The 2nd Sino-German Workshop on Optimization, Modeling, Methods and Applications in Industry and Management

September 22-27, 2012

Beijing, China

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Information for Participants

Conference Site

Conference Site:	Si-Yuan Building, Academy of Mathematics and Systems Science (AMSS), Chinese Academy of Sciences (CAS)
Address:	No. 55, Zhong Guan Cun East Road, Hai Dian District, Beijing, CHINA

Registration

Registration will take place on **September 22 from 9:00 to 18:00** at **the lobby of Park Plaza Beijing Science Park**. If you want to register at other time, please contact our conference secretary Ms. Ji-ping Wu.

From Park Plaza Beijing Science Park to conference site

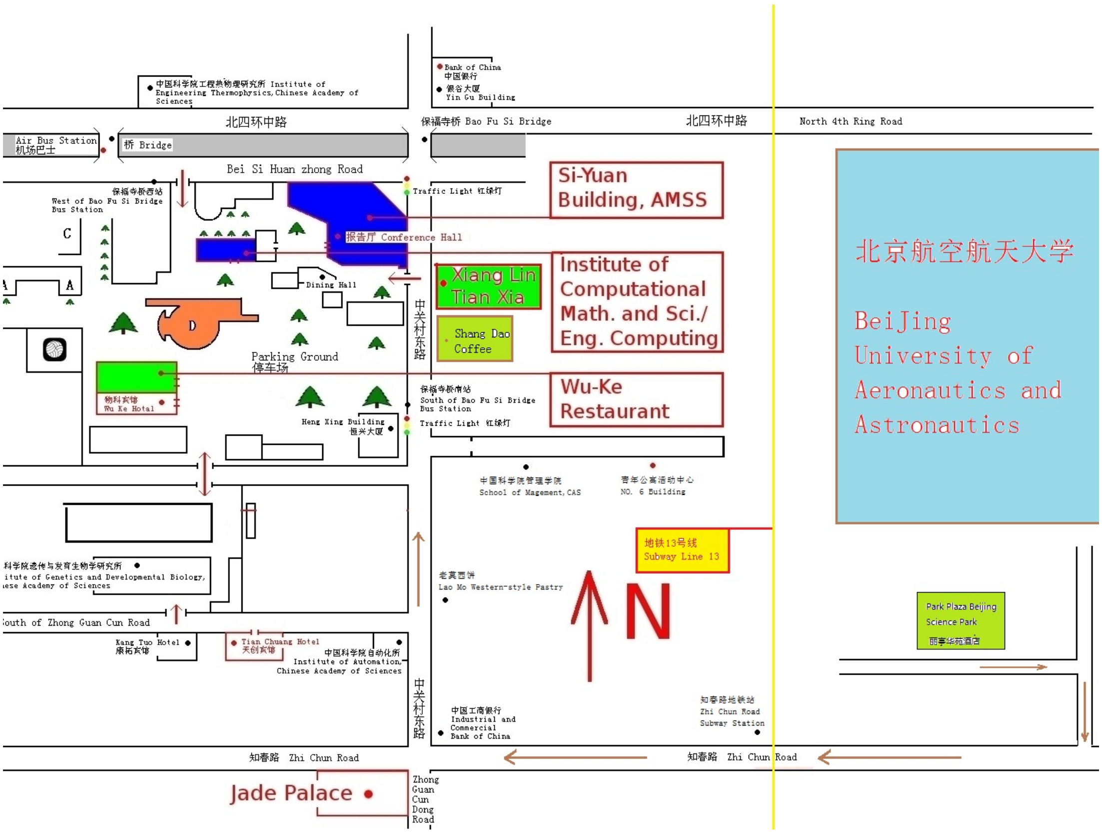
For participants accommodated at Park Plaza Beijing Science Park, you will be motored to the conference site in each morning of September 23-26. The bus will start at **08:40** on time. Please wait in the lobby in advance. There will be only one bus each morning. If you miss it, you have to go to the conference site by yourself.

Contact Information

If you need any help, please contact the conference secretary:

- Dr. Ya-Feng Liu: +86-158-1054-6125.

Local Map


Bank of China
中国银行
North 4th Ring Road
北四环中路
Bei Si Huan zhong Road
Si-Yuan Building, AMSS
报告厅 Conference Hall
Dining Hall
Xiang Lin Tian Xia
Shang Dao Coffee
Institute of Computational Math. and Sci./ Eng. Computing
Wu-Ke Restaurant
Parking Ground
停车场
Heng Xing Building
Traffic Light 红绿灯
北京航空航天大学
BeiJing University of Aeronautics and Astronautics
地铁13号线
Subway Line 13
N
South of Zhong Guan Cun Road
Kang Tuo Hotel
Tian Chuang Hotel
Park Plaza Beijing Science Park
知春路 Zhi Chun Road
Zhi Chun Road Subway Station
Jade Palace
Zhong Guan Cun Dong Road
中关村东路

Workshop Program

September 22 (Saturday), Arrival & Registration		
September 23 (Sunday), Optimization Theory and Methods (I)		
9:00 - 9:15	Opening Speeches	
9:15 - 10:00, Session Chair: Xiaodong Hu		
9:15 - 10:00	Keynote Speech Optimality Conditions and Smoothing Trust Region Newton Method for Non-Lipschitz Optimization	Ya-xiang Yuan
10:00 - 10:30	Photo Taking & Tea Break	
10:30 - 12:00, Session Chair: Thorsten Koch		
10:30 - 11:00	Numerical Aspects of Optimization Problems with Probabilistic Constraints under Gaussian Distribution	René Henrion
11:00 - 11:30	Successive Convex Approximations to Cardinality-Constrained Quadratic Programs: A DC Approach	Xiaoling Sun
11:30 - 12:00	Reflections on Stochastic Programming	Rüdiger Schultz
12:00 - 13:40	Lunch (AMSS Restaurant)	
13:40 - 15:10, Session Chair: Xiaoling Sun		
13:40 - 14:10	Convergence Analysis of Primal-Dual Algorithms for a Saddle-Point Problem in Total Variation Image Restoration	Bingsheng He
14:10 - 14:40	From Simulation to Optimization	Thorsten Koch
14:40 - 15:10	Simulation of Levy-Driven Models	Jianqiang Hu
15:10 - 15:40	Tea Break	
15:40 - 17:40, Session Chair: Marc Steinbach		
15:40 - 16:00	Alternating Direction Method of Multiplier: Splitting Techniques and Beyond	Xin Liu
16:00 - 16:20	Local Linear Convergence of the Alternating Direction Method of Multipliers for Quadratic Programs	Deren Han
16:20 - 16:40	Iterative Refinement for Linear Programming	Dan Steffy
16:40 - 17:00	Robust PCA for Ground Moving Target Indication in Wide-Area Surveillance Radar System	Qingna Li
17:00 - 17:20	Tangent Cone and Error Bound for Degenerate Constraint Set	Yiran He
17:20 - 17:40	On the Use of Two Simple Models in Bound Constrained Minimization Without Derivatives	Xiaodong Ding
17:40	Dinner (Seafood BBQ)	

