GENERAL INFORMATION

Foreword

As chairs of the international conference series *Parametric Optimization and Related Topics* it is our great pleasure to welcome you to the *10th International Conference on Parametric Optimization and Related Topics (paraoptX)* in Karlsruhe, September 20–24, 2010.

This conference series was founded in 1985 and, since then, took place each 2–3 years in different places: the latter six conferences were held in Enschede (1995), Tokyo (1997), Dubrovnik (1999), Puebla (2002), Cairo (2005), and Cienfuegos (2007). We are indebted and thankful to Jürgen Guddat (Humboldt University Berlin) and Hubertus Th. Jongen (RWTH Aachen University) for leading and promoting the *paraopt* conference series very successfully as its executive committee during the last two decades.

At *paraoptX*, the programme for the sixty participants from seventeen countries is composed of six invited and 41 contributed talks, held in 20 sessions. The program committee is especially thankful to our distinguished invited speakers, Christodoulos A. Floudas, Sven Leyffer, Boris Mordukhovich, Jiří Outrata, Teemu Pennanen, and Andreas Wächter, as well as to the organizers of the special sessions, Christian Kanzow and Jane Ye.

Finally we thank our sponsors: the German Research Foundation (DFG), the University of Birmingham, and the Karlsruhe Institute of Technology. Without their generous support this conference would not have been possible.

We wish you a very pleasant and stimulating *paraoptX*!

Jan-J. Rückmann and Oliver Stein
(paraopt chairs)

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- Michel Thera (Université de Limoges, France)
- Jane Ye (University of Victoria, Canada)

Conference Venue

Karlsruhe Institute of Technology
Campus South
Building 20.13
76131 Karlsruhe
Germany

Conference Desk

The conference desk is situated in Room 20.13-006.

Lecture Halls

The talks take place in the lecture rooms 20.13-001 and 20.13-111. To find your way to the lecture rooms, please follow the signs on site.

Presentation Instructions

Each lecture room is equipped with a computer and with a computer projector. You may also connect your own laptop. Overhead projectors can be provided upon request.

Each regular presentation is 30 minutes including questions. Chairs are requested to keep the session on schedule. Papers should be presented in the order in which they are listed in the program for the convenience of attendees who may wish to switch rooms mid-session to hear particular presentations. In the case of a no-show, please use the extra time for a break or a discussion so that the remaining papers stay on schedule.

Computer Access

Login names and passwords for free Wi-Fi access are distributed with your conference materials. In addition, a small number of PCs will be available in the conference office.

Lunch

Participants are asked to have their own lunches in nearby restaurants. A selection of recommended places is available at the conference desk.

Public Transportation

Your name badge allows you to use the Karlsruhe public transportation system for free from Monday, September 20 to Friday, September 24, 2010.

Social Program

- Sunday, September 19, 18:00 – 21:00 : informal **get-together** in Building 20.13 with light snacks and drinks. The conference desk will be open (however, you may also pick up your conference materials anytime during the conference).
- Tuesday, September 21, 17:15 – 18:30 : **guided city tour**.
- Wednesday, September 22, 13:45 – 19:00 : **excursion** to the black forest.
- Thursday, September 23, 19:00: **conference dinner** in the restaurant *Badische Weinstuben*. We will **meet at 18:45** in building 20.13 and walk to the restaurant together.

The social program is covered by the conference fee.

Post-conference Publications

After a thorough refereeing process, a small number of papers presented at the conference will be published in special issues of two international journals. Details will be announced during the conference.

Program Schedule

Mo	Room	9:00–9:30	9:30–10:30	10:30–11:00	11:00–12:30	12:30–14:30	14:30–16:00	16:00–16:30	16:30–17:30	
	001	Opening Session	Plenary Floudas	Coffee Break	MPECs and Related Topics 1	Lunch Break	Semi-infinite and Bilevel Optimization	Coffee Break	Plenary Pennanen	

Tu	Room		9:00–10:00	10:00–10:30	10:30–12:00	12:00–13:45	13:45–15:15	15:15–15:30	15:30–17:00	17:15–18:30
	001		Plenary Mordukhovich	Coffee Break	MPECs and Related Topics 2	Lunch Break	Robust Optimization	Coffee Break	Theoretical Advances 1	Guided City Tour
	111								Theoretical Advances 2	

