FRICO 2012

15 – 18 Aug 2012

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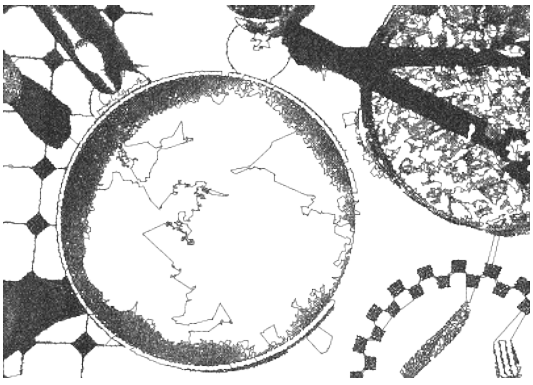

Schedule

Wednesday, 15 Aug 2012

10:00	**Martin Bergner** *Using graph clustering and partitioning algorithms for MIP structure detection*
10:40	**Michael Bastubbe** *A branch-and-price algorithm for rearranging a matrix into doubly bordered block-diagonal form*
11:20	**Christian Puchert** *Exploiting Problem Structures Heuristically within Column Generation Algorithms*
12:00	Lunch
13:30	**Stefan Wiesberg** *Finding the Basic Structure of a Complex Network*
14:10	**Alexander Reich** *Complexity of the Maximum Leaf Spanning Tree Problem on Regular Graphs*
14:50	**Rostislav Stanek** *Heuristiken für das optimale Data-Arrangement-Problem in einem Baum*
15:30	Coffee
16:00	**Markus Sinnl** *A computational study of the bi-objective prize collecting Steiner tree problem*
16:40	**Kai-Simon Goetzmann** *The Power of Compromise: Approximation in Multicriteria Optimization*
17:20	**Timo Berthold** *Measuring the impact of primal heuristics*

Thursday, 16 Aug 2012

10:00	**Sarah Kirchner** *Appointment Scheduling in a Hospital Environment*
10:40	**Frank Fischer** *A dynamic graph generation technique in Lagrangian relaxation for large time expanded networks*
11:20	**Andreas Schmutzer** *Targets Between Cuts*
12:00	Lunch
13:30	**Michael Engelhart** *A new test-scenario for analysis and training of human decision making with a tailored decomposition approach*
14:10	**Florian Stapel** *Network reduction for water distribution systems as a part of an optimization process*
14:50	**Ambros Gleixner** *Rapid Optimality-based Bound Tightening*
15:30	Coffee
16:00	**Julia Sponsel** *On standard quadratic optimization problems*
16:40	**Philipp Hungerländer** *A Comparison of Approaches for Ordering Problems*
17:20	**Luuk Gijben** *Scaling relationship between the copositive cone and Parrilo's first level approximation*

Friday, 17 Aug 2012 — Industry Day

10:00	**Maren Martens** *Optimization Problems in Logistics*
10:40	**Sleman Saliba** *Process and Production Optimization at ABB Corporate Research*
11:20	**Roland Wessäly** *Cost optimized optical fiber access network design*
12:00	Lunch
13:30	**Thomas Lehmann** *Combinatorial Optimization for Energy Management*
14:10	**Berkan Erol** *Operation of Energy-Assets using Stochastic Optimization*
14:50	**Maciej Warszawski** *Graphical Building of Mixed Integer Programs in the Energy Sector*
15:30	Coffee
16:00	**Nikolaus Witte** *Persistent Homology and Roundabout Detection*
16:40	**Gregor Karbstein, Mareike Massow** *The Next Big Thing in Duty Scheduling: Multicriterial Optimization*
18:00	Barbecue

Saturday, 18 Aug 2012

10:30	Brunch
12:00	**Matthias Walter** *On Simple Extended Formulations of Polytopes*
12:40	**Anja Fischer** *Polyhedral combinatorics for the asymmetric quadratic traveling salesman problem*
13:20	**André Chassein** *A column generation approach for workforce scheduling*
14:00	**Mohsen Rezapour** *Approximation algorithms for connected facility location with buy-at-bulk edge costs*
14:40	Coffee
15:10	Best Presentation Poll and Award

Abstracts Participants

Wed, 10:00 Martin Bergner (RWTH Aachen)

Using graph clustering and partitioning algorithms for MIP structure detection

It is known that methods such as Dantzig-Wolfe reformulation or Bender's decomposition are beneficial when solving certain mixed-integer optimization problems (MIPs). In order to fully explore the potential of both methods, certain structural information about the constraint matrix is necessary. For both algorithms, the matrix needs to be arranged in a bordered block diagonal form. While this information is available and well known for some types of problems, it is not clear whether this structure can be recognized automatically by a graph partitioning algorithm. Further, it is not evident how the quality of such a rearrangement can be measured a priori.