September 24 (Monday), Real-World Problem Modeling and Solution (I)		
9:00 - 9:45, Session Chair: Jörg Rambau		
9:00 - 9:45	Keynote Speech Freight Train Composition with Minimum Shunting Operations	Uwe Zimmermann
9:45 - 10:00	Tea Break	
10:00 - 12:00, Session Chair: Guochuan Zhang		
10:00 - 10:30	On Fingerprint Image Compression Based on Non-Negative Matrix Factorization	Tiande Guo
10:30 - 11:00	Robust Tail Assignment	Ralf Borndörfer
11:00 - 11:30	Optimization Based the Ship Stowage Planning Problem of Coils in Steel Industry	Lixin Tang
11:30 - 12:00	Graph Theoretic Approaches to Optimizing Transfer Quality in Public Transportation Networks	Sven Krumke
12:00 - 13:00	Lunch (AMSS Restaurant)	
13:00 - 13:30	Academic visit of AMSS library	
13:40 - 15:10, Session Chair: Rüdiger Schultz		
13:40 - 14:10	Measuring the Potentiality of Decision Making Units	Jinchuan Cui
14:10 - 14:40	Metric Inequalities for Robust Network Design	Arie Koster
14:40 - 15:10	Stochastic Programming Arising from Economic Dispatch with Reliability Risk Constraint in Smart Grid	Xiaojiao Tong
15:10 - 15:40	Tea Break	
15:40 - 17:40, Session Chair: Zhi-Quan Luo		
15:40 - 16:00	Optimal Fuel, Power and Load-Based Emissions Trades for Electric Power Supply Chain Equilibrium	Hongming Yang
16:00 - 16:20	A Primal-Dual Approximation Algorithm for the Two-Level Facility Location Problem	Dachuan Xu
16:20 - 16:40	Measuring the Impact of Primal Heuristics	Timo Berthold
16:40 - 17:00	A Penalty Decomposition Method for Probabilistically Constrained Convex Programs	Xiaojin Zheng
17:00 - 17:20	The Total Variation Model for Determining the Implied Volatility in Option Pricing	Yu-Fei Yang
17:20 - 17:40	Positive Semi-Definite Diffusion Tensor Model in High Angular Resolution Diffusion Imaging	Gaohang YU
17:40	Dinner (Da Zhai Men Restaurant)	

September 25 (Tuesday), Optimization Theory and Methods (II)		
9:00 - 9:45, Session Chair: Naihua Xiu		
9:00 - 9:45	Keynote Speech Linear Precoder Design and Admission Control for Wireless Networks	Zhi-Quan Luo
9:45 - 10:00	Tea Break	
10:00 - 12:00, Session Chair: Alexander Martin		
10:00 - 10:30	Modeling LIBOR Rates Before and During the Crisis	Antonis Papapantoleon
10:30 - 11:00	New Models for Network Connection Problems with Interval Data	Xiaodong Hu
11:00 - 11:30	Computing Material Composition from X-Ray Diffraction Data	Marc Steinbach
11:30 - 12:00	Improved Bounds for RIC in Compressed Sensing	Naihua Xiu
12:00 - 13:00	Lunch (AMSS Restaurant)	
13:00 - 13:30	Academic visit of State Key Laboratory of Scientific and Engineering Computing	
13:40 - 14:40, Session Chair: Ralf Borndörfer		
13:40 - 14:10	TSP with Release Times	Guochuan Zhang
14:10 - 14:40	Finding a Sparsest Solution of an Equation System	Marc Pfetsch
14:40 - 15:00	Tea Break	
15:00 - 16:10, Session Chair: Xin Liu		
15:00 - 15:30	The Constraint Condition and a Primal-Dual Interior-Point Algorithm for Nonlinear Semidefinite Programs	Xinwei Liu
15:30 - 15:50	Max-Min Fairness Linear Transceiver Design for a Multi-User MIMO Interference Channel	Ya-Feng Liu
15:50 - 16:10	Optimizing the Core Tensor in Tucker Decomposition: New Model and Algorithms	Zhening Li
16:10 - 18:00	Academic visit of Beijing Jiaotong University	
18:00	Dinner (Beijing Jiaotong University)	

September 26 (Wednesday), Real-World Problem Modeling and Solution (II)		
9:00 - 9:45, Session Chair: Hans Josef Pesch		
9:00 - 9:45	Keynote Speech Optimization Methods for Complex Industrial Scheduling Problems	Rolf Möhring
9:45 - 10:00	Tea Break	
10:00 - 12:00, Session Chair: Lixin Tang		
10:00 - 10:30	Homotopy Method for Solving Nonlinear Programming with Many Complicated Constraints	Bo Yu
10:30 - 11:00	Stochastic Dominance Analysis of Online Bin Coloring Algorithms	Benjamin Hiller
11:00 - 11:30	A New Approach for Optimal Air Flow Control of Mine Ventilation Network	Yu-Hong Dai
11:30 - 12:00	Makespan-Optimal Routing and Scheduling for Welding Robots	Jörg Rambau
12:00 - 13:40	Lunch (AMSS Restaurant)	
13:40 - 15:10, Session Chair: Tiande Guo		
13:40 - 14:10	Regularization for Sparse Portfolio Rebalancing and Selection Problems	Fengmin Xu
14:10 - 14:40	Solving MINLPs by Discretization Techniques with Applications in Energy Optimization	Alexander Martin
14:40 - 15:10	A New Type of Extragradient Method for Generalized Variational Inequalities	Yiju Wang
15:10 - 15:40	Tea Break	
15:40 - 17:25, Session Chair: Sven Krumke		
15:40 - 16:25	Keynote Speech An Introduction to Optimal Control of Partial Differential Equations with Real-Life Applications	Hans Josef Pesch
16:25 - 17:05	Keynote Speech Public Transit Scheduling: Modeling, Methods and Applications	Yindong Shen
17:05 - 17:25	Optimization-Based Bound Tightening and Lagrangian Variable Bounds	Ambros Gleixner
17:45	Dinner (Xiang Lin Tian Xia Restaurant)	

September 27 (Thursday), Sightseeing	
7:00	Set off from Park Plaza Beijing Science Park
Morning	Half-Day tour to the Great Wall
Time	Lunch (Beijing China Town Hotel)
Afternoon	Half-Day Tour to the Ming Dynasty Tombs
Time	Diner (Hai Di Lao Hot Pot)

Abstracts

Optimality Conditions and Smoothing Trust Region Newton Method for Non-Lipschitz Optimization

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Regularized minimization problems with nonconvex, nonsmooth, perhaps non-Lipschitz penalty functions have attracted considerable attention in recent years, owing to their wide applications in image restoration, signal reconstruction and variable selection. In this paper, we derive affine-scaled second order necessary and sufficient conditions for local minimizers of such minimization problems. Moreover, we propose a global convergent smoothing trust region Newton method which can find a point satisfying the affine-scaled second order necessary optimality condition from any starting point. Numerical examples are given to illustrate the efficiency of the optimality conditions and the smoothing trust region Newton method.

Numerical Aspects of Optimization Problems with Probabilistic Constraints under Gaussian Distribution

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The efficient solution of optimization problems requires to calculate gradients of the objective and constraints. If the latter are defined as probabilistic constraints induced by some multivariate Gaussian distribution then the computation of gradients can be analytically led back to the computation of function values. In the talk we discuss some numerical implications of this fact in the context of different practical applications.

