Ingo Stallknecht: Polynomial upper bounds on the number of differing columns of Δ-modular integer programs

We consider integer programs (IP) defined by equations and box constraints, where it is known that determinants in the constraint matrix are one measure of complexity. For example, Artmann et al. showed that an IP can be solved in strongly polynomial time if the constraint matrix is bimodular, that is, the determinants are bounded in absolute value by two. Determinants are also used to bound the ℓ_1-distance between IP solutions and solutions of its linear relaxation. One of the first works to quantify the complexity of IPs with bounded determinants was that of Heller, who identified the maximum number of differing columns in a totally unimodular constraint matrix. So far, each extension of Heller's bound to general determinants has been exponential in the determinants or the number of equations. We provide the first column bound that is polynomial in both values. As a corollary, we give the first 1-distance bound that is polynomial in the determinants and the number of equations. We also show a tight bound on the number of differing columns in a bimodular constraint matrix; this is the first tight bound since Heller's result. Our analysis reveals combinatorial properties of bimodular IPs that may be of independent interest, in particular in recognition algorithms for IPs with bounded determinants.

Regina Schmidt: On the Slater condition in conic optimization

We present sufficient conditions for strong duality in conic optimization. Often problems have a certain structure. We consider problems with equality and inequality constraints, problems with variables in the intersection of two cones (e.g. cone of doubly nonnegative matrices), problems with variables in the Minkowski sum of two cones (e.g. the dual cone of the cone of doubly nonnegative matrices) and problems with variables in the Cartesian product of two cones. In each special case we introduce a Slater-type condition to guarantee strong duality.

Rolf van der Hulst: A row-wise algorithm for network matrix detection

Total unimodularity is of great interest within mixed-integer and combinatorial optimization, as problems with totally unimodular constraint matrices can be solved efficiently under some mild conditions. Network matrices are a large subclass of totally unimodular matrices, which often occur within LP formulations of tractable problems such as network flow problems. For difficult mixed-integer-programming problems, multiple types of problem substructures embedded within the constraint matrix, such as multicommodity flow substructures and scheduling substructures, have been shown to be effective in reducing the solution time. These substructures often have a large associated (transposed) network submatrix embedded within the constraint matrix.

In this talk, we develop a new row-wise procedure to detect network matrices. We develop an algorithm and datastructures which can efficiently determine whether the addition of a row to a network matrix preserves the network matrix property. By sequentially adding all rows of a matrix, this algorithm can be used to detect whether a given matrix is a network matrix. Additionally, it yields a simple greedy heuristic for finding network submatrices. This simple greedy heuristic will be applied to problems from practice. We expect to have computational results on MIPLIB 2017 by September 2022.

Sabrina Bruckmeier: Constrained Sparse Approximation

Nowadays, more and more data is generated, but only a part of it might be necessary in order to already be capable of making predictions in a suf- ficiently good manner. Therefore, the question arises to best approximate a signal b by linear combinations of no more than vectors Ai from a suit- able dictionary $A = (A_1, ..., A_n) \in \mathbb{Z}^{m\times n}$. Additionally, many areas of application require the solution x to satisfy certain polyhedral constraints. Therefore, we focus on the problem

$$\min_x ||Axb||_2 \qquad s.t. \qquad x \in [0,1]^n \, and \, ||x||_0 \leq \sigma.$$

While there exists a large variety of ideas how to tackle this problem, the majority of them relies on the matrix A satisfying conditions as being sam- pled in a specific way or being close to behaving like an orthogonal system, that might be hard to verify. Additionally, these algorithms commonly yield results only with a certain probability or within an approximation factor that again highly depend on A. In contrast we develop an exact algorithm that without these limitations solves above problem in time $m||A||_\infty \mathcal{O}(m^2)$. We achieve this by showing a proximity result, in combination with a more generic al- gorithm: Given a set $D \subseteq \mathbb{R}^m$, we can either find a feasible point in D, even one that is closest to b, or decide that none exists in $|(D + B(0, m||A||_\infty) \cap \mathbb{Z}^m)|$ arithmetic operations. To complement our results, we show that only cases where b is representable with the ‘1-relaxation just so, or barely not, are hard.