We	Room		9:00–10:30	10:30–10:45	10:45–12:15	12:15–13:45	13:45–19:00			
	001		Applications 1	Coffee Break	Semi-infinite Optimization	Lunch Break	Excursion			
	111				Applications 2					

Th	Room		9:00–10:00	10:00–10:30	10:30–12:00	12:00–14:00	14:00–15:30	15:30–16:00	16:00–17:00	19:00
	001		Plenary Outrata	Coffee Break	Metric Regularity and Genericity	Lunch Break	Solution Methods	Coffee Break	Plenary Wächter	Conference Dinner
	111						Applications 3			

Fr	Room		9:00–10:30	10:30–11:00	11:00–12:30	12:30–14:00	14:00–15:00	15:00–15:30		
	001		MPECs and Related Topics 3	Coffee Break	Generalized Semi-infinite Optimization	Lunch Break	Plenary Leyffer	Closing Session		

Monday, 9:00 – 9:30, Room 001

Opening Session

Chair: *Oliver Stein,* Karlsruhe Institute of Technology, Germany

Welcome Address by *Jan-J. Rückmann,* Chair of the Program Committee

Welcome Address by *Horst Hippler,* President of the Karlsruhe Institute of Technology

Welcome Address by *Clemens Puppe,* Dean of the Faculty of Economics and Business Engineering

Organizational Remarks by *Oliver Stein,* Chair of the Organizing Committee

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Monday, 9:30 – 10:30, Room 001

Plenary Christodoulos A. Floudas

Chair: *Oliver Stein,* Karlsruhe Institute of Technology, Germany

Deterministic Global Optimization: Theory, Methods, and Large-Scale Applications

Christodoulos A. Floudas, Princeton University, United States of America

In this presentation, we will provide an overview of the research progress in global optimization. The focus will be on important contributions during the last five years, and will provide a perspective for future research opportunities. The overview will cover the areas of (a) twice continuously differentiable constrained nonlinear optimization, and (b) mixed-integer nonlinear optimization models. Subsequently, we will present our recent fundamental advances in (i) convex envelope results for multi-linear functions, (ii) a piecewise quadratic convex underestimator for twice continuously differentiable functions, (iii) the generalized alpha-BB framework, (iv) extended pooling problems, and (v) generalized pooling problems. Computational studies on medium and large scale global optimization applications will illustrate the potential of these advances.

Monday, 11:00 – 12:30, Room 001

MPECs and Related Topics 1

Chair: *Christian Kanzow,* University of Würzburg, Germany

Necessary Optimality Conditions for Multiobjective Bilevel Programs

Jane Ye, University of Victoria, Canada

The multiobjective bilevel program is a sequence of two optimization problems where the upper level problem is multiobjective and the constraint region of the upper level problem is determined implicitly by the solution set to the lower level problem. In the case where the Karush-Kuhn-Tucker (KKT) condition is necessary and sufficient for global optimality of all lower level problems near the optimal solution, we present various optimality conditions by replacing the lower level problem by its KKT conditions. For the general multiobjective bilevel problem we derive necessary optimality conditions by considering a combined problem where both the value function and the KKT condition of the lower level problem are involved in the constraints.

Optimality Conditions for Bilevel Programming Problems

Stephan Dempe, Technical University Bergakademie Freiberg, Germany

Bilevel programming problems are optimization problems where the feasible set is restricted (in part) by the graph of the solution set mapping of another (parametric) optimization problem, the so-called lower level problem. If the optimal solution of the lower level problem is not unique, the optimistic resp. pessimistic bilevel programming problems are investigated. For deriving optimality conditions for those problems, the lower level problem needs to be replaced with a nonsmooth inequality or a generalized equation. Then, variational analysis can be used to derive the desired conditions. Such results will be presented in the talk.

Strong Stationarity Conditions for Elliptic Mathematical Programs with Equilibrium Constraints

Thomas Surowiec, *Michael Hintermüller*, Humboldt University Berlin, Germany

An elliptic MPEC is a type of infinite dimensional mathematical program in which the solutions of a perturbed elliptic variational inequality make up part of the feasible set. After providing formulae for the contingent derivatives of the normal cone mapping associated with the variational inequality and its solution mapping, we are able to derive an upper approximation of the Fréchet normal cone to the feasible set of the MPEC. This leads to the derivation of dual optimality conditions (similar to so-called S-stationarity conditions in the MPEC literature).