In this talk, we present different models for matrix rearrangement such that a Dantzig-Wolfe reformulation or Bender's decomposition is applicable in the classical sense. In particular, we discuss how the problem of permuting a matrix to a block diagonal form can be solved by using graph partitioning and clustering algorithms on distinct graph representations of the constraint matrix. Both the advantages and drawbacks of the different algorithms and graph representations are discussed. Further, the application of graph algorithms for recognizing known structures are investigated for specific problems. Finally, we will provide experimental results on general and structured MIPs to illustrate the solution quality of the presented algorithms.

Joint work with Marco Lübbecke

Wed, 10:40 Michael Bastubbe (RWTH Aachen)

A branch-and-price algorithm for rearranging a matrix into doubly bordered block-diagonal form

We consider rearranging the rows and the columns of a matrix into doubly bordered block-diagonal (a.k.a. arrowhead) form. For a given number of blocks and some given balance condition on the blocks, this becomes an optimization problem in which the total number of border rows and border columns is to be minimized. In this talk we present an exact branch-and-price algorithm to this optimization problem.

For us, this matrix form is particularly interesting because it may help us applying a Dantzig-Wolfe decomposition of the underlying mixed integer program.

We extend a naive assignment IP formulation (that has a weak LP relaxation) by an exponentially number of block pattern variables to strengthen the LP relaxation. Our branch-and-price algorithm first solves the pricing problem heuristically by exploiting its special structure. If the heuristic solution of the pricing problem does not yield variables with negative reduced costs the pricing problem is solved exactly by an IP. We present the improvement of the LP relaxation and discuss the practicability of the algorithm.

Wed, 11:20 Christian Puchert (RWTH Aachen)

Exploiting Problem Structures Heuristically within Column Generation Algorithms

In many MIP applications, a problem with a particular structure is to be solved. This structure is reflected by the MIP's coefficient matrix, which takes e.g. a (bordered) block diagonal or a staircase form. For those problems, the *Branch-and-Price* scheme using the *Column Generation* procedure has proven to be a successful approach which relies on the *Dantzig-Wolfe decomposition*.

It reformulates the MIP as a master problem and several pricing subproblems, which can often be solved by a problem-specific combinatorial algorithm.

The performance of this scheme may be improved by supplying it with additional features such as *primal heuristics*. These aim at finding good feasible solutions as early as possible, thus helping to prune Branch-and-Bound nodes that are not worth exploring. We present heuristics that are specially tailored for Column Generation and exploit a given problem structure, but are still generic in that they are not restricted to any particular problem.

First, we investigate how *Diving Heuristics* can be applied within Branch-and-Price. Diving Heuristics perform a depth-first search on the Branch-and-Bound tree and thus may find feasible solutions that otherwise would only be found later on in the course of the algorithm. In our context, they may work on either the original problem or the master problem. We will give a comparison on these two variants and the different diving strategies and report on the impact they have on the performance of the overall algorithm.

Furthermore, we present two heuristics under development that are specially tailored for problems where the matrix has a staircase structure, namely *Fifty-fifty* and *Rolling Horizon*. These heuristics consecutively solve parts of the MIP while the other parts are fixed, thus breaking down the MIP into several smaller, hopefully easier to solve MIPs. We will present first preliminary results on how they perform on generic staircase-structured problems.

Joint work with Marco Lübbecke

Wed, 13:30 Stefan Wiesberg (Universität Heidelberg)

Finding the Basic Structure of a Complex Network

For an economical trade network, there are several possibilities for its organization. Some networks resemble production chains, whereas others might appear to be more centralized. Such meta descriptions of networks base on a clustering of the vertices into functional classes, called regular classes. Two members of such a class play the same functional role within the network.

We consider the problem of finding the most suitable meta description of a given network. We examine its complexity, its relation to other problems and give an overview on applications. A branch-and-cut algorithm is introduced and running-time improvements with respect to existing methods are reported.

Wed, 14:10 Alexander Reich (BTU Cottbus)

Complexity of the Maximum Leaf Spanning Tree Problem on Regular Graphs

In the Maximum Leaf Spanning Tree Problem (Mlst for short) one is looking for a spanning tree in an undirected and unweighted graph that maximizes the number of leaves over all spanning trees. This problem is not only known to be $\mathcal{NP}$-complete for general graphs, but also for a range of special classes of graphs. Among these classes are planar graphs with maximum degree 4, 4-regular graphs, as well as cubic graphs.

It is known that on arbitrary graphs, the problem is max $\mathcal{SNP}$-hard. Hence, the approximability has been studied exhaustively in recent years. For general graphs, a 2-approximation could be provided. Restricted to cubic graphs, there exists even a 3/2-approximation algorithm.

In this talk, we establish the $\mathcal{NP}$-completeness of the Mlst for graphs that are both, planar *and* cubic. Therefore, we specify the proof of Lemke (1988) to planar graph. More precisely, we provide a reduction from the planar version of Exact Cover By 3-Sets. In contrast to Lemke, our

gadgets for the 3-sets are considerably more intricate. Furthermore, the 3-sets have to be connected to each other. To preserve planarity, this is done with additional gadgets that cross the faces of some planar embedding of the X3C instance. Thus, our reduction becomes non-deterministic.