Successive Convex Approximations to Cardinality-Constrained Quadratic Programs: A DC Approach

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In this paper we consider a cardinality-constrained quadratic program that minimizes a convex quadratic function subject to a cardinality constraint and linear constraints. This class of problems has found many applications, including portfolio selection, subset selection and compressed sensing. We propose a successive convex approximation method for this class of problems in which the cardinality function is first approximated by a piecewise linear DC function (difference of two convex functions) and a sequence of convex subproblems are then constructed by successively linearizing the concave terms of the DC function. Under some mild assumptions, we establish that any accumulation point of the sequence generated by the method is a KKT point of the DC approximation problem. We show that the basic algorithm can be refined by adding valid inequalities in the subproblems. We report some preliminary computational results which show that our method is promising for finding good suboptimal solutions and is competitive with some other local solution methods for cardinality-constrained quadratic programs.

Reflections on Stochastic Programming

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Stochastic programming deals with deterministic substitute problems to optimization problems where model uncertainty can be expressed in terms of probability distributions of random data. A crucial requirement in stochastic programming is non-anticipativity, i.e., decisions must be taken without anticipation of future information. Depending on when information becomes available and on how this interacts with decision making over time, different principal model setups arise in stochastic programming, e.g., one-stage, two-stage, or multi-stage models. Selection and placement (in the objective or the constraints) of the statistical parameters according to which relevant random variables are to be evaluated is another important issue in stochastic programming. This allows to express perceptions such as reliability, risk neutrality, or risk aversion. Finally, the nature of the initial uncertain optimization problem (linear or nonlinear, with or without integer variables, finite- or infinite-dimensional) has crucial impact on the arising stochastic programming model. These aspects lead to a wide variety of stochastic programming models as well as to a wide variety of mathematical techniques for their analysis and algorithmic treatment. In the talk, we reflect on some of these models, on their mathematical analysis, and, last but not least, on algorithms and their behaviour in practical computation.

Convergence Analysis of Primal-Dual Algorithms for a Saddle-Point Problem in Total Variation Image Restoration

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Recently, some primal-dual algorithms have been proposed for solving a saddle-point problem, with particular applications in the area of total variation image restoration. This talk focuses on the convergence analysis of these primal-dual algorithms and shows that their involved parameters (including step sizes) can be significantly enlarged if some simple correction steps are supplemented. Some new primal-dual-based methods are thus proposed for solving the saddle-point problem. We show that these new methods are of the contraction type: the iterative sequences generated by these new methods are contractive with respect to the solution set of the saddle-point problem. The global convergence of these new methods thus can be obtained within the analytic framework of contraction-type methods. The novel study on these primal-dual algorithms from the perspective of contraction methods substantially simplifies existing convergence analysis. Finally, we show the efficiency of the new methods numerically.

From Simulation to Optimization

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The FORNE projects deals with several questions regarding the planning and operation of gas transport networks. One of the central questions is whether it is possible to find a stationary state for a particular demand/supply situation given all parameters of the network.

This includes discrete decisions like whether a given compressor is running at all and also continued ones like the rate of revolution of the compressor in case it is running. Traditionally, this problem is solved by use of an experienced human network planner together with a simulation tool. In this talk we report how we transformed this simulation problem into a fully automatized optimization model. A detailed account of the mathematical models and solution methods will be given. We will discuss the meaning of feasibility in this setting.

Furthermore, it is possible to answer several more involved questions, which also include stochastic aspects once the above procedure is available.

Simulation of Levy-Driven Models

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Levy processes have been widely used to model financial assets such as stock prices, exchange rates, interest rates and commodities. In this talk, we will give an overview on simulation methods for Levy processes. Generally speaking, there are three types of simulation methods for Levy processes: (i) compound Poisson approximation; (ii) discrete skeleton of increments; (iii) series representation. We will discuss advantages and disadvantages of each method. In addition, we will also discuss how to estimate performance sensitivities for Levy processes via simulation. Simple examples will be provided to illustrate simulation methods and associated sensitivity estimation.

Alternating Direction Method of Multiplier: Splitting Techniques and Beyond

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Alternating direction method of multiplier(ADMM) applies alternating technique on the KKT system of augmented Lagrangian function, which is a powerful algorithm for optimization problems with linear equality constraints and certain separable structures. In some applications, ADMM has excellent performance if we introducing some split techniques. In this talk, we show some techniques to make a good split and also demonstrate some preliminary result on the convergence of ADMM in general cases.

Local Linear Convergence of the Alternating Direction Method of Multipliers for Quadratic Programs

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The Douglas-Rachford alternating direction method of multipliers (ADMM) has been widely used in various areas. The global convergence of ADMM is well known, while research on its convergence rate is still in infancy. In this talk, we present the local linear convergence rate of ADMM for a quadratic program which includes some important applications of ADMM as special cases.

Key Words: Alternating direction method of multipliers, linear convergence rate, quadratic program, error bound.

Iterative Refinement for Linear Programming

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We describe an iterative refinement procedure for computing extended precision or exact solutions to linear programming problems (LPs). Arbitrarily precise solutions can be computed by solving a sequence of closely related LPs with limited precision arithmetic. The LPs solved at iterations of this algorithm share the same constraint matrix as the original problem instance and are transformed only by modification of the objective function, right-hand side, and variable bounds. Exact computation is used to compute and store the exact representation of the transformed problems, while numeric computation is used for computing approximate LP solutions and applying iterations of the simplex algorithm. We demonstrate that this algorithm is effective in practice for computing extended precision solutions and directly benefits methods for solving LPs exactly over the rational numbers.

This is joint work with Ambros Gleixner and Kati Wolter.

Robust PCA for Ground Moving Target Indication in Wide-Area Surveillance Radar System

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Ground moving target indication (GMTI) in wide-area surveillance radar system is the key task in wide-area surveillance radar system. Due to its great importance in future reconnaissance systems, it attracts great interest from scientists. Yan et al first introduced Robust PCA to model GMTI problem, and demonstrate promising simulation results to verify the advantages over other models. However, the robust PCA model can not fully describe the problem. This motivates our work in this talk, where we will detail GMTI problem, explore the mathematical properties and discuss how to set up better models to solve the problem. We establish two models, the structured RPCA model and the row-modulus RPCA model, both of which will better fit the problem and take more use of the structure of the sparse matrix. Simulation results are demonstrated to confirm the improvement of the proposed models over the previous one.

Tangent Cone and Error Bound for Degenerate Constraint Set

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Tangent cone formulae is an important topic in nonsmooth analysis, while error bound result has many important applications, say in convergence analysis and in penalty method. We will discuss tangent cone formulae and error bound result for inclusion problem, especially when the Robinson constraint qualification is not satisfied. This extends similar formulae for nonliear equation and improves our earlier result. Though our earlier result is a generalization of Robinson's result, it needs some restriction assumptions, which is removed in this work. The main difficulty are: inclusion problem is a nonsmooth problem in general, and the celebrated Robinson constraint qualification is not required.

On the Use of Two Simple Models in Bound Constrained Minimization Without Derivatives

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Derivative-free optimization (DFO) method is designed to deal with those problems for which the derivatives of objective functions are unavailable, which is usually the case for many real-world problems. Over the past 20 years DFO has experienced a renewed interest. Among these methods, trust-region methods based on interpolation models show their great advantages in number of function evaluations and dealing with noise functions. Based on the framework of trust-region methods, we present two simple interpolation models, linear model and quadratic model with diagonal Hessian matrix, for bound constrained minimization. Despite the simplicity, preliminary test results show their efficiency, compared with the BOBYQA Fortran package and DFO Fortran package. Furthermore, these two models have their respective advantages, therefore, a method which combines them together is also proposed.