The abstract results are then shown to yield the best known stationarity conditions due to Mignot and Puel for the optimal control of the solutions of the obstacle problem. We then derive explicit strong stationarity conditions for a class of elliptic MPECs arising in the theory of elastoplasticity in which the Euclidean norm of the gradient of the state are pointwise bounded. All necessary cones, e.g., tangent cones, normals cones, etc., are explicitly calculated. Thus, these new results lay the framework for future numerical studies.

Monday, 14:30 – 16:00, Room 001

Semi-infinite and Bilevel Optimization

Chair: *Vladimir Shikhman,* RWTH Aachen University, Germany

Bilevel Optimization: on the Structure of the Feasible Set

Hubertus Th. Jongen, Vladimir Shikhman, RWTH Aachen University, Germany

We consider bilevel optimization from the optimistic point of view. Let the pair (x, y) denote the variables. The main difficulty in studying such problems lies in the fact that the lower level contains a global constraint. In fact, a point (x, y) is feasible if y solves a parametric optimization problem $L(x)$. In this paper we restrict ourselves to the special case that the variable x is one-dimensional. We describe the generic structure of the feasible set M. Moreover, we discuss local reductions of the bilevel problem as well as corresponding optimality criteria. Finally, we point out typical problems that appear when trying to extend the ideas to higher dimensional x-dimensions. This will clarify the high intrinsic complexity of the general generic structure of the feasible set M and corresponding optimality conditions for the bilevel problem U.

SIP: Critical Value Functions have Finite Modulus of Non-Convexity

Dominik Dorsch, Harald Günzel, Hubertus Th. Jongen, RWTH Aachen University, Germany
Francisco Guerra-Vazquez, Universidad de las Américas Puebla, Mexico
Jan-J. Rückmann, University of Birmingham, United Kingdom

We consider semi-infinite programming problems SIP(t) depending on a finite dimensional parameter $t \in \mathbb{R}^p$. Provided that $\bar{x}$ is a strongly stable stationary point of SIP$(\bar{t})$, there exists a locally unique and continuous stationary point mapping $t \mapsto x(t)$. This defines the local critical value function $\varphi(t) := f(x(t), t)$, where $x \mapsto f(x, t)$ denotes the objective function of SIP(t) for a given parameter vector $t \in \mathbb{R}^p$. We show that φ is the sum of a convex function and a smooth function. In particular, this excludes the appearance of negative kinks in the graph of φ.

Convexification of the Lagrangian in Semi-Infinite Programming

Francisco Guerra-Vazquez, Universidad de las Américas Puebla, Mexico
Jan-J. Rückmann, University of Birmingham, United Kingdom

In this lecture we apply two convexification concepts to the Lagrangian of a non-convex semi-infinite programming problem. Under the reduction approach it is shown that, locally around a local minimizer, this problem can be transformed equivalently in such a way that the transformed Lagrangian fulfills saddle point optimality conditions, where the original objective function and the constraints are substituted by their pth powers with sufficiently large power p. These results allow that local duality theory and corresponding numerical methods (e.g. dual search) can be applied to a broader class of non-convex problems.

Monday, 16:30 – 17:30, Room 001

Plenary Teemu Pennanen

Chair: *Ralf Werner,* Hochschule München, Germany

Convex Duality in Stochastic Programming and Mathematical Finance

Teemu Pennanen, Aalto University, Finland

We propose a general duality framework for the problem of minimizing a convex integral functional over a space of stochastic processes adapted to a given filtration. The dualization is obtained by a slight modification of the conjugate duality framework of Rockafellar on optimization problems depending on parameters. Our framework unifies some well-known duality frameworks from operations research and mathematical finance by relaxing the integrability conditions on decision variables and by allowing for more general dualizing parameterizations. The relaxed formulation allows for closing the duality gap in some situations where traditional topological arguments fail.