Elisabeth Halser: Inverse Robust Multicriteria Optimization of Building Energy Supply Design

Energy supply of buildings is a significant driver of human caused carbon emissions. For its new building, the Fraunhofer ITWM wants to know which machines should be purchased to deal with uncertain future heating and cooling loads in a preferably cheap and carbon saving way. We formulate this problem as bicriteria mixed integer problem, where we want to optimize annual investment plus operational costs and carbon emissions simultaneously. Thereby, the decision variables of primary in- terest are those which describe the dimensions of the bought machines. However, to determine the optimal machine dimensions, we have to know the energy demands (called loads). Therefore, we take a sample year and simultaneously optimize the control states and the machine dimensions for this year with the constraint that all loads are fulfilled in every time step. Considering only one sample year gives rise to the question if the selected machines are also optimal or at least feasible for different weather scenarios (elements of an uncertainty set). In classical worst-case robust optimization, we would seek for solutions that are feasible in all these scenarios. But what if we weaken this constraint and introduce a third dimension to the objective space, which is: maximize the share of the uncertainty set for which the machine selection is feasible. This inverse robust approach is not well-known yet and just referred to in an unpub- lished paper. In the talk, I am going to introduce the problem, show my consider- ations about some simple cases of inverse robust optimization as well as point out open questions.

Christian Nöbel: Congruency constraint Optimization

A long standing open conjecture in integer programming is whether integer programs (IPs) with bounded subdeterminants are efficiently solvable. Beside the classical case of TU matrices there has been made progress recently when Artmann, Weismantel, and Zenklusen [STOC 2017] showed how to efficiently solve bimodular IPs (i.e., IPs with subdeterminants that are bounded by two in absolute value). Their approach is based an a reduction to parity constraint IPs with a TU matrix and then they solve the latter by a decomposition that uses Seymour's decomposition of TU matrices.

This motivates the study of IPs with a TU matrix and more general congruency constraints. In particular as subproblems classical combinatorial problems - like minimum cost flow or submodular function minimization - with an additional congruency constraint have to be solved but . I will present recent progress on this line of research, with a focus on open questions.

Kirill Kukharenko: Polytope Extentions with Small Diameter

Bounding the combinatorial diameter of a polytope is a well-known and longstanding open problem. A great theoretical and practical interest in this question originates from the desire to efficiently solve linear programming. In this regard, since the ultimate goal is to optimize over polytopes, it is well worth looking at extended formulations as well. In this talk we will discuss polytope extensions having surprisingly small combinatorial diameter.

Stefan Kuhlmann: Lattice width and its relation to Hilbert bases

Understanding the complexity of algorithms in Integer Programming with respect to their input parameters has always been a central challenge in the field. A parameter, which recently gained much attention, is the maximal subdeterminant in absolute value of a given integral constraint matrix. In this talk, we investigate the lattice width of lattice-free polyhedra with respect to this parameter. Upper bounds on the lattice width play a role for running time results of lattice width based algorithms such as Lenstra's algorithm. Our main goal of this talk is to highlight a novel connection between the lattice width, the diameter of finite abelian groups and geometric properties of a finite generating set, the Hilbert basis. The presentation is based on joint work with Martin Henk and Robert Weismantel.

Corinna Mathwieser: Mobile health care services and colored matching problems

Providing reliable and efficient supply with medical treatment and health related services is a truly challenging task. Some of these challenges including travel time, coverage and reachability are increased by the fact that health care infrastructure is usually designed to be stationary, i.e. patients need to seek treatment at a hospital or a doctor's office. Some health care services such as vaccinations do not require a lot of stationary infrastructure and thus allow for a more mobile approach. In this talk, I will introduce different matching problems on edge colored graphs, discuss their complexity and discuss how these matching problems can be used to model the routing of mobile health care services.

Nathalie Frieß: Optimal Technology Choice for a Sustainable Bus Transportation System

The transportation sector is facing a major shift towards electric propulsion systems to contribute to its share in emission reduction. Urban bus systems are particularly suited for early electrification projects as vehicles have high mileage, routes and driving times are predictable, and service trips are concentrated in small geographic areas. As multiple electric technology options with different advantages and disadvantages are available on the market, it is not trivial to select a suitable technology for a given transportation system. Therefore, we developed an optimization model that is based on a broad input database and allows a customized adaption to local circumstances. The ultimate goal of the model is to choose one or several optimal technologies considering the establishment of infrastructure and fleet composition, both highly influenced by vehicle schedules. Given a set of locally emission-free technology options, minimizing cost is an obvious approach to determine the optimal design of a decarbonized electric bus system. However, the deployment of batteries and materials produced in carbon- intensive manufacturing processes, as well as the use of electricity or hydrogen for propulsion causes indirect emissions and can result in high cumulative energy use. To incorporate such objectives in our decision-support tool, the epsilon constraint method is applied to derive a pareto frontier of solutions for the local decision-maker.