Freight Train Composition with Minimum Shunting Operations

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Planning freight train schedules in dense rail networks provides an enormous challenge. In fact, railway transport companies face a high-dimensional complex optimization problem. Resulting models include a tremendous number of eligible train routes and departure times restricted by sparse infrastructure capacities. Furthermore, minimizing the total travel distance for rolling stock as well as the individual due dates for freight delivery define important but conflicting objectives that have to be handled.

Based on joint work with Ronny Hansmann within a three-year BMBF-supported applied project, we will outline first results from our ongoing cooperation with the Deutsche Bahn (DB). Due to requests of the customers of the DB, a large amount of freight has to be moved from origins to destinations throughout Germany every day. In this talk, we focus on the necessary composition of rail cars in freight trains. According to the requested amount of freight, rail cars are routed from origin to destination and are assigned to a suitable sequence of previously scheduled freight trains. Additionally, the sequence of the rail cars within a freight train may be chosen. The real challenge consists in assigning rail cars to freight trains with choice of their sequence within the train minimizing the total number of the time-consuming shunting operations in the visited rail yards.

To our knowledge, the resulting NP-hard problem was previously not studied in the literature. We will present new mixed integer programming formulations. Some heuristical solution methods as well as preliminary computational experience for practical data from the DB will be presented. We conclude the talk with some remarks on future research.

On Fingerprint Image Compression Based on Non-Negative Matrix Factorization

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Robust Tail Assignment

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Tail assignment is one of the classical planning problems in the operation of an airline. It deals with the construction of rotations for individual units of aircraft in order to cover the legs of a flight schedule. Tail assignment is not a cost minimization problem; the number of aircraft that is needed to operate a flight schedule is determined in the preceding fleet assignment step. One rather optimizes aircraft maintenances and, in particular, buffer times between successive flights of an aircraft in such a way that delays can be absorbed and the operation becomes more "robust". In fact, the ongoing dissemination of optimization technology is cutting at safety margins, such that deviations between the plan and the actual operation have become an increasingly serious problem in the last decade. We propose an efficient column generation method to minimize the probability of delay propagations along aircraft rotations. In this way, delay resistant schedules can be constructed. Computational results for large-scale real-world problems demonstrate substantial punctuality improvements. The method can be generalized to crew and integrated scheduling problems.

Joint work with Ivan Dovica (Charles University Prague), Ivo Nowak, and Thomas Schickinger (both from Lufthansa Systems AG).

Optimization Based the Ship Stowage Planning Problem of Coils in Steel Industry

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We consider a ship stowage planning problem (SSPP) where steel coils with known destination ports are to be loaded onto a ship. Different from stowage problems in previous studies, in this problem there are no fixed positions on the ship for the coils due to their different sizes. At a destination port, if a coil to be unloaded is not at a top position, those blocking it need to be shuffled. In addition, the stability of ship has to be maintained after unloading at each destination port. The objective for the stowage plan is to minimize the dispersion of coils to be unloaded at each destination port, minimize the shuffling needed, and maximize the stability of the ship throughout the entire voyage. We formulate the problem as a novel mixed integer linear programming model. Several valid inequalities are derived to help reducing solution time. A tabu search algorithm is developed for the problem with the initial solution generated using a three-stage heuristic. Computational results show that for small problems, which can be solved optimally by the model, the proposed algorithm can generate close-to-optimal solutions. For large practical problems the algorithm improves the current manual solutions significantly within a short time.

Keywords: stowage planning, steel coils, integer programming, tabu search.

Graph Theoretic Approaches to Optimizing Transfer Quality in Public Transportation Networks

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Inconvenient transfer times in a public transfer system restrain people from using it by choice. In general, one wishes to avoid short, risky waiting times as well as too long and tedious waiting times. The problem of synchronizing transfers by shifting tours is and NP-hard problem and usually modeled as a quadratic semi-assignment problem. We show how to take a different approach via unsatisfiable systems with two variables per inequality (so called 2-VPI systems). By using a graph-theoretic view on the problem we design various approximation algorithms for the task of maximizing the number of ensured transfers and minimizing the number of "bad" transfers. For the maximization problem, we give a simple α-approximation, where α is the arboricity for the corresponding graph, i.e., the minimum number of forests in which the graph can be decomposed. We also show how to obtain a 2-approximation for the complementary minimization problem in planar graphs by the means of a primal-dual approximation framework. Our results extend to weighted versions of the problem and to variants in which the shifts of the tours are constrained to intervals and other polynomial time verifiable sets. We complement the approximation results by new hardness results on restricted classes of graphs.

Measuring the Potentiality of Decision Making Units

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Metric Inequalities for Robust Network Design

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For network design with a static traffic matrix, it is well known that the problem can be formulated on the capacity variables only by so-called metric inequalities. A straightforward generalization of these inequalities to the robust case where traffic uncertainty is modelled a la Bertsimas and Sim (2003,2004) does not yield a correct formulation. In this work, we derive the class of robust metric inequalities that have the property again of providing a formulation of the robust network design problem.

Stochastic Programming Arising from Economic Dispatch with Reliability Risk Constraint in Smart Grid

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In this talk, we consider a class of stochastic programming arising from economic dispatch (ED) in smart grid. The background of power system operation with reliability risk is introduced. Then based on the conditional value-at-risk (CVaR) management, we study the single-stage ED optimization model and the solution algorithm. Furthermore, according to the ED decision pattern of modern smart grid, we set up two types of three-stage stochastic programming with respect to the different case of random information giving. Numerical example for the single-stage ED problem is proposed to validate the model and solution method.

Optimal Fuel, Power and Load-Based Emissions Trades for Electric Power Supply Chain Equilibrium

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This paper proposes a model to determine equilibrium fuel, power and emissions trades in an electric power supply chain (fuel/generation/transmission/distribution/consumption) framework with a load-based (LB) emissions trading program. The model represents the oligopolistic gaming behavior of generation companies (Gencos) and load serving entities (LSEs), and equilibrium conditions for fuel, power and emissions allowance markets which are integrated through endogenous prices. The model is solved by using a practical heuristic method based on the Fisher-Burmeister nonlinear complementarity function (NCP) and smoothing technique. An application to a four-node system with three Gencos and LSEs is also presented to illustrate the effects of emission allowances trading, renewable energy generation and network congestion on equilibrium solutions.

A Primal-Dual Approximation Algorithm for the Two-Level Facility Location Problem

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In this work, we propose a primal-dual combinatorial $3(1+\epsilon)$-approximation algorithm for the *two-level facility location problem* (2-LFLP) by exploring the approximation oracle concept. This result improves the previous primal-dual 6-approximation algorithm for the multilevel facility location problem, and also matching the previous primal-dual approximation ratio for the single-level facility location problem. One of the major merits of primal-dual type algorithms is their easy adaption to other variants of the facility location problems.

This is a joint work with Chenchen Wu and Donglei Du.

Measuring the Impact of Primal Heuristics

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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 assesses 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.

A Penalty Decomposition Method for Probabilistically Constrained Convex Programs

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We consider a probabilistically constrained convex program (PCCP), where the random vector follows a finite discrete distribution. The problem can be reformulated as a mixed-integer convex program (MICP), which is in general NP-hard. By exploiting the special structure of the probabilistic constraint, a penalty decomposition method is presented for finding a suboptimal solution of PCCP. This method uses an alternating direction scheme, in which a convex programming subproblem and a 0-1 knapsack subproblem are solved alternatively at each iteration. We show that the 0-1 knapsack subproblem has closed form solution in the case of equal probabilities. Convergence to a suboptimal solution is established under mild conditions. We report preliminary computational results on the VaR-constrained portfolio selection problem and the stochastic transportation problem. Numerical results show that the proposed method is promising for finding good quality suboptimal solutions and compares favorably with other existing approximation methods for PCCPs of medium to large sizes.

