if they are long enough, which in practice means to limit the impact of those cycles in quality of the linear relaxation lower bounds. In this work we aim at using the same logic as that of the ng-route relaxation but to forbid cycles based on another criterion: the (monotone) consumption of some resource. We present the shortest path problem with resource constraints and resource-based cycle elimination (SPPRC-RBCE). In the SPPRC-RBCE, with each customer we associate a tolerance W representing the minimum consumption of a resource that can be allowed in a cycle. Short cycles (those that consume W or less units of the resource) are forbidden, wehere as long cycles (those that consume strictly more than W units of the resource) are allowed. We present computational experiments aimed as assessing the effectiveness of the proposed approach.

State space reduced dynamic programming for the aircraft sequencing problem with constrained position shifting

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In this paper we present state space reduction techniques for a dynamic programming algorithm applied to the Aircraft Sequencing Problem (ASP) with Constrained Position Shifting (CPS). We consider the classical version of the ASP, which calls for determining the order in which a given set of aircraft should be assigned to a runway at an airport, subject to

minimum separations in time between consecutive aicraft, in order to minimize the sum of the weighted deviations from the scheduled arrival/departure times of the aircraft. The focus of the paper is on a number of ways of improving the computation times of the dynamic programming algorithm proposed. This is achieved by using heuristic upper bounds and a completion lower bound in order to reduce the state space in the dynamic programming algorithm. We compare our algorithm to an approach based on mixed integer linear programming, which was adapted from the literature for the case of CPS. We show using real-world air traffic instances from the Milan Linate Airport that the dynamic programming algorithm significantly outperforms the MILP. Furthermore, we show that the proposed algorithm is capable of solving very large instances in short computation times, and that it is suitable for use in a real-time setting.

Using an interior point branch-price-and-cut method for solving variants of the vehicle routing problem

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Branch-price-and-cut methods have been successfully used to solve many combinatorial optimization problems. As recently present in the literature, the performance of these methods can be improved by combining them with the primal-dual interior point algorithm. The resulting interior point branch-price-and-cut method typically shows more stability in the column generation, smaller number of valid inequalities and less nodes in the search tree. As a result, the total CPU time may be significantly reduced. These improvements are mainly due to the centrality of primal and dual solutions provided by the interior point algorithm, even when these solutions are non-optimal. In this talk, we describe the challenges of implementing an interior point branch-price-and-cut for solving a practical variant of the vehicle routing problem with time windows. This variant involves deciding how many deliverymen to assign to each vehicle, in addition to the usual routing and scheduling decisions. Such situation is faced by many companies in practice, especially those which must perform a large number of deliveries in very busy urban areas, such as dairy, beverage and tobacco industries. We present the results of computational experiments which indicate the advantages of using an interior point branch-price-and-cut method in this context.

MIP-based heuristics for driver rostering

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The driver rostering problem in a public transport bus company consists of defining rosters, that is, assigning daily crew duties to the company's drivers for a pre-defined time horizon, ensuring transport demand in a specific area, at low operating costs, while complying with legal requirements and agreements between the company and the driver unions. In most public urban transport companies, drivers are divided into small groups depending on several factors. The rostering for each group may stand on different strategies. The problem here presented is devoted to the assignment of a set of crew duties that must be covered by a pool of drivers who work according to a pre-defined days-off pattern (DRPP). Each pattern is composed by a set of days-off schedules where each days-off schedule defines a

feasible sequence of workdays and rest periods. The DRPP aims at determining the set of drivers to assign to each days-off schedule and the set of crew duties to be assigned to each driver that minimize driver costs, related with the number of drivers assigned to work and the respective salaries, and ensure roster balancing. We show that the DRPP with cyclic days-off patterns is NP-hard. We propose three mixed integer linear programming formulations for the DRPP: an assignment/covering model (AC), a multi-commodity flow model (MF) and a mixed multi-commodity assignment model (MFA). In AC the days-off pattern is defined by a 0-1 matrix whereas in MF and MFA it is described by a network. Lower bounds obtained from the linear relaxations of the three models are compared from a theoretical point of view. Taking advantage of the special structure of each mathematical model we propose two MIP-based heuristics. For the AC model a Relax-and-Fix heuristic that combines variable fixing with branch and bound techniques is developed. For MF and MFA models a Decompose-and-Fix heuristic that works in three steps is developed. First, a multi-commodity flow problem is solved to determine the minimum set of active schedules, which gives the minimum number of drivers that will cover all daily crew duties. In the second step, starting from the solution obtained in step one, a greedy heuristic fixes the subset of variables related with the assignment of each driver to a specific schedule so as to minimize salary costs. Finally, in the third step, the resulting restricted MF/MFA model is solved by a branch-and-bound algorithm that assigns daily crew duties to specific drivers ensuring roster balance. Computational experience with real data and data from benchmark instances is presented and discussed.