Johanna Wiehe: Acyclic Colorings and the Chromatic Polynomial of a Digraph

The notion of classic graph coloring deals with finding the smallest integer k such that the vertices of an undirected graph can be colored with k colors, where no two adjacent vertices share the same color. The chromatic polynomial counts those proper colorings a graph admits, subject to the number of colors. Tutte developed a dual concept, so-called nowhere-zero flows, which build a polynomial, the flow polynomial, too. Regarding directed graphs, or digraphs for short, the dichromatic number is a natural generalization of the chromatic number. It was introduced by Neumann-Lara in 1982 as the smallest integer k such that the vertices of the digraph can be colored with k colors and each color class induces an acyclic digraph. It is easy to see that both notions coincide in the symmetric case, where an arc exists if and only if its antiparallel also exists. Moreover Neumann-Lara conjectured that every orientation of a simple planar graph can be acyclically colored with two colors. Regarding the dichromatic number this is not the only conjecture remaining widely open. Applications can be found in scheduling and deadlock resolution, where the size of acyclic subdigraphs plays an important role. We are going to present a simple representation of a polynomial, counting the number of acyclic colorings of a directed graph, using a flow theory similar to Tutte‘s theory of nowhere-zero flows.

Jenny Segschneider: Modeling the Two-Dose Vaccination Scheduling Problem with b-Matchings

Due to the COVID-19 pandemic and the shortage of vaccinations during its roll-out, the question regarding the best strategy to achieve immunity throughout the population by adjusting the time between the two necessary vaccination doses was intensively discussed. This strategy has already been studied from different angles by various researches. However, the combinatorial optimization problem has not been the focus of attention.

For most available vaccines, each person has to receive two doses in a specific time frame, e.g., the second dose has to be given three to six weeks after the first dose. This leads to another problem: which doses are given to new patients as a first dose and which are used as a second dose for those who already received a first dose. We will call this problem the Two-Dose Scheduling Problem. More specific, given are n discrete time steps, the number of doses of vaccine delivered in each time step and the value of an appointment consisting of a time for a first and second dose. The problem then consists of finding a schedule of appointments for the first and second doses with maximum value such that for each of these appointments, the second dose is given within a predefined time frame after the first dose.

In this talk, we study different versions of this problem by first proposing a simple approach using a matching algorithm. Then, we extend the approach by adding constraints. Finally, we discuss a variation of the problem where three vaccinations are necessary, including the so-called “booster”. This problem turns out to be NP-hard.

Jamico Schade: Lattice-free simplices with lattice width $2d - o(d)$

When trying to fit a convex set between the points of a lattice, it becomes apparent that such a set always has to be somewhat flat. The lattice-width of a convex body is a quantity that measures this flatness with regard to the lattice that constricts the body. The well-known Flatness Theorem states that the lattice-width of a d-dimensional lattice-free convex set is bounded from above by a constant $Flt(d)$ that only depends on the dimension d. This theorem has multiple applications in integer optimization, most famously in Lenstra's algorithm for integer programming in fixed dimension. While there have been lots of results concerned with upper bounds to this constant, only few techniques are known to obtain lower bounds and so far, the best known lower bound was $Flt(d) \geq 1.138d$. In this talk, we will discuss a construction of a series of simplices that yields the lower bound $Flt(d) \geq 2d - o(\sqrt{d})$.

This talk is joint work with Lukas Mayrhofer and Stefan Weltge.

Stefan Kober: Polyhedral properties of the stable set problem with bounded odd cycle packing number

We consider the stable set problem restricted to graphs with bounded odd cycle packing number, i.e. graphs that only contain a bounded number of node-disjoint odd cycles. Recently, it was shown with the help of heavy machinery, that such integer programs can be solved in strongly polynomial time. We analyze this type of problem from a geometric side and give bounds on the gap between the linear relaxation and the integer polytope. In addition, we prove that the Sherali-Adams hierarchy produces a close approximation of the integer polytope after a number of steps that is bounded only in terms of the odd cycle packing number. This is joint work with Samuel Fiorini and Stefan Weltge.