The Total Variation Model for Determining the Implied Volatility in Option Pricing

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Volatility is a very important parameter in financial economy, it is necessary to accurately measure it in portfolio selection, asset pricing and risk management. In the underlying asset market, people tend to want to know the future price volatility of underlying assets so as to understand the future risk of assets structure. Determining the implied volatility is a typical PDE inverse problem. In this paper, based on the Black-Scholes theoretical framework, we propose the total variation regularization model for determining the implied volatility and make a rigorous mathematical analysis for this inverse problem. We not only discuss the existence and uniqueness to the solution, but also give the necessary optimality conditions for the related minimization problem. Furthermore, the stability and convergence analyses for this regularized approach are presented.

Positive Semi-Definite Diffusion Tensor Model in High Angular Resolution Diffusion Imaging

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Due to the well-known limitations of diffusion tensor imaging (DTI), high angular resolution diffusion imaging (HARDI) is used to characterize non-Gaussian diffusion processes. One approach to analyze HARDI data is to model the apparent diffusion coefficient (ADC) with higher order diffusion tensors (HODT). The diffusivity function is positive semi-definite. In the literature, some methods have been proposed to preserve positive semi-definiteness of second order and fourth order diffusion tensors. None of them can work for arbitrary high order diffusion tensors. In this talk, we propose a comprehensive model to approximate the ADC profile by a positive semi-definite diffusion tensor of either second or higher order. We call this model PSDT (positive semi-definite diffusion tensor). PSDT is a convex optimization problem with a convex quadratic objective function constrained by the nonnegativity requirement on the smallest Z-eigenvalue of the diffusivity function. Then we propose some invariants for the ADC profile analysis. In addition, the diffusion orientation distribution function (ODF), as a probability distribution function, should be nonnegative. In this talk, we also present a nonnegative ODF model and provide formulas for determining the principal directions (maxima) of the ODF, based on optimization theory. Experiment results show that higher order tensors could improve the estimation of anisotropic diffusion and the PSDT model can depict the characterization of diffusion anisotropy which is consistent with known neuroanatomy.

Linear Precoder Design and Admission Control for Wireless Networks

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We consider the problem of joint physical layer multicasting and user admission control for a wireless network. This is a difficult problem which involves in both integer variables (user selection) and continuous variables (beamformers). We formulate the problem as a mixed-integer quadratic program (MIQP), and solve it using semi-definite relaxation and sparse optimization techniques. We identify when the SDP relaxation is tight and give approximation bounds when it is not.

Modeling LIBOR Rates Before and During the Crisis

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The ongoing financial crisis has had a severe impact on interest rates markets. Several certainties about what is "risk-free" have been shattered, and this includes not only AAA-rated corporate and government bonds, but also the LIBOR rate itself. In this talk, we will first describe how the LIBOR rate was conceived and modeled before the credit crunch, what were the mathematical difficulties and how one could overcome them. Then, we will discuss how the LIBOR rate is actually constructed and why it is not considered risk-free any more. We will then focus on modeling LIBOR rates in the present environment.

New Models for Network Connection Problems with Interval Data

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In this talk, I will present a new approach for dealing with network connection problems with uncertain parameters, where, it is assumed, cost on a link/node in a given network fall into an interval. We introduced two risk models for these problems, proposed polynomial-time algorithms for solving the problems and conducted computational experiments on algorithms proposed. Our theoretical and computational results show the flexibility of this new approach for decision makers at different levels of aversion to risk, as well as satisfactory performance of standard CPLEX solver on our model.

This is a joint work with Xujin Chen.

Computing Material Composition from X-Ray Diffraction Data

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X-Ray diffraction is a standard method for quantitative material analysis in areas like crystallography, chemistry, or biochemistry: X-Ray exposure yields intensity distributions that depend on the molecular structure and that can be measured with high precision over a certain range of diffraction angles.

Material parameters are then obtain by suitable parameter estimation methods. The talk presents the resulting class of potentially ill-conditioned constrained inverse problems and reports on the development and implementation of a real time solution algorithm. Main components of the algorithm include a Levenberg-Marquardt method, a truncated CG method featuring certain projection techniques, and sparse linear algebra exploiting the specific Jacobian structure.

The post-optimality analysis includes a detection of modeling redundancy and a covariance computation based on an SVD or a QR decomposition with pivoting.

Improved Bounds for RIC in Compressed Sensing

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This talk mainly gives the improved bounds for restricted isometry constant (RIC) in compressed sensing. Let Φ be a $m \times n$ real matrix and k be a positive integer with $k \leq n$. We show that if the restricted isometry constant of Φ satisfies

$$\delta_{k+ak} < \frac{3}{2} - \frac{1+\sqrt{(4a+3)^2-8}}{8a} \text{ for } a > \frac{3}{8},$$

then k-sparse solution can be recovered exactly via l_1 minimization in the noiseless case. In particular, when $a = 1, 1.5, 2$ and 3, we have $\delta_{2k} < 0.5746$, $\delta_{2.5k} < 0.7074$*, $\delta_{3k} < 0.7731$ and $\delta_{4k} < 0.8445$, which are the best bounds for RIC to our knowledge.

This is a joint work with Shenglong Zhou and Lingchen Kong.

*$\delta_{2.5k}$ means $\delta_{\lceil 2.5k \rceil}$. In whole paper, for a positve real number a, the δ_{ak} and $\theta_{k,ak}$ are defined as $\delta_{\lceil ak \rceil}$ and $\theta_{k,\lceil ak \rceil}$, respectively.

TSP with Release Times

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We consider a generalization of the well-known Traveling Salesman Problem, called the Vehicle Scheduling Problem (VSP), in which each city is associated with a release time and a service time. The salesman has to visit each city at or after its release time. In this talk we will introduce three results. First, we devise an approximation algorithm for VSP with performance ratio less than 5/2 when the number of distinct release times is fixed, improving the previous algorithm proposed by Nagamochi et al. (1997). Then we analyze a natural class of algorithms and show that no performance ratio better than 5/2 is possible unless the Metric TSP can be approximated with a ratio strictly less than 3/2, which is a well-known longstanding open question. Finally, we consider a special case of VSP with a heavy edge, and present an approximation algorithm with performance ratio less than 5/2 as well.

Joint work with Mordcai Golin and Wei Yu.

Finding a Sparsest Solution of an Equation System

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The investigation of the NP-hard problem to determine a solution to an underdetermined equation system that has as few nonzeros as possible has become increasingly popular in the last years. It is one of the main goals in the area of compressed sensing. Almost all existing articles in this field deal with conditions under which the problem can be solved efficiently. In this talk we will concentrate on the original problem and develop an exact branch-and-cut approach; the basic framework can also be used to find the smallest circuit in a matroid. We investigate methods to find valid inequalities of the corresponding polytope and study their practical performance. The corresponding computational results highlight the increasing complexity of the problem if the underlying data tends to violate the conditions under which the problem can be solved efficiently through other methods.