FB-II

10:30 - 12:10
Room: Miguel Ângelo II

Integer Linear Programming VII

Contributed session
chair: Janny Leung

Linear Arrangement Problems and Interval Graphs

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We present here new results on the Linear Arrangement Problem (LAP) on interval graphs. We first propose a new lower bound, which links LAP with the Max Cut Problem and show that this lower bound is tight for unit interval graphs. Next, we focus on arbitrary interval graphs, and derive a polynomial time approximation algorithm.

Linear Ordering Problem with Penalties

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In addition to its theoretical interest, the LOPP has a direct application in practice. For example, the problem of minimizing the total distance traveled between depots, placed in a row separated by a fixed distance, with certain flow between them, or minimizing the

wiring of electric nodes in a linear chasis, can be modeled as an LOPP. Considering the exact approaches in the related literature, Integer Linear Programming (ILP) techniques have proven very effective for the LOP. Encouraged by this success, we develop a Branch-and-Cut algorithm for the LOPP.

Circuit and bond polytopes in series-parallel graphs

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In an undirected graph, a circuit is a subset of edges inducing a connected subgraph in which every vertex has degree two. Given a graph and costs on its edges, the circuit problem consists in finding a circuit of maximum cost. This problem is already NP-hard in planar graphs [Garey and JohnsonBauer, 1976], yet some polynomial cases are known, for instance when the costs are non-positive. Although characterizing a polytope corresponding to an NP-hard problem is unlikely, a partial description may be sufficient to develop an efficient polyhedral approach. Concerning the circuit polytope, which is the convex hull of the (edge-)incidence vectors of the circuits of the graph, facets have been exhibited in [Bauer, 1997] and [Coulard and Pulleyblank, 1989], and the cone has been characterized in [Seymour, 1979]. For a better understanding of the circuit polytope in planar graphs, a natural first step is to study it in smaller classes of graphs. For instance, in [Coulard and Pulleyblank, 1989], the authors provide a complete description in Halin graphs. Another interesting subclass of planar graphs are the series-parallel graphs, the graphs having no K4-minor [Duffin, 1975]. Due to their nice properties, many problems NP-hard in general are polynomial for these graphs, in which case it is quite standard to (try to) characterize the corresponding polytopes. Since a linear combinatorial algorithm solves the circuit problem in series-parallel graphs, an obvious question arising is the description of the corresponding polytope. Surprisingly, it does not appear in the literature, and we fill in this gap with this presentation. As a consequence of this result, using planar duality, we obtain a description of the bond polytope in series-parallel graphs.

On the Mixed Odd Hole Inequality

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We study the polyhedral structure of the mixed set covering, partitioning and packing problem, which has drawn little attention in the literature but has many real-life applications. By taking the "interactions" between the different types of edges into account, we derive a new class of valid inequalities, which we call the mixed odd hole inequality. The inequality is strong in the sense that it is facet-defining for the mixed odd hole polytope except in two special cases, where it represents an improper face. With the inclusion of the inequality, the mixed odd hole polytope is completely characterized. We also provide several classes of valid inequalities (including implicit constraints of covering and packing types), generalize the mixed odd hole inequality to accommodate the use in general mixed problems and provide a sufficient condition for the inequality to be facet-defining.