Sabine Münch: Generalized Housing Model and the Top-Trading-Cycles Algorithm

We study a generalization of the Scarf-Shapley Housing model, in which $n \in \mathbb{N}$ agents trade $q \in \mathbb{N}$ different types of goods, in order to maximize utility. Each agent i has an initial endowment $(g_{i,1}, \ldots, g_{i,q})$ consisting of one good of each type of goods and some money. In addition, we assume that each agent has an additive separable, strict valuation and wants to maximize his individual utility by buying and selling some goods. We show that a fair allocation of goods to agents at fair prices exist in this market. We develop a mechanism, which is based on David Gale's Top-Trading-Cycles algorithm combined with an ascending auction. We prove that the proposed method leads to an individually rational ε-Walras equilibrium.

Max Ilsen: Capacity-Preserving Subgraphs of Directed Flow Networks

We introduce and discuss the Minimum Capacity-Preserving Subgraph (MCPS) problem: Given a directed graph and a retention ratio $\alpha \in (0, 1)$, find the smallest subgraph that, for each pair of vertices (u, v), preserves at least α of a maximum u-v-flow's value. This problem originates from the practical setting of reducing the power consumption in a computer network: It models turning off as many links as possible while retaining the ability to transmit at least times the traffic compared to the original network. First we prove that the decision variant of MCPS is NP-hard already on directed acyclic graphs (DAGs). Our reduction also shows that it is NP-hard to approximate a closely related problem (which only considers the arguably most complicated core of the problem in the objective function) with a factor better than $\ln(N)$, where N is the instance size, already on DAGs. In terms of positive results, we present a simple linear time algorithm that solves MCPS optimally on directed series-parallel graphs (DSPs). Further, we introduce the family of laminar series-parallel graphs (LSPs), a generalization of DSPs that also includes cyclic and very dense graphs. Not only are we able to solve MCPS on LSPs in quadratic time, but our approach also yields straightforward quadratic time algorithms for several related problems such as Minimum Equivalent Digraph and Directed Hamilton Cycle on LSPs.

Jasper van Doornmalen: Integer Programming Methods for Round Robin Tournaments

Using integer programming for sport scheduling optimization is very popular, because it allows a modeler to add various types of constraints for various sport competitions. A common competition type is a round robin tournament, where all matches between teams are played in a set of rounds.

In our work, we consider compact single round robin tournaments without side-constraints, where every match is played exactly once, and where all teams play in each round. Provided that scheduling a match on a round comes at a cost, we study the NP-hard optimization problem of finding a minimum cost single round robin tournament.

We compare a well-studied classical compact integer programming formulation of this problem with two new formulations: the so-called matching formulation and the permutation formulation. These two new formulations are not compact, as they have an exponentially sized class of variables. However, we show that the pricing problem can be solved in polynomial time. In particular, these formulations are suitable for use in a branch-and-price context, since the pricing problems remains polynomial-time solvable even when matches are readily fixed to rounds.

We compare the relative strength of each of these formulations by comparing the relaxation values, and conducted a computational study by using the academic constraint integer programming solver SCIP.

Maja Hügging: Bounded variation in binary sequences

We investigate a problem in which a linear function is optimized over the set of binary vectors of a given finite length with a bounded variation, i.e. a bound on the number of different consecutive entries. This problem has been well- studied for other types of practical constraints, such as minimum dwell time, but no results seem to exist for a bounded variation. This is surprising considering that this problem arises naturally as a subproblem in many applications, e.g., when discretizing binary optimal control problems subject to a bounded total variation. We study two versions of the problem, depending on whether the variation is penalized in the objective function or whether it is bounded by a hard constraint. We show that, while the former version is easy to deal with, the latter is more complex, but still tractable: We give a complete polyhedral description for the convex hull of feasible solutions and study the optimization as well as the separation problem devising two optimization algorithms and an exact linear-time separation algorithm.