Bonsma and Zickfeld (2008) conjectured the MLST to be max $\mathcal{SNP}$-hard on cubic graphs. As our second result we show that MLST is $\mathcal{APX}$-complete on 5-regular graphs. This pretty similar result could be a first step to prove this conjecture.

WED, 14:50 Rostislav Stanek (Universität Graz)

Heuristiken für das optimale Data-Arrangement-Problem in einem Baum

Das Minimum-Data-Arrangement-Problem in vollständigen Bäumen einer gegebenen Ordnung (MinDAPBaum) ist ein kombinatorisches Optimierungsproblem. Das Ziel dieses Problems ist es, die Knoten eines gegebenen ungerichteten (ungewichteten) Graphen G in den Blättern eines vollständigen Baumes T einer gegebenen Ordnung d so einzubetten, dass die Summe der Abstände zwischen je zwei Blättern von T, die einer Kante in G entsprechen, minimiert wird. Dieses Problem ist ähnlich wie das Minimum-Linear-Arrangement-Problem (MinLAP) ein Spezialfall des gut untersuchten Graphen-Einbettung-Problems (GEP), das stets NP-schwer ist. Die Komplexität des MinDAPBaums wurde zum ersten mal von Luczak und Noble bewiesen. Nach einer kurzen Einführung in die Problematik werden zuerst einige problemspezifische Eigenschaften erläutert. Danach wird eine untere Schranke definiert, die als Verallgemeinerung einer ähnlichen unteren Schranke für das MinLAP von Petit gesehen werden kann. In weiterer Folge werden einige Heuristiken für das MinDAPBaum präsentiert und deren Performance bei Zufallsgraphen untersucht. Im Rahmen dieser Untersuchungen wird auch der Erwartungswert und die Varianz des Zielfunktionswertes eines zufälligen Arrangements ermittelt. Danach werden Greedy-Heuristiken und Verfahren, die die lokale Suche als Hauptidee benutzen, präsentiert und getestet. Kurz werden auch einige polynomiell lösbare Spezialfälle behandelt. Und letztendlich werden einige nummerische Ergebnisse präsentiert, die ermöglichen, die vorgestellten Heuristiken zu vergleichen.

Joint work with Eranda Çela

WED, 16:00 Markus Sinnl (Universität Wien)

A computational study of the bi-objective prize collecting Steiner tree problem

When modeling real world problems as combinatorial optimization problems one often needs to consider two or more conflicting objectives. Thus, a whole bunch of methods for solving such bi- and multi-objective problems has been proposed during the last decades. While early works mainly focused on theoretical aspects, computational studies have been performed only recently. The latter is especially true for integer linear programming based approaches that aim to find all efficient solutions, i.e., the complete Pareto frontier. Still, however, there is a lack of computational studies comparing a significant amount of these methods, i.e., usually only one or at most two different methods are applied to a considered problem.

With this work, we aim to change this fact by a thorough computational study comparing the ϵ-constraint method, binary search in objective space, the parallel partitioning method, and a weighted Tschebyscheff norm method. All these methods work by repeatedly solving integer linear programs (ILPs).

The methods are studied using the bi-objective variant of the prize collecting Steiner tree problem (PCSTP) on a graph where the amount of revenues collected and the resulting costs are considered as objective functions. From a practical perspective, this natural extension of the PCSTP is important

whenever just maximizing the difference between the total revenue and the solutions' cost is not meaningful, e.g., if revenues are not given in terms of monetary prizes.

In this computational study we also demonstrate how to exploit information gained during the search for the Pareto frontier: We present heuristics to generate starting solutions for the ILPs, cut pools and a branching strategy based on previously found Pareto solutions. Moreover, we show how to define visit inequalities for our problem. Furthermore, the structure of our problem also allows the use of cover and and cutset-cover inequalities.

Computational results show that in general, the ϵ-constraint method exhibits the best performance for smaller instances and binary search in objective space exhibits the best performance for larger instances.

Wed, 16:40 Kai-Simon Goetzmann (TU Berlin)

The Power of Compromise: Approximation in Multicriteria Optimization

We study a concept in multicriteria optimization called *compromise solutions* (introduced in 1973 by Yu) and a generalized version of this, termed *reference point solutions*. Our main result shows the power of this concept: Approximating reference point solutions is polynomially equivalent to constructing an approximate Pareto set as studied by Papadimitriou and Yannakakis in 2000.

A reference point solution is the solution closest to a given reference point in the objective space. Compromise solutions use the component-wise minimum over all solutions as a reference point. These methods are widely spread in practice. While for a fixed norm it gives a single solution balancing the different criteria, by changing the norm in the objective space each point in the Pareto set can become the reference point solution, thus maintaining the full variability of multicriteria problems. Despite its apparent virtues only few theoretical and even less algorithmic results are known for reference point methods.