Tuesday, 9:00 – 10:00, Room 001

Plenary Boris Mordukhovich

Chair: *Marco A. López-Cerdá,* Alicante University, Spain

Set-valued Optimization with Applications to Economics

Boris Mordukhovich, Wayne State University, United States of America

This talk mainly concerns applications of advanced techniques of variational analysis and generalized differentiation to set-valued optimization and economic modeling. We pay special attention to establishing new relationships between multiobjective/set-valued optimization and basic models of welfare economics. The developed variational approach allows us to obtain new optimality conditions for various types of local and global optimal solutions to constrained multiobjective problems and to derive in this way far-going extensions of the so-called second fundamental theorem of welfare economics applied to Pareto/efficient as well as to weak, strict, and strong Pareto optimal allocations of nonconvex economies under certain qualification conditions.

Tuesday, 10:30 – 12:00, Room 001

MPECs and Related Topics 2

Chair: *Wolfgang Achtziger,* University of Erlangen-Nürnberg, Germany

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Regularization Methods for Mathematical Programs with Complementarity Constraints

Tim Hoheisel, Christian Kanzow, Alexandra Schwartz, University of Würzburg, Germany

Mathematical programs with complementarity (or equilibrium) constraints (MPCCs or MPECs for short) form a difficult class of constrained optimization problems. Most standard constraint qualifications are violated at any feasible point. Therefore, more specialized algorithms are typically applied which take into account the particular structure of an MPEC. One of the most popular methods is the regularization scheme by Scholtes. In the meantime, however, there exist a number of different regularization approaches for the solution of MPECs. Here we first give a survey of the existing methods, then we show how the convergence assumptions of these methods can be relaxed, and finally we present a new regularization scheme with very strong global convergence properties.

Mathematical Programs with Equilibrium Constraints: Enhanced Fritz John-Conditions, New Constraint Qualifications and Improved Exact Penalty Results

Christian Kanzow, Alexandra Schwartz, University of Würzburg, Germany

Mathematical programs with equilibrium (or complementarity) constraints (MPECs for short) form a difficult class of optimization problems. The standard KKT conditions are not always necessary optimality conditions due to the fact that suitable constraint qualifications are often violated. Alternatively, one can therefore use the Fritz John-approach to derive necessary optimality conditions. While the usual Fritz John-conditions do not provide much information, we prove an enhanced version of the Fritz John-conditions. This version motivates the introduction of some new constraint qualifications (CQs) which can then be used in order to obtain, for the first time, a completely elementary proof of the fact that a local minimum is an M-stationary point under one of these CQs. We also show how these CQs can be used to obtain a suitable exact penalty result under weaker or different assumptions than those that can be found in the literature.

Relaxed Pessimistic Solutions to MPECs

Michal Červinka, Jiří Outrata, Academy of Sciences of the Czech Republic, Czech Republic

The talk is devoted to the so-called pessimistic version of mathematical programs with equilibrium constraints (MPECs). A local pessimistic solution exists only under rather restrictive assumptions on problem data. We therefore replace the so-called pessimistic value function with its lower-semicontinuous regularization and speak about relaxed pessimistic solutions. We comment on properties of relaxed pessimistic solution and on its role in a new numerical method combining an MPEC solver with a derivative-free optimization method. We also present new subdifferential conditions for pessimistic solutions to MPECs with continuous pessimistic value function.

Tuesday, 13:45 – 15:15, Room 001

Robust Optimization

Chair: *Alexander Mitsos,* Massachusetts Institute of Technology, United States of America

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Costs and Benefits of Robust Optimization

Ralf Werner, Hochschule München, Germany

In recent years the robust counterpart approach, introduced by Ben-Tal and Nemirovski, gained more and more interest among both academics and practitioners. Although being well-established in the meantime it is to some extent unclear, if and what the benefits are when using the robust counterpart formulation. Further, it is not obvious at which costs these benefits come. In one of the earlier papers, Ben-Tal and Nemirovski proved a result for robust linear optimization concerning the costs of the robust formulation. Under slightly stronger assumptions we derive similar results for general robust convex conic programs. Concerning benefits of the robust counterpart we both give a discouraging example for polyhedral uncertainty and a positive result for ellipsoidal uncertainty.