Mariia Anapolska: User-friendly elective surgery scheduling

Operating room scheduling is being extensively studied both in the medical research and in combinatorial optimization. This is primarily due to the cost impact of the operating rooms: Executed surgeries present a major part of hospital's income, while running the operating rooms is one of the important expenses. In this ongoing work, we consider the problem of assigning elective patients to surgery days. During a visit to one German hospital, the author observed that the planning of elective surgeries is done by an intuitive greedy strategy, which fails to account for urgent patients and thus leads to systematic postponements or cancellations. This results in high utilization of operating rooms, but also in high patient dissatisfaction and additional workload for staff caused by rescheduling. The goal of this work is to develop a similarly user-friendly online scheduling strategy that leaves enough slack for urgent patients and simultaneously achieves high operating room utilization. To get a better understanding of the problem, we begin with considering the offline version of the problem. We investigate its complexity and present solutions that optimize the number of cancellations, patients' waiting time and OR utilization. Next, we consider the online version of the problem, where the patient requests for surgeries follow a known probability distribution. We define the Gradual Capacity Release strategy, which makes additional schedule slots available at predefined time points, and investigate the quality of the resulting schedules.

Lasse Wulf: Exact Matching and Top-k Perfect Matching

The Exact Matching Problem is a well-known problem which permits a randomized poly-time algorithm, but derandomizing this algorithm to obtain a deterministic poly-time algorithm has remained elusive for the last 35 years. During the last decades, a lot of problems have been discovered which are equivalent to the Exact Matching Problem. All of these problems share the same property that we know a randomized, but no deterministic fast algorithm for it. In this talk, we add another problem to the list, called the Top-k Matching Problem. Here the problem is, given a weighted graph and an integer k, to find a perfect matching such that the total weight of the k heaviest edges of the matching is maximized. (The top-k objective function has also been called k-sum or k-centrum in the literature.) We show that Top-k Matching is equivalent to Exact Matching. Top-k Matching is special, because there are some ideas which suggest that the Sherali-Adams hierarchy could provide a PTAS for Top-k matching. If this would turn out to be true, it would be the first PTAS of a problem equivalent to Exact Matching.

Nicolas El Maalouly: Exact Matching in Graphs with Small Independence Number

The abstract is the following: In the Exact Matching problem, we are given a graph with edges colored red and blue, and an integer k. The goal is to output a perfect matching with exactly k red edges. After introducing the problem in 1982, Papadimitriou and Yannakakis conjectured it to be NP-hard. Soon after, however, Mulmuley et al. proved that it can be solved in randomized polynomial time, which makes it unlikely to be NP-hard. Determining whether Exact Matching is in P remains an open problem and very little progress has been made towards that goal. For special graph classes Yuster showed that Exact Matching is in P for $K_{3,3}$-minor free graphs, which include planar graphs. Karzanov showed that it is in P for complete and bipartite complete graphs. In this talk I will show how to solve Exact Matching on graphs of bounded independence number and show ideas for how to get an FPT algorithm parameterized by the independence number.

Nils Hausbrandt: From Many to Multi!? — Reducing the Number of Objectives

Real-world optimization problems inherently involve several objective functions: Typically, one aims at saving time, money or environmental resources, while maximizing quality, flexibility or robustness of solutions for these optimization problems. The discipline dealing with several objectives instead of only one is called Multiobjective Optimization which aims at computing good compromises, i.e., so-called Pareto optimal solutions. Interestingly, solving Multiobjective Optimization Problems is NP-hard for common classes of optimization problems and the cardinality of Pareto optimal solutions grows exponentially in the encoding length of an input. Thus, the idea of computing polynomial-size approximations of the Pareto set arose. In fact, one can guarantee the existence of (a multiobjective version of) an FPTAS for Multiobjective Problems and constant factor approximations can be computed in polynomial time for many problems. The corresponding results, however, require that the number of objectives is constant (and pretty small). Lately, quite some attention is given to Multiobjective Optimization Problems with a huge number of objectives. Such problems are called "many" objective problems and the approaches suggested so far are meta-heuristics or nature-inspired methods that can produce arbitrarily bad solutions. Up to now, the literature on exact or approximation approaches for this kind of problem is very limited which motivates our research interest. In this talk, we will address the question of reducing the number of objectives of a Multiobjective Optimization Problem. In particular, we will introduce the topic and present an overview of existing and own results. The main focus of our talk is on linear problems with many objective functions some of which are "similar". This means that their coefficients differ only by a certain factor. We will present reduction techniques for the number of objectives which lead to algorithms of controllable approximation guarantees.