The Constraint Condition and a Primal-Dual Interior-Point Algorithm for Nonlinear Semidefinite Programs

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We present a primal-dual interior-point algorithm for nonlinear semidefinite programs with nonlinear equality and positive semidefinite constraints, which is an extension of a robust primal-dual interior-point method for nonlinear programs. The algorithm solves a well-behaved quadratic programming subproblem (not a quadratic semidefinite programming subproblem as the existing methods) in each iteration. The global convergence is promoted by the logarithmic barrier penalty function. A new constraint condition is presented, under which it is proved that there is a limit point of the iterative sequence generated by the algorithm is a Karush-Kuhn-Tucker point of the original program. The simple examples illustrate that the constraint condition may help us recognize some hard semidefinite programs. The algorithm can also find certain useful solution at which the constraint condition does not hold. Some preliminary numerical results are reported.

Max-Min Fairness Linear Transceiver Design for a Multi-User MIMO Interference Channel

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Consider the max-min fairness linear transceiver design problem for a multi-user multi-input multi-output (MIMO) interference channel. When the channel knowledge is perfectly known, this problem can be formulated as the maximization of the minimum signal to interference plus noise ratio (SINR) utility, subject to individual power constraints at each transmitter. We prove in this paper that, if the number of antennas is at least two at each transmitter and is at least three at each receiver, the max-min fairness linear transceiver design problem is computationally intractable as the number of users becomes large. In fact, even the problem of checking the feasibility of a given set of target SINR levels is strongly NP-hard. We then propose two iterative algorithms to solve the max-min fairness linear transceiver design problem. The transceivers generated by these algorithms monotonically improve the min-rate utility and are guaranteed to converge to a stationary solution. The efficiency and performance of the proposed algorithms compare favorably with solutions obtained from the channel matched beamforming or the leakage interference minimization.

Optimizing the Core Tensor in Tucker Decomposition: New Model and Algorithms

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Tucker decomposition decomposes a tensor into a set of matrices and one small core tensor. It may be regarded as a generalization of the CANDECOMP/PARAFAC decomposition, which decomposes a tensor into a summation of rank-one tensors. Historically, much of its interest was driven by the need to analyze empirical data, especial in psychometrics and chemometrics. Later it was studied by mathematicians who are interested in algebraic properties of tensors, as well as by engineers and statisticians who are interested in high order (tensor) statistics and independent component analysis. The "workhorse" algorithm for Tucker decomposition in the literature is alternating least square (ALS) method and its extensions. However, the ALS method is not guaranteed to converge to a global minimum or a stationary point. Moreover, the dimensions of the core tensor have to be predetermined, and the question of how to choose these dimensions is quite challenging. In this work, we apply recently developed block coordinate descent type search method, namely, maximum block improvement (MBI) to solve the Tucker decomposition with given dimensions of the core tensor, which guarantees to converge to a stationary point. A new model for the Tucker decomposition with unspecified dimensions of the core tensor is proposed and solved by using the MBI method. A heuristic approach is also proposed for computing the new model. Numerical experiments are conducted, and the results show that the new model and the algorithms outperformer the ALS method greatly in many instances.

Joint work with Bilian Chen and Shuzhong Zhang.

Optimization Methods for Complex Industrial Scheduling Problems

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Many complex production processes require that a set of jobs is put into a sequence that subsequently requires detailed scheduling to make efficient use of resources needed for production. Typical examples are coil coating in integrated steel production or the scheduling of filling lines in dairy production. The aim is to find a production plan, i.e., a sequence reflecting the processing order, and a feasible schedule for this sequence that minimizes the makespan. The makespan depends on both the sequence and a schedule for that sequence, and finding a provably good schedule for a fixed sequence may already be NP-hard.

We present an optimization model for such integrated sequencing and scheduling problems. Core components are a very fast genetic algorithm to solve the sequencing problem and graph theoretical models for the scheduling part. The latter are instrumental for building fast heuristics that are embedded into the genetic algorithm. The quality of our solutions is evaluated via integer programs based on combinatorial relaxations of the scheduling problems.

Finally, we demonstrate the benefits of this approach on two industrial applications from steel manufacturing and dairy production.

Homotopy Method for Solving Nonlinear Programming with Many Complicated Constraints

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Stochastic Dominance Analysis of Online Bin Coloring Algorithms

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In this talk we present a new method for probabilistic analysis of online algorithms based on the notion of stochastic dominance. We develop the method for the online bin coloring problem introduced by Krumke et al which models applications in elevator control and high rack warehouses. Using methods for the stochastic comparison of Markov chains we establish the result that the performance of the online algorithm GreedyFit is stochastically better than the performance of the algorithm OneBin for any number of items processed. This result gives a more realistic picture than traditional competitive analysis and explains the behavior observed in simulations much better.

This is joint work with Tjark Vredeveld.

A New Approach for Optimal Air Flow Control of Mine Ventilation Network

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The optimal air flow control problem is a fundamental problem in the mine ventilation network and has wide applications. In this talk, we propose a bilevel optimization model for the problem. This bilevel model contains the upper-level problem which controls the air flow within the given region or minimizes the cost for controlling the resistances of the pipes and the lower-level problem which describes the natural ventilation problem and some other control variables. Based on the derivative information of the flow with respect to the resistances of the controlled pipes, we simplify the bilevel model as an ordinary nonlinear programming. Then, we use the classical Lagrangian multipliers method to solve this nonlinear program. Some preliminary numerical results show the efficiency of our approach.

This is a joint work with Bo Jiang and Yinyu Ye.

Makespan-Optimal Routing and Scheduling for Welding Robots

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In some car body manufacturing shops, laser arc welding techniques are applied. The laser sources that supply the robots with energy are very expensive resources, and it is of interest to share them among the welding robots. This poses, however, a synchronization problem among the robots, since a laser source can only supply one robot at a time with energy. Moreover, a given cycle time must not be exceeded.

We present an exact algorithm that can solve the so-called laser sharing problem to optimality for industrial scale instances: find explicitly scheduled tours of the robots through all jobs with a given number of laser sources so that robots connected to the same laser source do not weld simultaneously and so that the makespan is minimal. The main idea of our algorithm is to use NP-hard combinatorial relaxations in a branch-and-bound framework rather than LP relaxations.

Joint work with Cornelius Schwarz.

Regularization for Sparse Portfolio Rebalancing and Selection Problems

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Recently, statistical regularization have been attracted extensive attention and successfully applied in mean-variance portfolio selection for promoting out-of-sample properties and decreasing transaction costs. In this topic, we considers a sparse portfolio rebalancing problem in which rebalancing portfolios with minimum number of assets are sought, and a sparse portfolio selection model based on our recent studies of nonconvex L1/2 regularization.

On the one hand, we propose a sparse portfolio rebalancing model by adding an L1 penalty into the objective function of general portfolio rebalancing model. In this way, the model is sparse with low transaction costs and can decide whether and which assets to adjust based on inverse optimization. Numerical tests on four typical data sets show that optimal adjustment given by the proposed sparse portfolio rebalancing model has the advantage of sparsity and better out-of-sample performance than general portfolio rebalancing model.

On the other hand, we propose a sparse portfolio selection model and extend half thresholding algorithm to a fast and efficient penalty half thresholding algorithm for solving the new model. Moreover, we propose an optimal regularization parameter setting strategy of proposed algorithm, the parameter can automatically be corrected to appropriate optimal value whatever the initial condition is. Empirical tests on two benchmark datasets show the effectiveness of the model and algorithm in terms of sparsity and regularization parameter selection.

Solving MINLPs by Discretization Techniques with Applications in Energy Optimization

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Motivated by optimzation problems on energy networks we develop discretization techniques to solve the resulting mixed integer nonlinear optimizations problems (MINLPs) to global optimality. We demonstrate the success of this technique on real-world instances from industry.