FB-III

10:30 - 12:10
Room: Miguel Ângelo III

Polyhedra

Contributed session
chair: Mourad Baiou

On the exact separation of rank inequalities for the stable set problem

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When looking for a stable set of maximum cardinality in a given graph, Rank Inequalities (RIs) prescribe that, for any induced subgraph, at most as many nodes as its stability number can be part of the solution. Many of the classes of valid inequalities proposed for the max stable set problem (e.g., clique, odd hole, odd antihole, web, and antiweb inequalities) are obtained as a special case of RIs, when restricted to subgraphs of a certain topology. To our knowledge, the only computational attempts at separating the general family of RIs (without topological restrictions) are heuristic in nature, based on the notion of edge projection introduced by Mannino and Sassano (1996). Our contribution is threefold. First, we show how to exactly separate RIs via Mixed-Integer Programming (MIP) techniques. We propose a separation procedure, parametric in the stability number of the induced subgraph, which reduces the separation problem to a finite sequence of MIPs. Then, we introduce Rounded Fractional Rank Inequalities (RFRIs), a weaker version of RIs which is obtained when relaxing the stability number of the in- duced subgraph into its fractional stability number (FSN), rounded down. The intersection between the two families contains all the inequalities corresponding to subgraphs with a difference between their stability and fractional stability numbers (which we refer to as integral stability gap, ISG) strictly smaller than the unit. RFRIs contain clique, odd holes, and antiweb inequalities, whereas they do not include odd antiholes and web inequalities. We formulate the separation problem for RFRIs as a bilevel program where, at the first level, we look for an induced subgraph of maximum weight and, at the second level, for a maximum fractional stable set in such subgraph. By exploiting LP duality, we can state the whole separation problem as a single level MIP. The corresponding separation procedure is not parametric. We also consider a third (parametric) procedure which, by exploiting Farkas' Lemma, allows to generate the only RFRIs for which the corresponding subgraph has an ISG of 0, i.e., all those RFRIs which are, in fact, also RIs. Preliminary computational results are reported and illustrated. We discuss some issues concerning the tightness of the inequalities that we obtain, with focus on the introduction of maximality and connectivity constraints. Overall, the results show that the gap closed by RIs and RFRIs can be substantial. As to RIs, the results also indicate that, on some instances, their closure can be tighter than that obtained via SDP relaxations based on Lovasz's theta number.

On the Asymmetric Connected Facility Location Polytope

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In the last years, the connected facility location problem (ConFL) and variants of it have received considerable attention from the operations research community. Despite the large body of work on the ConFL, to our knowledge, there are no results on the facial structure of the underlying polytopes.
Our work is a first polyhedral study on the asymmetric ConFL. Our motivation for studying the asymmetric ConFL is twofold: 1) in some practical applications traversal of an edge in two opposite directions may involve different costs, and 2) the best performing computational approaches to ConFL are based on directed reformulations. In this paper we prove that some of the inequalities used in previous computational studies are facet-defining, and derive some new families of facet-defining inequalities. We also show how to lift known facets of the related Steiner arborescence and of the facility location polytope.
The obtained theoretical results are supported by a computational study on a newly generated benchmark set of digraphs.

The dominating set polytope via facility location

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In this paper we present an extended formulation for the dominating set polytope via facility location. We show that with this formulation we may describe the dominating set polytope for some class of graphs as cacti graphs, though its description in the natural node variables dimension has been only partially obtained. Moreover, the inequalities describing this polytope have coefficients in -1,0,1. This is not the case for the dominating set polytope in the node-variables dimension. It is known from Bouchakour, Contenza, Lee and Mahjoub [Eur.J.Com. 29 (2008)] that for any integer p, there exists a facet defining inequality having coefficients in 1,...,p. We also show a decomposition theorem by means of 1-sums. Again this decomposition is much simpler with the extended formulation than with the node-variables formulation given by Bouchakour, Contenza, Lee and Mahjoub [Eur.J.Com. 29 (2008)].

FC-I

14:00 - 15:15
Room: Miguel Ângelo I

Stochastic

Contributed session
chair: Rüdiger Schultz

A Multi-period Bi-level Stochastic Programming with Decision Dependent Uncertainty in Supply Chains

Yohanes Kristianto, *University of vaasa*, ykristiantonugroho@gmail.com

The closed loop supply chain faces some challenges related to the complexity of setting production capacity, maximizing the product architecture modularity and operations scheduling when remanufacturing is included in the supply chain networks. A multi-period bi-level stochastic programming framework is used by setting product architecture modularity design is integrated with supply chain networks design at the upper level and multi-period operations scheduling at the lower level. The result show that supply chain tends to postpone the product architecture modularization until the end of product life is imminent. The

bi-level optimization is proven to be good approach to get global optimum of the closed loop supply chain.

Proactive Reactive Scheduling in Resource Constrained Projects with Flexibility and Quality Robustness Requirements

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This paper presents a new approach to proactive reactive scheduling of stochastic resource-constrained project scheduling problems with known probability distributions of activity durations. To facilitate the search for cost-flexible proactive schedules that are adjustable and incur lower expected cost of future rescheduling, a new family of cost-based flexibility measures is introduced. Under these measures, cost is incurred on each rescheduling while taking into account the temporal distance of changes in the baseline schedule. We propose a new model that describes the integrated approach using the proposed cost-based flexibility measures where, in each stage, reactive scheduling can adjust the baseline schedule to accommodate flexibility and quality requirements. The model is based on bounded stochastic shortest path with finite state and action spaces. The commonly used schedule stability measure is put in the context of proposed family of flexibility measures and contrasted to them in the terms of project execution system properties.