Niklas Schlomberg: Cycle Packing in planar graphs

In the (Vertex- or Edge-disjoint) Cycle Packing Problem the task is to find, given a family $\mathcal{C}$ of cycles in a graph G, a maximum-cardinality vertex- or edge-disjoint subset $C \subseteq \mathcal{C}$. Several special cases for $\mathcal{C}$ are of interest, e.g. the set of all cycles in G, the set of all odd cycles in G or the set of all cycles that meet a specified edge set in G. A particularly interesting choice for $\mathcal{C}$ is, given a set $D \subseteq E(G)$ of edges in G, the set of all cycles that contain precisely one edge from D, in which case the Cycle Packing Problem corresponds to the Vertex- or Edge-disjoint Paths Problem.

Although the general Cycle Packing Problem seems hard to approximate, there are constant-factor approximations for several special cases of $\mathcal{C}$ if G is planar. The approaches are quite different and usually exploit the respective structure of $\mathcal{C}$.

We will see that many examples of interest for $\mathcal{C}$ (e.g. all examples given above) share a common structure, which was observed by Goemans and Williamson, and how to use this structure to obtain constant-factor approximation algorithms for Cycle Packing in a very general setting.

Wiete Keller: The general (p:q)-Discrepancy Game in Hypergraphs

We introduce the (p:q)-Game played on a hypergraph $H = (V, E)$ with $|E| = m$ by two players, Balancer and Unbalancer. In each round of the game Balancer selects p elements of the vertex set V before Unbalancer selects q elements of the vertex set V. The game is played until all vertices are selected or one player has achieved his win condition. Balancer's aim is to have around $\frac{p}{p+q}|e_j|$ vertices in every edge $e_j \in E$. Unbalancer tries to prevent Balancer from achieving this goal. Balancer's winning condition can be formulated in the following way. For every edge $e_j \in E$ let $b_j \geq 0$ be the allowed deviation. Balancer wins, if his selected number of vertices t_j in edge e_j satiesfies $\left|t_j - \frac{p}{p+q}|e_j|\right| \geq b_j$ for all edges e_j. We are looking for the smallest possible deviation b_j. Alon et al. (2005) proved that for the (1:1)-Game $b_j \geq \sqrt{2\ln(2m)|e_j|}$. They posed the analysis of the general (p:q)-Game as a challenging open problem. In fact, no nontrivial deviation was known. We give a polynomial time algorithm for Balancer to win the game provided the allowed deviation is large enough. In particular, Balancer wins the general (p:q)-Game for $b_j \geq \sqrt{2\ln(2^{\max(p,q)+1}|e_j|m)|e_j|}$.

Oliver Bachtler: Unavoidable structures in graphs of bounded path-width

Let $\mathcal{G}$ be a class of graphs with a membership test, $k \in \mathbb{N}$, and let $\mathcal{G}^k$ be the class of graphs in $\mathcal{G}$ of path-width at most k. We present an interactive framework that finds an *unavoidable set* for $\mathcal{G}^k$, that is, a set of graphs $\mathcal{U}$ such that any graph in $\mathcal{G}^k$ contains an isomorphic copy of a graph in $\mathcal{U}$. At the core of our framework is an algorithm that verifies whether a set of graphs is, indeed, unavoidable for $\mathcal{G}^k$. If it is not, it provides a counterexample that can be used to extend the set $\mathcal{U}$.

In general, it is undecidable whether a finite set of graphs is unavoidable for a given graph class, even if the graphs in the class are all of path-width 2 and the class itself is decidable. However, we give a criterion for termination: our algorithm terminates whenever $\mathcal{G}$ is "locally checkable" (in some sense), of bounded maximum degree, and $\mathcal{U}$ is a finite set of connected graphs. We put special emphasis on the case that $\mathcal{G}$ is the class of cubic graphs and tailor the algorithm to this case.