We study minimization problems with a constant number of criteria. In addition to the equivalence of approximability of reference point solutions and the Pareto set, our techniques allow us to show that the Pareto set has a constant factor approximation if and only if the single-criterion problem has a constant factor approximation. We further give several general techniques to obtain solutions for reference point methods. The main algorithmic result is an LP-rounding technique that achieves the same approximation factors for reference point solutions as in the single-criterion case for many classical combinatorial problems, including set-cover and several machine scheduling problems.

Joint work with Christina Büsing, Jannik Matuschke, and Sebastian Stiller

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Wed, 17:20 Timo Berthold (Zuse-Institut Berlin)

Measuring the impact of primal heuristics

In modern MIP-solvers like the branch-cut-and-price-framework SCIP, primal heuristics play a major role in finding and improving feasible solutions at the early steps of the solution process.

However, classical performance measures for MIP such as time to optimality or number of branch-and-bound nodes reflect the impact of primal heuristics on the overall solving process rather badly. Reasons for this are that they typically depend on the convergence of the dual bound and that they only consider instances which can actually be solved within a given time limit.

In this talk, we discuss the question of how the quality of a primal heuristic should be evaluated and introduce a new performance measure, the "primal integral". It depends on the quality of solutions found during the solving process as well as on the point in time when they are found. Thereby,

it assess the impact of primal heuristics on the ability to find feasible solutions of good quality, in particular early during search.

Finally, we discuss computational results for different classes of primal heuristics that are implemented in SCIP.

Thu, 10:00 Sarah Kirchner (RWTH Aachen)

Appointment Scheduling in a Hospital Environment

Today patient appointments are scheduled locally in most german hospitals. In every hospital unit a scheduler assigns appointments sequentially to incoming treatment requests. As the settlement amount for a patient is determined by his diagnoses and received treatments and not by the length of his hospitalization it is desirable for hospitals to reduce the average length of hospitalization. Therefore it is necessary to coordinate appointments for all treatments on a patients care pathway. This problem can be seen as a new variant of the well known job shop scheduling problem where patients correspond to jobs and treatments for patients correspond to tasks of jobs. Other than in the job shop problem in our problem the time horizon is divided into days. Every treatment of a patient has to end the same day it was started. The objective is to minimize the average number of days of hospitalization. In this talk we introduce this new scheduling problem and present first models and solution approaches.

Joint work with Marco Lübbecke

Thu, 10:40 Frank Fischer (TU Chemnitz)

A dynamic graph generation technique in Lagrangian relaxation for large time expanded networks

One typical way to model scheduling or timetabling problems is the use of time expanded networks. The schedule of each single object then corresponds to a path in the respective network while certain resource restrictions, like, e.g., limited capacities of some machines, that prohibit the simultaneous planning of some steps, are modeled via coupling constraints. In large scale applications these models are typically tackled using Lagrangian relaxation or column generation approaches, that require the repeated solution of shortest path problems in these networks.

A major disadvantage is that the time expanded networks grow quickly with increasing size of the planning horizon or decreasing discretisation step sizes. This leads to huge models intractable with standard approaches.

We propose a dynamic graph generation technique that can be used to reduce the size of the networks dramatically. Instead of generating the fully expanded networks the specially structured objective functions are exploited so that only a small subgraph has to be stored in memory on which the shortest path problems are solved. If this subgraph is too small to determine the shortest path correctly then this situation is detected and the graph is enlarged dynamically. We present some numerical experiments on a large train timetabling problem of Deutsche Bahn.

Joint work with Christoph Helmberg

Thu, 11:20 Andreas Schmutzer (Universität zu Köln)

Targets Between Cuts

Several mathematical optimization problems can be modeled using betweenness variables $b_{i,j,k} \in \{0,1\}$ with $i < j$. Betweenness variables represent the fact that k is either between i and j or not, without restricting the relative positions of i and j. Hence a feasible betweenness vector $b = (b_{i,j,k})_{i<j,k}$ must be compatible with a linear ordering of i, j and k, i.e. $b_{i,j,k} = 1$ iff k is between i and j while i may occur before j or the other way around.

We will present a well-known relation of betweenness and cut polytopes. Further we will show how this relation can be used to derive facets of the betweenness polytope. In order to find facets of larger polytopes we used special projections and so-called target cut separation.

Finally we will show some interesting applications of the betweenness polytope, i.e. solving linear arrangement and scheduling problems.

Thu, 13:30 Michael Engelhart (Universität Heidelberg)

A new test-scenario for analysis and training of human decision making with a tailored decomposition approach

In the research domain *complex problem solving* in psychology, where the aim is to analyze complex human decision making and problem solving, computer-based test-scenarios have increasingly been used over the last years. The approach is to evaluate the performance of participants within *microworlds* and correlate it to certain attributes, e.g. the participant's capacity to regulate emotions.