The Computational Complexity of Stochastic Optimization

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This paper presents an investigation on the computational complexity of stochastic optimization problems. We discuss a scenario-based model which captures the important classes of two-stage stochastic combinatorial optimization, two-stage stochastic linear programming, and two-stage stochastic integer linear programming. This model can also be used to handle chance constraints, which are used in many stochastic optimization problems. We derive general upper bounds for the complexity of computational problems related to this model, which hold under very mild conditions. Additionally, we show that these upper bounds are matched for some stochastic combinatorial optimization problems arising in the field of transportation and logistics.

FC-II

14:00 - 15:15
Room: Miguel Ângelo II

Integer Linear Programming VIII

Contributed session
chair: Conceição Fonseca

Multi-objective Cuckoo Search with Leader Selection Strategies

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Cuckoo Search has been recently added to the pool of nature inspired metaheuristics. Its promising results in solving single objective optimization motivate its use in multiobjetive context. In this paper we describe a Pareto based multiobjective Cuckoo search algorithm. Like swarm based metaheuristics, the basic algorithm needs to specify the best solutions in order to update the population. As the best solution is not unique in multiobjective optimization, this requires the use of a selection strategy. For this purpose, we propose in this paper investigation of five leader selection strategies namely random selection, sigma method, crowding distance method, hybrid selection method and MaxiMin method. Performance of the proposed algorithm has been assessed using benchmark problems from the field of numerical optimization. Impact of selection strategies on both convergence and diversity of obtained fronts has been studied empirically. Experimental results show in one hand the great ability of the proposed algorithm to deal with multiobjective optimization and in the other hand that no strategy has been shown to be the best in all test problems from both convergence and diversity points of view. However they may impact significantly the performance of the algorithm in some cases.

A mixed integer linear program for planning and scheduling the meat production in a pork supply chain

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Pork is the most produced meat worldwide. In recent years it has been observed that most pork production is turning to be produce under larger productive structures called Pork Supply Chains. Inside those structures several complex problems are faced by the chain manager, who needs to integrate the stakeholders operations in order to coordinate the flow of product through the chain. One of the most challenging problems is the one related with the planning and scheduling of operations to process the carcass (body of the animal gutted and bloodless) into pork and by-products, taking into account vertical integration links.
Pork production planning involves determining the production levels of each product and its inventory. Those decisions depend on how to cut up the carcasses in order to satisfied consumer base. Several cutting patterns exist in the market; each cutting pattern is related with a set of products and specific reward. The concern here is to determine the number of times each cutting pattern is applied on the available carcasses. Moreover, other aspects of the problem are that products have short shelf life, large lead time and large variability in

the available type of carcasses.
To tackle this problem, this paper reports a mixed integer linear program for planning and scheduling pork production. The proposed model consider a given set of time periods over a short time planning horizon, multiple products, a given set of patterns, and a know demand in order to meet contracts established under supply chain relationships. The objective is to maximize the profit from selling products yielded from cutting patterns, considering the different cost that appear in the production system such as: inventory holding cost, production cost, freezing cost and unmet costumer demand cost. On the other hand the different constraints in the model represent the labour capacity, the yield by cutting patterns, the balance constraints matching production levels and the number of required carcasses, constraints to schedule the arrivals of animals from the suppliers, the demand and inventory constraints for fresh and frozen products. In the case of the fresh ones we represent the shelf life aspect of the product. Also, it is important to note that the arrival of animals is by batch, aspect that also imposes the use binary variables that are added to the list of integer decision variables related to the use of pattern and multiple products that meet an integer demand given by type of packing. Usually those problems give rise to medium and large scale problems as in our case. We present some results for medium size problems and point out some future work related with a strategy to solve larger ones.

Multicriteria pedestrian evacuation plan for natural disasters with safety and duration

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The first thing to do when a natural disaster like landslide, earthquake, flooding or tsunami strike an area is to evacuate victims. However due to damages on roads (crumbling, falling trees, or flooded roads) the evacuation can become dangerous and can even lead to the death of some evacuees. For instance those situations can be extended to the case of nuclear power plant accident on which we have to put in safe as much persons as we can before a radioactive cloud with different levels of radiation reach living places. In our case we have to evacuate an entire city on which a natural disaster occur and people have to leave their home for a while. We consider a dynamic network with a set of gathering points (source vertices) and a set of shelter locations (sink vertices). A number of evacuees have to go from each gathering point and each shelter location has a maximum capacity. We also have capacities and travel durations on edges and safety on vertices (probabilities to successfully cross vertices). Our motivation is to know how many evacuees can reach shelter locations without being injured before a deadline T. We prove that this problem is strongly NP-Hard even in a static network with one source and one sink. Using a bounded time-expanded network and epsilon constraints approaches, we solve the multicriteria problem on which the overall duration T of the evacuation is minimized while the number of saved persons is maximized. Exact and heuristic approaches will be given to address this problem.