Simon Thomä: New Tractable Policies and Approximation Bounds for Multi-Stage Adjustable Robust Optimization

In practice, most decision-making problems have to be solved in view of uncertain parameters. Over recent years, robust optimization emerged as a prominent and scalable framework to inform such decisions. Against this background, we study piecewise affine policies for multi-stage adjustable robust optimization (ARO) problems with non-negative right-hand side uncertainty. First, we construct new dominating uncertainty sets and show how the ARO problem can be solved efficiently with a linear program, when uncertainty is replaced by these new sets. We then demonstrate how solutions for this alternative problem can be transformed to solutions for the original problem. By carefully choosing the dominating sets, we proof strong approximation bounds for our policies that extend many previously best known bounds for the two-staged problem version to its multi-stage setting. Moreover, the new bounds are - to the best of our knowledge - the first bounds shown for the general multi-stage ARO problem considered. Using the newly found bounds, we show that no approximation bound for affine policies on hypersphere uncertainty exists that is better than the bound we show for our policies. For budgeted uncertainty on the other hand, we show that affine policies strictly dominate our piecewise affine policies. These findings confirm results that have been reported for the two-stage variant, where affine policies do not perform well for hypersphere uncertainty, while performing very well for budgeted uncertainty.

Erik Jansen: Mixed-Integer Optimization and Parameter Analysis of Energy Networks based on Iron

For reaching current climate goals and reducing CO2-emissions, nations are increasing their efforts to utilize renewable energy. Since renewable energy sources are not uniformly distributed and available around the globe, the ability to store renewable energy over long time periods in large quantity as well as to transport them over long distances are key points for the transformation towards sustainable power supply. One chemical group capable of providing such properties are metals, especially iron. Metals are capable of storing and releasing energy repeatedly via reduction and oxidation and are typically easier to transport and store than e.g., hydrogen. Furthermore, iron can release the stored energy via oxidation in the form of combustion without the emission of CO2 in existing coal power plants with similar efficiencies. The optimal design of such iron-based circular energy and logistic networks induce multi-criteria mixed-integer problems. One issue which has to be discussed is what optimal means in this context. Such considerations lead to the typical energy trilemma between costs, emissions and resilience, as well as questions regarding its representation and treatment in the optimization problem. Another issue to consider is the competition between different energy carriers. By extending the optimization problem to alternative carriers, we can calculate the optimal allocation of carriers for different routes and identify sensitive parameters influencing such allocations. The analysis of these sensitivities is non-trivial due to the presence of discrete variables displaying location and technology decisions. Calculating parameter intervals or sets in which the optimum maintains the original discrete values is challenging. The presented approach for calculating these sets is based on the determination of active inequalities of the convex integer hull.

Kathrin Prinz: Multi-Modal Routing with Resource Constraints

We investigate the problem of finding a multi-modal fastest path in a time-dependent transportation network, including walking, cycling, driving, and public transportation. In addition, we do not only want to find the fastest path but also minimize other criteria such as ecological damage, number of transfers, or walking distance. This results in the multicriteria multi-modal time-dependent shortest path problem with the additional difficulty of non- continuous cost functions, stemming from public transport schedules. It is well known that the multicriteria shortest path problem is difficult as there might exist an exponential number of Pareto-optimal shortest paths. Furthermore, while an FPTAS exists in the literature for the multicriteria time-dependent shortest path problem it is not applicable in our case, since it requires continuous cost functions. Thus, we instead model the additional criteria as constraints. While this remains a difficult problem, there are multiple algorithms in the literature that perform well on large non-time- dependent graphs. In this talk, we discuss how to model and combine the different modes of transportation in a multi-modal transportation network and how regular languages can be used to generate feasible multi-modal journeys. We then talk about different exact resource constrained shortest path algorithms, and how they might be adapted to the multi-modal time-dependent setting. Furthermore, we look at the difficulties in finding approximations.

Dominik Kamp: Flow Formulation of the Stochastic Guaranteed Service Model with Demand Propagation

The Stochastic Guaranteed Service Model with Demand Propagation (SGSM-DP) is a model in multi-echelon inventory optimization for a cost-minimal allocation of safety stocks in a distribution network with emergency supply options. It can be stated as a big-M-linearized mixed integer program. As such it suffers from a considerable integrality gap rendering the use of highly developed solvers intractable already for small problem instances. In this talk an alternative formulation of the SGSM-DP is presented, which is based on the logical material flow through a time-expanded network with arcs going backwards in time (F-SGSM-DP). It maintains a substantially smaller integrality gap at the cost of a more extensive model. With this new F-SGSM-DP significantly larger networks with even harder parameters can be solved to optimality in reasonable time than with the original formulation of the SGSM-DP. Therefore, the F-SGSM-DP makes it possible for the first time to evaluate optimal solutions of the SGSM-DP for realistic inventory networks within a dynamic simulation environment.