In the past, however, these test-scenarios have usually been defined on a trial-and-error basis, until certain characteristica became apparent. The more complex models become, the more likely it is that unforeseen and unwanted characteristics emerge in studies. To overcome this important problem, we propose to use mathematical optimization methodology on three levels: first, in the design stage of the complex problem scenario, second, as an analysis tool, and third, to provide feedback in real time for learning purposes.

We present a novel test scenario, the *IWR Tailorshop*, with functional relations and model parameters that have been formulated based on optimization results. The resulting optimization problems are *nonconvex mixed-integer nonlinear programs*, for which we present a tailored decomposition approach. The implementation of the new model features a web-based interface and uses the widely spread *AMPL* interface, which allows, e.g., the use of a variety of powerful optimization algorithms.

Joint work with Joachim Funke and Sebastian Sager

Thu, 14:10 Florian Stapel (Universität Paderborn)

Network reduction for water distribution systems as a part of an optimization process

Optimization in water distribution systems has gained more and more attention in the last two decades. Currently, a broad variety of mathematical programming models concerning different aspects as planning tasks or problems of optimal operation are available. Due to aspects such as the nonlinear network hydraulics or integer decisions, the mathematical problems can become hard to solve. Additionally, the number of variables and constraints for a specific instance may have a big influence on the solution time or the solvability in general. Therefore, reducing the size of the network model is an important task.

Network reduction is applied as a preprocessing step before the generation and solution of the mathematical programming instance. Since all operations are performed on a network model, further difficulties can occur. When considering an optimization model whose solution may introduce changes to the network topology or parameters of aggregated network elements, a matching between the solution vector of the reduction based mathematical program and the non-simplified network model is not trivial. In this talk we will give an overview of existing techniques to simplify water distribution systems, thereby also discussing the problems one is confronted with when separating the network reduction from the mathematical programming model and its solution.

Thu, 14:50 Ambros Gleixner (Zuse-Institut Berlin)

Rapid Optimality-based Bound Tightening

Optimality-based Bound Tightening (OBBT) is a well-known, simple, yet computationally expensive procedure to reduce variable domains of mixed-integer nonlinear programs (MINLPs) by solving a series of auxiliary linear programs (LPs). We present techniques to reduce the computational effort incurred by OBBT and exploit dual information from the LP solutions during a subsequent branch-and-bound solution process. We evaluate the performance impact of these techniques using an implementation within the MINLP solver SCIP.

Thu, 16:00 Julia Sponsel (Universität Trier)

On standard quadratic optimization problems

Many NP-hard problems can be reformulated as copositive programs, i.e., linear optimization problems over the copositive cone. The difficulty then lies in the cone constraint. Testing copositivity of a given matrix Q is a co-NP-complete problem which can be stated as a standard quadratic optimization problem of the following form

$$\begin{array}{ll} \min & x^T Q x \\ \text{s.t.} & e^T x = 1 \\ & x \geq 0 \ . \end{array} \tag{StQP}$$

The matrix Q is copositive if and only if the optimal value of (StQP) is nonnegative. We consider relaxations of this problem and the case where Q is a 5×5-matrix which is of special interest, since there are copositive 5×5-matrices which cannot be decomposed into the sum of a positive semidefinite and a nonnegative matrix whereas this is possible for every copositive $n \times n$-matrix with $n \leq 4$.

Thu, 16:40 Philipp Hungerländer (Alpen-Adria-Universität Klagenfurt)

A Comparison of Approaches for Ordering Problems

Ordering problems are a special class of combinatorial optimization problems, where weights are assigned to each ordering of n objects and the aim is to find an ordering of maximum weight. Even for the simplest case of a linear cost function, ordering problems are known to be NP-hard. They arise in a large number of applications in such diverse fields as economics, VLSI and FMS design, scheduling, graph drawing and computational biology.

In this talk we discuss optimization methods based on linear and semidefinite relaxations for solving reasonably sized instances of ordering problems to provable optimality despite their theoretical

complexity class. We consider problems where the cost function is either linear or quadratic in the relative positions of pairs of objects. That includes well-established combinatorial optimization problems like the Linear Ordering Problem, the minimum Linear Arrangement Problem, the Single Row Facility Layout Problem, the weighted Betweenness Problem, the Quadratic Ordering Problem and Multi-level Crossing Minimization.

Up to now there existed quite diverse exact approaches to the various ordering problems. We will highlight their connections and present a new semidefinite method that can be successfully applied to all kinds of ordering problems. We give some theoretical results that showcase the polyhedral advantages of the semidefinite approach compared to ILP Branch-and-Cut algorithms. For practically tackling ordering problems, we construct an algorithm that uses a method from nonsmooth optimization to approximately solve the proposed semidefinite relaxations and applies a rounding scheme to the approximate solutions to obtain (near-)optimal orderings. We show the efficiency of the algorithm for a large variety of problem classes, solving many instances that have been considered in the literature for years to optimality for the first time. Finally the main aim of the talk is to clearly identify the strengths and weaknesses of the discussed linear and semidefinite approaches and hence to provide a reasonable guideline for the choice of the right approach for a specific ordering problem.