FC-III

14:00 - 15:15
Room: Miguel Ângelo III

Trees III

Contributed session
chair: Bernard Fortz

Integer Programming Formulations for the Node-Weighted Group Steiner Tree Problem

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We consider the following problem: Given a graph with node weights and a set of terminal nodes, find a minimum-cost connected subgraph that contains a neighbor of each terminal or the terminal itself. The problem is motatived by applications in the design of telecommunication networks. The problem is shown to be equivalent to the Node-Weighted Group Steiner Tree (NWGST) Problem, which is the problem of finding a minimum-cost connected subgraph that contains one node from each group for a prespecified collection of groups. Integer Programming (IP) formulations for the NWGST problem usually employ $O(m)$ variables. We introduce formulations that only use node-based variables and that model connectivity through cut inequalities, which can be separated in polynomial time. The smaller number of variables is expected to lead to a better computational performance when solving very large problem instances. We discuss necessary and sufficient conditions for the model inequalities to define facets. We also derive additional facet-definining inequalities to strengthen the linear relaxation of our formulations. Finally, we discuss formulations based on a Steiner arborescence model, describe some facets of that polytope and report on our computational experiments with the various formulations.

Formulations and heuristic methods for the Weight-Constrained Minimum Spanning Tree Problem

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The Weight-constrained Minimum Spanning Tree problem (WMST) aims at finding a spanning tree of minimum cost with total weight not exceeding a given specified limit. This problem is a NP-hard combinatorial optimization problem and has important applications in the telecommunication networks design and communication networks. We present several formulations and report computational experience for comparing the formulations. An hybrid procedure that results from strengthening a formulation based on the MTZ inequalities with the cut-set inequalities proves to be the best. With the goal to obtain near optimal solutions to the WMST problem, we use heuristic methods for finding an integer feasible solution. Extensive computational results show that the heuristic methods are quite effective in finding integer feasible solutions and present small gap values.

Mathematical programming models for Traffic Engineering in Ethernet networks implementing the Multiple Spanning Tree Protocol

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With the increasing demand for Internet and cloud computing services, the need for large scale data centers has become paramount. In these data centers, switched Ethernet networks are becoming popular, because of the way they effectively manage traffic. Their topology must be cycle-free, to avoid broadcast radiation. Therefore, Ethernet networks only activate, at a given time, a subset of the existing links that must verify the IEEE 802.1d standard, which defines the topology of the sub-network as a spanning tree. One of the drawbacks of this protocol is that the network only ends up using a small number of the existing links. To overcome this, Ethernet networks began using the Multiple Spanning Tree Protocol, which maintains a set of spanning trees that are used for routing the traffic demands in the network. This is highly advantageous for the traffic performances of Ethernet networks, as the traffic can be spread throughout a bigger number of links. We present different mixed integer programming models for the Traffic Engineering problem of optimally designing a network implementing the Multiple Spanning Tree Protocol, such that link utilization is minimized. Although some variants of this problem have been treated in the literature, this is the first approach that focuses on using exact methods. We present tests in order to compare the formulations, in terms of linear relaxation strength and computing time. We also propose a binary search algorithm that has proven to be efficient in obtaining quasi-optimal solutions for this problem.

FD-I

15:30 - 16:45
Room: Miguel Ângelo I

Graphs III

Contributed session
chair: Ioannis Milis

Coupled-tasks in presence of bipartite compatibilities graphs

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The detection of an object by a radar system generally uses the following process: a transmitter emits a pulse in some direction which propagates though the environmental medium. If the pulse encounters an object, it is reflected back to the transmitter. Using the transmit time and the direction of the pulse, the transmitter can compute the position of the object. A natural way to model data acquisition process by a radar system is to use coupled-tasks, is to use coupled-tasks, introduced first by Shapiro: each acquisition task is a coupled-task $A_i = (a_i, L_i, b_i)$ composed by two sub-tasks of processing time a_i and b_i, respectively dedicated for wave transmission and echo reception. Between these two sub-tasks there is a fixed idle time L_i which represents the spread of the echo in the medium.
We tackle the makespan minimization coupled-tasks problem in presence of compatibility