Leander Schnaars: Coflow Scheduling

Coflow Scheduling is an abstraction of a scheduling problem commonly found in datacenters and similar environments. The basic idea is that one wants to send packets of information between servers to enable distributed computing. This exchange of information usually happens during a dedicated phase, so it is important to keep this phase as short as possible.

We consider the offline setting in which all demands are known from the start. The underlying datastructure is modelled as a bipartite (multi)-graph, where an edge represents some packet of data which has to be transferred from some input to some output port. During each time step, only a single packet of data can be sent to or received at each port. Each coflow (=job) consists of a number of edges which have to be scheduled before the coflow is considered completed. We aim to minimize the weighted sum of completion times. For the general case without release times, several different 4-approximations are known. For the lower bound, there is only a (2-ϵ)-hardness inherited from a more restricted scheduling problem called Concurrent Open Shop Scheduling.

If, instead of basing on a bipartite graph, a matroid is used, a recent result shows a $(2+\epsilon)$-approximation.

The goal of this talk is to survey the state of the art and highlight promising directions and open questions.

David Könen: A note on finding all supported efficient solutions for multi-objective integer network flow problems

This note addresses the problem of determining all so-called supported efficient solutions for a linear multi-objective integer minimum cost flow (MOIMCF) problem. Assuming that for each maximally non-dominated face, an extreme supported solution and associated weight vector are deter- mined in a first step, we derive an output-polynomial time algorithm that runs in $\mathcal{O}(Sd(m+n)+tmn)$ time to determine the complete set of all S supported efficient solutions and hence all supported non-dominated vectors in a directed network with d objectives, n nodes, and m arcs, where t is the number of maximally non-dominated faces. The algorithm successively de- termines all solutions in the preimage of each maximally non-dominated face by determining all optimal solutions for the corresponding single-objective parametric network flow problem using the all optimum flow (AOF) algo- rithm recently presented in [11]. For a bi-objective integer minimum cost flow (BOIMCF) problem, the enhanced parametric network approach deter- mines all N extreme non-dominated points in $\mathcal{O}(Nn(m + n \log n))$ time [14]. Using this approach in the first step leads to an output-polynomial time al- gorithm that runs in $\mathcal{O}(Nn(m+n\log n)+S(m+n))$ time to determine all S supported efficient solutions of a BOIMCF problem. Identifying the set of supported non-dominated vectors/efficient solutions provides a first ap- proximation of the entire set of non-dominated vectors/efficient solutions. It can be used, for example, in two-phase methods where first the sup- ported non-dominated vectors/efficient solutions and then the unsupported non-dominated vectors/efficient solutions are determined.

Sarah Feldmann: The spread dimension problem

Assume that we have a signal spreading through a weighted connected graph $G = (V, E)$ with the following properties: The signal is sent with a constant velocity $c > 0$ from a unique unknown source node $s \in V$ at a starting time t_s. We have the possibility to measure the time $t_v \in \mathbb{R}$ at which the signal reaches the node $v \in V$ for every node in our graph G. So, we have $t_v = t_s + cd(s, v)$, where $d(s, v)$ denotes the length of the shortest path from s to v. A spread-resolving set is a subset $B \subseteq V$ such that $\forall t, c \in \mathbb{R}$ with $c > 0$ and $\forall v \neq w \in V$ we have $d(v, B) \neq t\mathbb{1} + cd(w, B)$, where $d(v, B)$ is the vector of ordered dis- tances from v to every node $b \in B$ and $\mathbb{1}$ denotes the vector of ones. With measurements t_b for nodes b in the spread-resolving set B we are able to compute the source node s, the time offset ts and the velocity c. The goal of the spread dimension problem is to find a spread- resolving set containing as few nodes as possible. In this talk we get to know the spread dimension problem and its appli- cations. We will focus on the NP-completeness of this problem and on algorithms that compute spread-resolving sets. An open problem is to find approximation algorithms for the spread dimension problem with provable approximation ratios.