Joint work with Miguel F. Anjos, Markus Chimani, and Franz Rendl

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Thu, 17:20 Luuk Gijben (University of Groningen)

Scaling relationship between the copositive cone and Parrilo's first level approximation

Several NP-complete problems can be turned into convex problems, in a natural way, by formulating them as optimizion problems over the copositive cone. The copositive cone somewhat resembles the positive semidefinite cone and is defined as follows

$$\mathcal{C}^n = \{A \in \mathcal{S}^n | x^T A x \geq 0 \text{ for all } x \in \mathbb{R}^n_+\}$$

Where $\mathcal{S}^n$ is the set of symmetric matrices and $\mathbb{R}^n_+$ is the set of nonnegative real vectors. Unfortunately checking membership of the copositive cone is a co-NP-complete problem in itself. To deal with this problem, several approximation schemes have been developed. One of them is the hierarchy of cones introduced by P. Parillo (*Structured semidefinite programs and semi-algebraic geometry methods in robustness and optimization*, PhD-thesis, 2000), membership of which can be checked via semidefinite programming. This hierarchy of cones is defined as follows,

$$\mathcal{K}^r_n = \{A \in \mathcal{S}^n | (\sum_{i,j=1}^{n} A_{i,j} x_i^2 x_j^2)(\sum_{i=1}^{n} x_i^2)^r \text{ is Sum of Squares}\}$$

for $r = 0, 1, 2, \ldots$ and we have that $\mathcal{K}^0_n \subseteq \mathcal{K}^1_n \subseteq \mathcal{K}^2_n \subseteq \ldots \subseteq \mathcal{C}^n$ and the closure of $\bigcup_{i \in \mathbb{N}} \mathcal{K}^r_n$ is equal to $\mathcal{C}^n$. We know that for matrices of order $n \leq 4$ the zero order Parillo cone equals the copositive cone. The question has been raised whether such equalities also hold for different values of n and r. In this talk we will investigate the relation between the hierarchy and the copositive cone for $n \geq 5$ in order to answer this question. Furthermore a surprising result is found for the case $n = 5$.

Sat, 12:00 Matthias Walter (Otto-von-Guericke Universität Magdeburg)

On Simple Extended Formulations of Polytopes

We introduce the *simple extension complexity* of a polytope P as the smallest number of facets of any *simple* polytope which can be projected onto P. After providing examples of compact simple

extended formulations of certain combinatorial polytopes, we devise methods to find lower bounds on the simple extension complexity. We apply them to investigate the simple extension complexity of the k-hypersimplex in $\mathbb{R}^n$ and the spanning tree polytope of complete graph K_n on n nodes which are both exponential in n. Our main result is that the simple extension complexity of the perfect matching polytope of the K_{2n} is equal to the number of perfect matchings in K_{2n} and thus exponential in n. To obtain our result we improve a result of Padberg and Rao on the adjacency structures of perfect matching polytopes.

Joint work with Volker Kaibel

Sat, 12:40 Anja Fischer (TU Chemnitz)

Polyhedral combinatorics for the asymmetric quadratic traveling salesman problem

The well known asymmetric traveling salesman problem (ATSP) asks for a cost minimal tour in a directed graph where the costs depend on each two successive nodes traversed by the tour. In contrast, in the asymmetric quadratic traveling salesman problem (AQTSP) the costs depend on each three nodes that are traversed in succession. The AQTSP can be formulated as an integer optimization problem over the polytope associated with the ATSP together with a quadratic cost function.

The AQTSP was introduced in connection with an application in biology. Another application is the angular-metric TSP that is used in the design of robot paths and penalizes sharp turns of the path. A further example is the TSP with reload costs that appears in the planning of telecommunication and transport networks where switches between different providers should be minimized.

We present a polyhedral study for a linearized integer programming formulation. This includes the dimension of the associated polytope as well as classes of inequalities that forbid conflicting configurations. Furthermore we provide a general strengthening approach for lifting valid inequalities for ATSP. Applying this approach to the subtour elimination constraints leads to facet-defining inequalities but finding a maximally violated one is NP-complete.

Using the new cutting planes in a branch-and-cut framework allows to solve instances from biology with up to 100 nodes in less than 11 minutes. This improves the running times known in the literature by several orders of magnitude. For random instances the linear relaxation is surprisingly weak. In this case semidefinite relaxations improve the gaps at the root node significantly.

Joint work with Christoph Helmberg

Sat, 13:20 André Chassein (Universität Kaiserslautern)

A column generation approach for workforce scheduling

In this presentation, we solve a real-world workforce scheduling problem occurring in the utility or telecommunication industry. A common problem in workforce management is the allocation of skilled technicians to customer orders and the routing of technicians. Using a column generation approach, we obtain proven optimal or near optimal solutions. This maximizes customer satisfaction while lowering the overall cost of service delivery and service assurance and ensures the allocation of appropriately skilled workers to each customer order.