constraints, which occur when several sensors using different frequencies can work in parallel, while acquisitions using the same frequency have to be delayed in order to avoid interferences. In particular, we focus on stretched coupled-tasks, i.e. coupled-tasks having the same sub-tasks execution time and idle time duration. We study severals problems in frame works of classic complexity and approximation for which the compatibility graph G_c or its underlying undirected version $uug(G_c)$ (according to the topology) is bipartite (star, chain, ...). In such context, we design some efficient polynomial-time approximation algorithms according to difference parameters of the scheduling problem.
We present in this paper severals NP-complete and polynomial results. We first show the problem is NP-hard even when the compatibility graph is a star, but then show it is solvable with a $O(n^3)$ time complexity algorithm when G is a chain. Then we focus our analysis when G_c is a 1-stage bipartite graph. We prove the problem is solvable with a $O(n^3)$ polynomial algorithm if $Delta_G = 2$, but becomes NP-hard when $Delta_G = 3$. Then we extend computational results by providing new approximation results : when G_c is a k-stage bipartite graph, we propose, among other, a $\frac{7}{6}$-approximation algorithm when k=1, and a $\frac{13}{9}$-approximation algorithm when k=2. We also show the existence of PTAS algorithms when G_c is a complete 1-stage bipartite graph.

Stochastic Graph Partitioning

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We study the stochastic problem of partitioning networks of processes onto a fixed number of nodes. Given a dataflow application, the objective is to assign the tasks to processors in order to minimize the total communications among them without exceeding the limited capacity of each processor in terms of resources (memory footprint, core occupancy, etc.). This problem, as an extension of the Node Capacitated Graph Partitioning problem proposed by C. E. Ferreira and al [Math.Prog.81, 1998], is obviously NP-hard. The stochastic version we study here is the partitioning for which the weights of the tasks are uncertain resource requirements and thus, we have to solve the chance constrained program for which the capacity of each processor is respected for each resource with a minimal probability target. We focus our studies on the case of individual chance constraints in which different probability levels can be assigned to different constraints. An extension of the central limit theorem was used to approximate our constraints, in which the distribution of uncertain resources is arbitrary, by the new constraints of normal distribution. For probability levels greater than one half, these constraints are convex. We reformulate them in the form of second-order cone constraints. We then study several quadratic programming formulations for the problem and var- ious solution techniques. The first technique to solve such problems is the so called Second-Order Cone Programming (SOCP) that amounts to transform each quadratic function defining the constraints separately by a second-order cone constraint. The two other solution techniques, based on reformulating the problem as a mixed-integer linear program, are the Fortet's classical linearization technique and the linearization technique recently proposed by Hanif D. Sherali and J. Cole Smith [Opt.Let.1, 2007]. We have conducted numerical experiments comparing the various solution techniques in a branch-and-bound approach. The results

obtained tend to suggest that, among the solution techniques considered, the linearization technique of Hanif D. Sherali and J. Cole Smith is often the most efficient and the SOCP technique is often the less efficient. These experiments also show the importance of taking data variations into account as compared to the deterministic version.