A New Type of Extragradient Method for Generalized Variational Inequalities

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In this paper, we present a new type of extragradient method for generalized variational inequalities with multi-valued mapping in an infinite-dimensional Hilbert space. For this method, the generated sequence possesses an expansion property with respect to the initial point, and the existence of the solution to the problem can be verified through the behavior of the generated sequence. Furthermore, under mild conditions, we show that the generated sequence of our method strongly converges to the solution of the problem which is closet to the initial point.

An Introduction to Optimal Control of Partial Differential Equations with Real-Life Applications

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When analyzing mathematical models for complex dynamical systems, their analysis and numerical simulation is often only a first step. Thereafter, one often wishes to complete the analysis by an optimization step to exploit inherent degrees of freedom for optimizing a desired performance index with the dynamical system as side condition. This generally leads to optimization problems of extremely high complexity if the underlying system is described by (time dependent) partial differential equations (PDEs) or, more generally, by a system of partial differential algebraic equations (PDAEs).

In the talk we will report on some of the lastest achievements on the field of optimization with PDEs and exhibit the challenges we are facing and have to cope with to solve such tasks. [5]

In the introduction three problems from engineering sciences are addressed for motivation:

1. Hot cracking is a common risk in welding of aluminium alloys. According to a Russian patent this risk can be avoided by applying a so-called multi-beam laser welding technique. By two additional laser beams the thermal stress introduced by the main welding laser can be compensated, if the additional laser beams are optimally placed and sized while they must not melt on the material. Mathematically one obtains a semi-infinite optimization problem with PDE and inequality constraints. [6]

2. Future concepts for intercontinental flights of passenger aircraft envisage aircraft which are able to fligh at hypersonic speeds. Due to such high velocities the thermal heating of the aircraft is an issue which has to be taken into account. This multi-physics problem leads to an optimal control problem for a system of ordinary differential equations where the heating of the aircraft's body is modelled as a quasilinear heat equation with nonlinear boundary conditions. The temperature of the thermal protection system must be limited and plays the role of a state variable inequality in this ODE-PDE optimal control problem. [2, 13]
3. The main example, which will be discussed in more detail in the second part of the talk, is concerned with the optimal control of certain fuell cell systems for an environmentally friendly production of electricity. Reaction-advection equations, a heat equation, additional ordinary as well as algebraic and integro equations sum up to a coupled system of up to 28 PDAEs of extremely high complexity. The inflow data into the anode inlet, the input data for the catalytic burner, and the amount of fed back from the cathode outlet are the control variables of this system. [1, 7–11]

After this motivation an outline of the mathematical theory of optimal control problems [12] for one elliptic equation is given to depict the purpose of solving optimal control problems by first order necessary conditions. Thereafter two numerical concepts, namely *first optimize then discretize* and *first discretize then optimize* [3] are discussed with respect to their pros and cons as well as an overlook on the mathematical toolbox from the literature is given.

The main part of the talk then deals with the results for optimal load changes when applying the two aforementioned methodologies including a method for the practical realisation of the computed optimal solutions based on model reduction techniques. [4]

Keywords: Optimal control, partial differential equations, numerical methods, real-time, state constraints, fuel cell systems, laser welding, hypersonic aircraft

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Public Transit Scheduling: Modeling, Methods and Applications

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The bus transit scheduling problem is of great practical importance as efficient schedules can make huge monetary savings and/or increase the capacity of bus transit services. The problem has attracted much research interest since the 1960's. Many approaches have been developed and applied in developed countries. However, research on bus transit scheduling using computers in China has just started in recent years. Much of it attempts to build a mathematical or heuristic model to tackle the bus vehicle scheduling problem on a line-by-line basis. It still requires much effort to meet the practical requirements of bus operators. So far, the bus operators commonly schedule their buses and drivers manually on a line by line basis.

This paper first presents the bus service in China, in which the particular characteristics are pointed out whilst the major problems encountered by bus operators and government are summed up.

In order to solve the practical public transit scheduling problem in China, we have put a great effort into the enhancement of the management mode and scheduling means and the development of suitable scheduling approaches.

To demonstrate our work on assisting bus companies with the change from the line-by-line mode to the inter-line mode, an applied study of scheduling buses and drivers for the Beijing Bus Group (BJBUS) is presented. This is pioneering research in China for bus transit scheduling using computers based on an inter-line mode of operation. Next, some popular models and approaches for driver scheduling are presented. Finally, a brand new idea of compiling schedules based on AVL data is reported.

Optimization-Based Bound Tightening and Lagrangian Variable Bounds

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Optimization-based Bound Tightening (OBBT) is a simple, yet computationally expensive procedure to reduce variable domains of mixed-integer nonlinear programs (MINLPs) by minimizing and maximizing each variable over a convex relaxation. We present techniques to reduce the computational effort incurred by OBBT and exploit dual information to construct globally valid inequalities (Lagrangian Variable Bounds). Propagating these yields a computationally cheap approximation of OBBT that helps to reduce the running time and number of nodes of a subsequent branch-and-bound solution process. We evaluate the performance impact of our techniques using an implementation within the MINLP solver SCIP.

This is joint work with Timo Berthold (Zuse Institute Berlin) and Stefan Weltge (Otto-von-Guericke-Universität Magdeburg).

Sightseeing Information

Great Wall[1]

The Great Wall (Chinese: 万里长城; pinyin: Wàn Lǐ Cháng Chéng; literally, *Ten-Thousand-Mile-Long Wall*) of China is a series of stone and earthen fortifications in northern China, built originally to protect the northern borders of the Chinese Empire against intrusions by various nomadic groups. Several walls have been built since the 5th century BC that are referred to collectively as the Great Wall, which has been rebuilt and maintained from the 5th century BC through the 16th century. One of the most famous is the wall built between 220-206 BC by the first Emperor of China, Qin Shi Huang. Little of that wall remains; the majority of the existing wall was built during the Ming Dynasty.

The Great Wall stretches from Shanhaiguan in the east, to Lop Lake in the west, along an arc that roughly delineates the southern edge of Inner Mongolia. The most comprehensive archaeological survey, using advanced technologies, has concluded that the entire Great Wall, with all of its branches, stretches for 8,851.8 km (5,500.3 mi). This is made up of 6,259.6 km (3,889.5 mi) sections of actual wall, 359.7 km (223.5 mi) of trenches and 2,232.5 km (1,387.2 mi) of natural defensive barriers such as hills and rivers.

The Chinese were already familiar with the techniques of wall-building by the time of the Spring and Autumn Period, which began around the 8th century BC. During the Warring States Period from the 5th century BCE to 221 BCE, the states of Qin, Wei, Zhao, Qi, Yan and Zhongshan all constructed extensive fortifications to defend their own borders. Built to withstand the attack of small arms such as swords and spears, these walls were made mostly by stamping earth and gravel between board frames.