In our problem we schedule a given worker set to a given set of orders, spread in a street network. All orders have time windows, in which they are available. So it is not possible just to try minimizing costs, which are normally related to travel distances, without respecting the time consumption of every order and the time the worker needs to travel from one to another order. Additionally, we have to account for mandatory breaks during the day for the technicians.

We formulate the problem as integer program and solve it with column generation and a labeling algorithm as dynamic pricing. In this talk, we will focus on the describing the column generation approach to find a good combination of feasible routes for the technicians. In order to tackle the real-world problem we use an interesting counter-intuitive kind of modeling the problem. We will describe the idea behind column generation and the implementation and apply CPLEX to solve the Linear Program, which is generated during the column generation algorithm.

We will then briefly describe the Labeling Algorithm, which allowed us to model the world related constraints, which determine the feasibility of a route. The Labeling Algorithm proofed to guarantee a reasonable compromise between computing time and solution quality. The successful interplay between these two parts is reached by so called negative reduced costs. To present the ideas behind this concept, will be the main part of our talk.

We will conclude our talk with computational experiments showing computed routes and schedules.

Sat, 14:30 Mohsen Rezapour (TU Berlin)

Approximation algorithms for connected facility location with buy-at-bulk edge costs

We consider a generalization of the Connected Facility Location problem where clients may connect to open facilities via access trees shared by multiple clients. In addition to choosing facilities to open and connecting them by a core Steiner tree (of infinite capacity), we need to buy cables from an available set of cables with different costs and capacities to route all demands of clients to open facilities. We assume that the cable costs obey economies of scale. The objective is to minimize the total cost of opening facilities, building the core Steiner tree among them, and installing capacities on the access tree edges. We present the first approximation algorithm for this problem. We also consider the simplified version of the problem where capacity of an edge is provided in multiples of only one cable type and present a better constant factor approximation algorithm for this case.

Abstracts Industry Day

Fri, 10:00 Maren Martens (PSI Logistics GmbH)

Optimization Problems in Logistics

Logistics is everywhere and everything in logistics can be optimized! However, many of the arising optimization problems are NP-hard, implying that in real life logistics approximations are indispensable.

In this talk, we first give an overview on mathematical problems in logistics. Often classical NP-hard optimization problems do not show up independently, but rather the real life turns out to be an aggregation of several such problems. In our investigations, we concentrate on two routing problems: one being a routing problem in a supply chain when delivering goods from suppliers through production sites and distribution centers to customers, the other being a generalized packet routing problem in the warehouse. The objective in both such problems is to minimize costs, which arise, e. g., from transportation, storage, or time restrictions. Various constraints make the two problems NP-hard. For the first problem such constraints contain, for example, unsplittability of orders or minimum throughputs for warehouses. For the second problem, we extend the general packet routing problem in basically two ways: Firstly, we introduce operating times for every packet in every node; secondly, we give each packet sets of nodes from which one node for every set has to be visited.

Fri, 10:40 Sleman Saliba (ABB AG)

Process and Production Optimization at ABB Corporate Research

The focus of the research group process and production optimization is to solve real-world problems arising in industrial applications with mathematical optimization. Current research projects are enterprise wide production scheduling in the metals industry, crane scheduling on container terminals, workforce scheduling in the utility industry, and energy management systems for energy-intensive industries.

In this talk, we will present a hybrid algorithm for production planning on a hot rolling mill. A production schedule for the hot rolling mill consists of a set of production campaigns (rolling programs), which are composed of a finite number of slabs/coils. The hot rolling scheduling problem consists of creating feasible rolling programs and sequencing them on the plant.

A pure single-step mathematical programming approach can neither capture all the relevant problem aspects nor meet the performance criteria. Therefore, a two-step approach combining heuristics and mathematical programming methods has been developed. In the first step, we use a construction heuristic to build parts of the rolling program, which are then combined into rolling programs by assigning them a cost/profit and by solving a min-cost-flow problem. The built programs are then sequenced in the second step, which is a traditional scheduling-type of problem. An MILP formulation of the problem is proposed taking into account due date and production mix constraints.

Fri, 11:20 Roland Wessäly (atesio GmbH)

Cost optimized optical fiber access network design

In this talk we will provide a short introduction into fiber access network design from a practical perspective. We will present an overview on challenging mathematical problems arising in this context. Eventually, we demonstrate on some examples from real-life projects the effectiveness of

optimization methods which use at its core various mixed-integer programs to solve subproblems of the overall planning task.

Fri, 13:30 Thomas Lehmann (Siemens AG)

Combinatorial Optimization for Energy Management

The Research Group *Power Management & Control* is part of the Technology Field *Power and Actuators* within Siemens Corporate Technology. Siemens Corporate Technology is to help secure Siemens' technological and innovation base as well as Siemens' technological future and is to support the development of an integrated technology company.

One important topic of the Research Group *Power Management & Control* is energy management. The Research Group focuses on mathematical programming for solving complex real-world problems in areas such as smart grid, production scheduling and energy-efficient plant control, electric vehicle infrastructure as well as building automation. In this talk two different applications will be presented leading to complex scheduling problems. One of these can naturally be extended to become a Mixed-Integer NonLinear Program (MINLP).