Solving Graph Partitioning problems arising in tagless cache management

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The instruction cache is a critical component in any microprocessor. It must have high performance to enable fetching of instructions on every cycle. In this paper, an optimization problem arising in the management of a new hybrid hardware and linker-assisted approach for cache memories management is considered. According to the proposed cache hardware features, the software (memory content) needs to be split into a few special "tagless" regions where the most used instructions need to be stored. To avoid some intrinsic overheads and get the most out of this scheme, we have to: - fill tagless regions carefully, privileging frequently used instruction groups (named basic-blocks); - limit as much as possible both successive access to different tagless regions and successive accesses to tagless and non-tagless memory regions. The behavior of a running application determines the access pattern to basic blocks (BBs), and thus to regions. A BB is a sequence of consecutive instructions ending with a jump instruction, and not having other jumps inside. Hence, BBs are executed sequentially and can have various lengths. The exact access pattern of an application run is represented by a graph called the Control Flow Graph (CFG), a weighted directed graph where nodes correspond to BBs and weights on edges between two BBs represent the number of times from the predecessor BB the program execution jumps to the successor BB. In the exposed scenario, the limitation of the overheads of the tagless cache can be achieved with a careful assignment of BBs to available tagless regions, taking into account the CFG and the following qualitative criteria: - We want to spend as much time as possible executing instructions from a tagless region. Therefore, nodes in CFG, i.e., basic blocks, having incoming edges with high weights should be preferred over those with edges with low weights. - We want to minimize switching amongst tagless regions, and at a more limited extension to/from BBs outside tagless regions, as this induces overhead due to partial cache flushing. Hence, BBs connected by edges with high weights should be preferably kept in the same tagless region. - We want to fill the tagless regions as much as possible to maximize the tagless accessing. This poses further challenges as, for instance, BBs have different sizes and tagless regions can be filled using leftover BBs that do not significantly impact the other two goals. Another phenomenon, called "leeway management", poses further challenges as the compiler increases or reduces the size of a basic block, according to the basic blocks it can possibly jump to and that are allocated far, e.g., in another tagless region or outside any tagless region. In this paper, the problem arising in the management of tagless cache memories is addressed. The problem can be formulated as a graph partitioning problem with side constraints and features. Different ILP formulations are proposed, obtained by strengthening and/or relaxing constraints and by reducing the number of integer variables. Some theoretical results are presented that allow to compare the different formulations. The formulations are tested on large instances (with thousands of nodes and

edges) arising from real applications. Computational results show that optimal or near optimal solutions can be achieved by using a state-of-the-art mathematical programming solver.

FD-II

15:30 - 16:45
Room: Miguel Ângelo II

Integer Linear Programming IX

Contributed session
chair: José Valério de Carvalho

Modeling Two-Dimensional Guillotine Problems via Integer Programming

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Two dimensional cutting problems are about obtaining a set of small (rectangular) items from one or more (rectangular) large stock pieces. Cutting problems are of great relevance in metal, wood, paper or glass industries, but also in loading, transportation, telecommunications and resource allocation in general. Depending on the industry, special features for the cuts may be required; a very common one which applies to glass and wood cutting is to have guillotine cuts. In guillotine cutting problems, small rectangular items are obtained from large rectangular stock through cuts that are parallel to the sides of the stock and cross the stock from one side to the other. Guillotine cuts are performed in stages, where each stage consists of a set of parallel guillotine cuts on the shapes obtained in the previous stage. In this paper, we do not restrict the number of stages, and allow the first cut to be either horizontal or vertical. Our objective is to propose a way of modeling guillotine cuts in Mixed Integer Linear Programs; we mainly concentrate our analysis on the Guillotine Two Dimensional Knapsack Problem (G2KP), where we are given one stock rectangle of length L and width W, and a list of n rectangular items. Each item i is characterized by a length li, a width wi, a profit pi, and is available in ui copies. The problem is to cut the subset of items of largest profit which can fit in the stock rectangle. We extend an idea originally proposed by Dyckhoff for the one dimensional case to two dimensions. We introduce the concepts of cut and plate, where a plate can be either the stock rectangle or a smaller rectangle obtained from the stock as result of a sequence of guillotine cuts. The main idea of the model for the G2KP that we propose is the following: starting from the stock rectangle, we obtain two smaller plates through a horizontal or vertical guillotine cut; for each obtained plate, we need to decide where to perform further cuts, or eventually to keep the plate as it is when its dimensions equal the dimensions of one of the items we want to obtain. The process is iterated until there are available plates large enough to fit some available item. In our model each cut decision is represented by a triple (q; j; o), where q is the distance from the bottom left corner of a plate of type j where a cut with orientation o is performed. The model maximizes the profit associated with the obtained items; a set of constraints imposes that: i) the number of times a given plate is cut does not exceed the number of times the same plate is obtained from other plates, ii) the stock rectangle in not used more than once, and iii) the items availability is not exceeded. The model has pseudo-polynomial size, indeed, in the worst case the number of plates is LW, and each plate can be cut horizontally in O(W) positions and vertically in O(H) positions. The overall number of variables is thus

O(WH(W +H)). However, we discuss conditions under which the number of variables can be safely reduced. We report a set of computational experiments investigating the actual size of the model for a set of benchmark instances, the quality of the solutions which can be obtained by restricting the set of considered variables, and the size of the instances which can be solved by a state-of-the-art MIP solver.

Maximum Generalized Assignment with Convex Costs

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We consider a generalization of the maximum generalized assignment problem (GAP). GAP is given by a set of items and a set of bins. For every item i there is an associated profit p_{ij} and a weight w_{ij} when assigned to bin j. The task is to assign a subset of the items to the bins such that the total profit is maximized and every bin's capacity B_j is satisfied.