Qin Shi Huang conquered all opposing states and unified China in 221 BCE, establishing the Qin Dynasty. Intending to impose centralized rule and prevent the resurgence of feudal lords, he ordered the destruction of the wall sections that divided his empire along the former state borders. To protect the empire against intrusions by the Xiongnu people from the north, he ordered the building of a

[1]From Wikipedia: http://en.wikipedia.org/wiki/Great_Wall_of_China.

new wall to connect the remaining fortifications along the empire's new northern frontier. Transporting the large quantity of materials required for construction was difficult, so builders always tried to use local resources. Stones from the mountains were used over mountain ranges, while rammed earth was used for construction in the plains. There are no surviving historical records indicating the exact length and course of the Qin Dynasty walls. Most of the ancient walls have eroded away over the centuries, and very few sections remain today. The human cost of the construction is unknown, but it has been estimated by some authors that hundreds of thousands, if not up to a million, workers died building the Qin wall. Later, the Han, Sui, and Northern dynasties all repaired, rebuilt, or expanded sections of the Great Wall at great cost to defend themselves against northern invaders. The Tang and Song Dynasties did not build any walls in the region. The Liao, Jin, and Yuan dynasties, who ruled Northern China throughout most of the 10-13th centuries, had their original power bases north of the Great Wall proper; accordingly, they would have no need throughout most of their history to build a wall along this line. The Liao carried out limited repair of the Great Wall in a few areas, however the Jin did construct defensive walls in the 12th century, but those were located much to the north of the Great Wall as we know it, within today's Inner and Outer Mongolia.

The Great Wall concept was revived again during the Ming Dynasty in the 14th century, and following the Ming army's defeat by the Oirats in the Battle of Tumu in 1449. The Ming had failed to gain a clear upper hand over the Manchurian and Mongolian tribes after successive battles, and the long-drawn conflict was taking a toll on the empire. The Ming adopted a new strategy to keep the nomadic tribes out by constructing walls along the northern border of China. Acknowledging the Mongol control established in the Ordos Desert, the wall followed the desert's southern edge instead of incorporating the bend of the Huang He.

Unlike the earlier Qin fortifications, the Ming construction was stronger and more elaborate due to the use of bricks and stone instead of rammed earth. As Mongol raids continued periodically over the years, the Ming devoted considerable resources to repair and reinforce the walls. Sections near the Ming capital of Beijing were especially strong.

During the 1440s-1460s, the Ming also built a so-called "Liaodong Wall".

Similar in function to the Great Wall (whose extension, in a sense, it was), but more basic in construction, the Liaodong Wall enclosed the agricultural heartland of the Liaodong province, protecting it against potential incursions by Jurched-Mongol Oriyanghan from the northwest and the Jianzhou Jurchens from the north. While stones and tiles were used in some parts of the Liaodong Wall, most of it was in fact simply an earth dike with moats on both sides.

Towards the end of the Ming Dynasty, the Great Wall helped defend the empire against the Manchu invasions that began around 1600. Even after the loss of all of Liaodong, the Ming army under the command of Yuan Chonghuan held off the Manchus at the heavily fortified Shanhaiguan pass, preventing the Manchus from entering the Chinese heartland. The Manchus were finally able to cross the Great Wall in 1644, after Beijing had fallen to Li Zicheng's rebels, and the gates at Shanhaiguan were opened by the commanding Ming general Wu Sangui, who hoped to use the Manchus to expel the rebels from Beijing. The Manchus quickly seized Beijing, and defeated both the rebel-founded Shun Dynasty and the remaining Ming resistance, establishing the Qing Dynasty rule over the entire China. In 2009, an additional 290 km (180 mi) of previously undetected portions of the wall, built during the Ming Dynasty, were discovered. The newly discovered sections range from the Hushan mountains in the northern Liaoning province, to Jiayuguan in western Gansu province. The sections had been submerged over time by sandstorms which moved across the arid region.

Under Qing rule, China's borders extended beyond the walls and Mongolia was annexed into the empire, so construction and repairs on the Great Wall were discontinued. On the other hand, the so-called Willow Palisade, following a line similar to that of the Ming Liaodong Wall, was constructed by the Qing rulers in Manchuria. Its purpose, however, was not defense but rather migration control.

Ming Dynasty Tombs[1]

The Ming Dynasty Tombs (Chinese: 明十三陵; pinyin: Míng Shí Sān Líng; literally, *Thirteen Tombs of the Ming Dynasty*) are located some 50 kilometers due north of central Beijing, within the suburban Changping District of Beijing

[1]From Wikipedia: http://en.wikipedia.org/wiki/Ming_Dynasty_Tombs.

municipality. The site, located on the southern slope of Tianshou Mountain (originally Mount Huangtu), was chosen on the feng shui principles by the third Ming Dynasty emperor Yongle (1402-1424), who moved the capital of China from Nanjing to its the present location in Beijing. He is credited with envisioning the layout of the Ming-era Beijing as well as a number of landmarks and monuments located therein. After the construction of the Imperial Palace (the Forbidden City) in 1420, the Yongle Emperor selected his burial site and created his own mausoleum.

From the Yongle Emperor onwards, 13 Ming Dynasty Emperors were buried in this area. The Xiaoling Tomb of the first Ming Emperor, Hongwu, is located near his capital Nanjing; the second emperor, Jianwen was overthrown by Yongle and disappeared, without a known tomb. The "temporary" Emperor Jingtai was also not buried here, as the Emperor Tianshun had denied him an imperial burial; instead, Jingtai was buried west of Beijing. The last Ming emperor Chongzhen, who hanged himself in April 1644, named Si Ling by the Qing emperor, was the last to be buried here, but on a much smaller scale than his predecessors.

During the Ming dynasty the tombs were off limits to commoners, but in 1644 Li Zicheng's army ransacked and set many of the tombs on fire before advancing and capturing Beijing in April of that year.

The site of the Ming Dynasty Imperial Tombs was carefully chosen according to Feng Shui (geomancy) principles. According to these, bad spirits and evil winds descending from the North must be deflected; therefore, an arc-shaped area at the foot of the Jundu Mountains north of Beijing was selected. This 40 square kilometer area –enclosed by the mountains in a pristine, quiet valley full of dark earth, tranquil water and other necessities as per Feng Shui – would become the necropolis of the Ming Dynasty.

A seven kilometer road named the "Spirit Way" (Shen Dao) leads into the complex, lined with statues of guardian animals and officials, with a front gate consisting of a three-arches, painted red, and called the "Great Red Gate". The Spirit Way, or Sacred Way, starts with a huge stone memorial archway lying at the front of the area. Constructed in 1540, during the Ming Dynasty, this archway is one of the biggest stone archways in China today.

Farther in, the Shengong Shengde Stele Pavilion can be seen. Inside it, there is a 50-ton tortoise shaped dragon-beast carrying a stone tablet. This was added during Qing times and was not part of the original Ming layout. Four white marble Huabiao (pillars of glory) are positioned at each corner of the stele pavilion. At the top of each pillar is a mythical beast. Then come two Pillars on each side of the road, whose surfaces are carved with the cloud design, and tops are shaped like a rounded cylinder. They are of a traditional design and were originally beacons to guide the soul of the deceased, The road leads to 18 pairs of stone statues of mythical animals, which are all sculpted from whole stones and larger than life size, leading to a three-arched gate known as the Dragon and Phoenix Gate.

Export all coordinates as KML Export all coordinates as GeoRSS Map of all microformatted coordinates Place data as RDF At present, only three tombs are open to the public. There have been no excavations since 1989, but plans for new archeological research and further opening of tombs have circulated. They can be seen on Google earth: Chang Ling, the largest; Ding Ling, whose underground palace has been excavated; and Zhao Ling.

The Ming Tombs were listed as a UNESCO World Heritage Site in August 2003. They were listed along with other tombs under the “Imperial Tombs of the Ming and Qing Dynasties” designation.

The organizing committee wishes you a pleasant stay in Beijing!