The first application arises within production planning in an electric steel plant, where restrictions on the available energy need to be taken into account. The production schedule has to ensure, that the maximal amount of energy available in every 15 minute interval is not exceeded.

The second example arises in the context of smart grids and electric vehicle infrastructure. The main topic is the integration of electric mobility infrastructure into the power networks of buildings. Feasible charging schedules not only have to take into account the limited capacity of the building's grid connection point, but should also guarantee power quality and power network stability within the building.

Fri, 14:10 Berkan Erol (Decision Trees GmbH)

Operation of Energy-Assets using Stochastic Optimization

The transition in the European energy industry is leading to more and more volatile market prices and growing risks in the evolution of future revenues of energy assets like gas storages, gas/coal-fired power plants and hydro power plants. Therefore, the importance of stochastic models that consider risks in market prices as well as outages is rising for the valuation and operation of these assets.

Decision Trees GmbH has been doing pioneer work in the area of stochastic optimization for the daily operation of energy assets and has introduced stochastic models at various utilities in Germany and Austria into practice successfully. Regularly exercised benchmarks against deterministic models show that the contribution margin of assets operated with stochastic models can be increased.

In this talk, we will describe how to model a Combined Cycle Gas Turbine (CCGT) Plant and the uncertain influencing factors that should be considered in its operation.

Fri, 14:50 Maciej Warszawski (ProCom GmbH)

Graphical Building of Mixed Integer Programs in the Energy Sector

ProCom GmbH is a specialist in planning and optimizing energy production and trade. With its standard optimization product BoFiT it covers the complete process starting with the building of mixed integer models and ending with the automatized integration of optimization runs and results

in the business processes of the customers. The supported business processes range from intraday and day ahead calculations up to long term scenarios for fuel planning or investment decisions. BoFiT is able to cover problems containing e.g. thermal production, power exchange, fuel contracts, storages, emission trading or district heat distribution. The modeling of the optimization problems is based on a graphical approach in terms of a material flow problem. A large number of predefined modeling components as contracts, turbines or balance nodes is combined to a model. Each component represents a given subset of mathematical equations while the connections between the components represent additional restrictions on the variables. By introducing constraints to the different variables the mathematical problem is completed and solved by commercially available standard solvers.

This session will give you an insight into ProCom as a company and its product BoFiT. Find out how new optimization components are developed: from the initial idea, the mathematical modeling and graphical presentation to the final integration into the product and day-to-day use in customers' hands.

Fri, 16:00 Nikolaus Witte (TomTom)

Persistent Homology and Roundabout Detection

One problem in automatised map correction is to distinguish road crossings from roundabouts. We present an algorithm based on the theory of Persistent Homology for detecting roundabouts based on GPS probe data. The Persistent Homology describes the changes in homology of a sequence of topological spaces. In particular it records the "live span" of homology generators when viewing the sequence of spaces as the evolution of a single topological space. In this talk the basic concepts of a topological space, its homology and Persistent Homology is explained. Then we show how Persistent Homology can be applied to roundabout detection.

Fri, 16:40 Gregor Karbstein, Mareike Massow (IVU Traffic Technologies AG)

The Next Big Thing in Duty Scheduling: Multicriterial Optimization

After a short presentation of IVU and our software domain, we explain the optimization tools used by our customers for planning in public transport. For the public transport companies, the general goal is to minimize costs. However, there are a multitude of different parameters which must be considered in the optimization. For example, in duty scheduling, one wants to limit the number of split duties, since these are unpopular among the drivers; and limit the number of line changes, since they reduce the stability of the duty schedule. So far, these parameters form additional constraints for the optimization problem, or are included in the objective function using weights.

In times of increasing market competition, one would like to understand the exact influences of the parameters on the solution, transforming the optimization into a management decision tool. A typical question in this context is: "How much am I willing to pay for the happiness of my employees?" The solution is a multicriterial optimization tool. We present strategies on how to integrate multicriterial optimization into our software and report on our experiences.

With some 300 engineers, IVU Traffic Technologies AG has for over 30 years ensured punctual and reliable transport in the world's large metropolises. In growing cities people and vehicles are constantly on the move — a logistic challenge calling for intelligent and secure software systems. Based on the standard products of the IVU.suite, IVU develops customised IT solutions for public passenger and goods transport and transport logistics.

General Information

Internet connection

Connection via open WLAN is available in the foyer of ZIB; connect to “Gast im ZIB”.

Lunch

Participants are eligible for free lunch at FU Mensa; take your name tag with you and show it at the cash point.

Best Presentation Award

After the last session there will be a poll among all speakers to elect the recipient of the prestigious Best Presentation Award.

Social Program

There will be visits at various Berlin pub locations on Wednesday and Thursday, a Barbecue at ZIB on Friday, and a Brunch on Saturday.