We consider a natural generalization of GAP by dropping the "hard" constraints for the bin capacities, and introduce for every bin a cost function c_j that depends on the total weight of items assigned to this bin. These costs are subtracted from the profits of assigned items, and the task is to find an assignment maximizing the resulting net profit. Motivated by the study of energy-efficient computing environments, we focus our attention on the case of convex cost functions.

We show that even restricted cases of this problem remain strongly NP-complete by a reduction from 3-Partition.

We identify two cases that can be solved in strongly polynomial time. First, if all machines and weights are identical, and profits only depend on the bin, we show that an assignment in round-robin manner is always optimal. Next, we show that the problem can be solved using a minimum cost flow algorithm if the weights of the items only depend on the bin.

Furthermore, we present a $(1 - 1/e)$-approximation algorithm for the general case. This algorithm uses a configuration based integer programming formulation for a randomized rounding procedure. In order to turn the rounded solution into a feasible solution, we define appropriate estimators that linearize the convex costs.

Multidimensional dual-feasible functions and fast lower bounds for the vector packing problem

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Until now, all the dual-feasible functions proposed in the literature were 1-dimensional functions. In this paper, we extend the principles of dual-feasible functions to the m-dimensional case by introducing the concept of vector packing dual-feasible function, and we propose and analyze different new families of functions. All the proposed approaches were tested extensively using benchmark instances described in the literature. Our computational results show that these functions can approximate very efficiently the best known lower bounds for this problem and improve significantly the convergence of branch-and-bound algorithms.

FD-III

15:30 - 16:45
Room: Miguel Ângelo III

Network Design III

Contributed session
chair: Vangelis Paschos

Vulnerability Assessment of Spatial Networks: Models and Solutions

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Based on a well-known network interdiction model we formulate a framework of combinatorial optimization problems whose solutions can be used for assessing the vulnerability of spatial networks in the case of disruptions. We design a flexible model of network disruption based on the geometric characteristics of spatial networks. This model incorporates the nature of the disruptions present in different situations such as military planning, terrorist attacks or emergency control of infectious disease spreading. The proposed problems, along with the model of disruption, span several realizations of network interdiction providing a useful tool to characterize network vulnerability. Our aim is to propose a methodology that uses network optimization problems to characterize the robustness of a network in the presence of multiple failures.

On Min-Cost Flows in Planar Graphs

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We prove that there is a deterministic combinatorial subquadratic algorithm for the min-cost flow problem on planar graphs. To this end, we specialize an earlier result for general graphs to planar networks. In a previous paper, we showed that there is a combinatorial min-cost flow algorithm running in $\tilde{O}(m^{3/2})$-expected time. This algorithm is based on a potential reduction interior point method introduced by Ye in 1990. It needs $\tilde{O}(\sqrt{m})$ iterations and solves an electrical flow problem in each of them. For this paper, we observe that the randomized algorithm used for solving the electrical flow problem on general graphs can be replaced by Alon and Yuster's deterministic solver for planar Laplacian systems of linear equations, which is based on nested dissection. It runs in $O(n^{\omega/2})$ time yielding an overall running time of $\tilde{O}(n^{(\omega+1)/2})$ for our algorithm on planar graphs. For the best known bound on the matrix multiplication exponent ω, this running time can be written as $\tilde{O}(n^{1.68635})$. In case of $\omega = 2$, our bound would match the running time of current state-of-the-art methods for the min-cost flow problem. Since min-cost flows in planar graphs are relevant for image processing, we also consider parallelizations to leverage the capabilities of modern GPUs. Our parallel algorithm runs in $O(n^{2/3+\delta})$-expected time using $O(n^{5/6-\delta})$ processors, for any $\delta > 0$. We achieve this by plugging Koutis and Miller's randomized parallel planar Laplacian solver into our method.

Approximation Algorithm for the Broadcast Time in k-path Graph

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Broadcasting is an information dissemination problem in a connected network in which one node, called the originator, must distribute a message to all other nodes by placing a series of calls along the communication lines of the network. Every time the informed nodes aid the originator in distributing the message. Finding the broadcast time of any vertex in an arbitrary graph is NP-complete. The polynomial time solvability is shown only for certain graphs like trees, unicyclic graphs, tree of cycles, necklace graphs, 2-restricted cactus graphs, fully connected trees and tree of cliques. In this paper we study the broadcast problem in a k-path graph for which we present a $(4-\epsilon)$ -approximation algorithm for any originator of the k-path graph, $0 < \epsilon < 1$.

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Notes