Robust Design Using Semi-Infinite Optimization

Matthew D. Stuber, Paul I. Barton, Massachusetts Institute of Technology, United States of America

The increasing complexity of novel industrial systems, such as subsea oil production, is accompanied by extraordinarily high costs associated with operational failures. The primary objective of a design engineer must be to ensure the proposed system will meet all predetermined performance and safety specifications given limited environmental information and feedback control. In order to make such robustness guarantees, uncertainty in the disturbances to the system must be taken into account. Since this requires that every realization of uncertainty and its affect on the system must be considered, only a model-based numerical approach can be taken. Furthermore, since numerical models describing physical systems are inherently inaccurate, uncertainty in the model parameters must also be taken into account.

In the past, the robustness problem has been formulated as a bilevel optimization problem with the model equations written as equality constraints, and the performance and safety specifications written as inequality constraints. This bilevel formulation is extremely difficult and often impossible to solve for even the simplest systems. In this paper, the model is solved for the state variables as implicit functions of the controls and uncertainty, therefore eliminating functional dependence on them. The robustness problem can then be formulated into an equivalent semi-infinite program (SIP). A new algorithm for solving SIPs with implicit semi-infinite constraints is proposed in this work. Upon solving the implicit SIP, a rigorous 'yes/no' answer to robust feasibility of the physical system is given.

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Optimization Robust to Implementation Errors

Spencer D. Schaber, Paul I. Barton, Massachusetts Institute of Technology, United States of America

Optimization formulations and algorithms have recently been proposed that are robust to implementation errors (Bertsimas et al. (2007, 2009)). In their robust optimization formulation, Bertsimas and coworkers only allow solutions that would be feasible under worst-case implementation errors. Although this is reasonable for some types of decision variables, it is an unnecessary restriction for some optimization problems. We present a novel formulation to solve problems with the type of physical constraint just described, in addition to two other types of constraints that cannot be addressed with the previous formulation. The first type of constraint is relevant when even if the nominal decision variables are chosen such that a constraint is active with zero implementation error, the system is such that a realization of implementation errors will never violate the constraint (e.g., an inlet stream to a chemical process that is controlled by a valve position will never flow backward under reasonable operating conditions). The second type of constraint is relevant when a nominal decision variable must satisfy a constraint (such as bounds on a temperature set point), but implementation errors that take the realized set point out of bounds are acceptable. Both of these constraints are relaxations of the constraints proposed previously by Bertsimas et al, so they have the potential to allow solutions that are better than the optima of the previous formulation.

Tuesday, 15:30 – 17:00, Room 001

Theoretical Advances 1

Chair: *Andreas Fischer,* Dresden University of Technology

Motzkin Decomposable Functions

Miguel A. Goberna, University of Alicante, Spain,
Juan-Enrique Martínez-Legaz, Universitat Autonoma de Barcelona, Spain,
Maxim I. Todorov, Universidad de las Américas Puebla, Mexico

A set is called Motzkin decomposable when it can be expressed as the Minkowski sum of a compact convex set with a closed convex cone. This talk deals with the class of the extended functions whose epigraphs are Motzkin decomposable sets. Any convex lsc proper function which is bounded on a bounded domain is Motzkin decomposable whereas the strictly convex functions do not belong to this class. The main property of these function in the optimization framework is that they attain their global minima when they are bounded from below. The generation of functions of this class from other functions of the same type is also considered.

Source: M.A. Goberna, J.E. Martínez-Legaz, and Maxim I. Todorov, *On Motzkin decomposable sets and functions*, Manuscript.

Operator Splitting Algorithms for Nonconvex Approximation with Poisson Noise

Russell Luke, University of Göttingen, Germany

An important problem in diffraction imaging is the 'phase retrieval problem' whereby an object is recovered by its diffraction image. Mathematically one seeks to recover a function from the magnitude of its Fourier transform. This is a well-known nonconvex inverse problem which is easily solved numerically via operator splitting algorithms such as alternating projections. A complete mathematical analysis of these algorithms has proven elusive for the phase problem. We present the key analytical roadblocks facing any analysis of the phase problem. To this we add the further difficulty that the data is corrupted by Poisson noise. We present an approach to efficiently approximating Bregman projections appropriate for such a noise model.

Some Remarks On SDP and CP Programming Relaxations

Georg Still, University of Twente, The Netherlands

We consider semidefinite (SDP) and completely positive (CP) programming relaxations of integer and (non-convex) quadratic programs. In a paper of Kojima/Tuncel (2000) a comparison between the feasible sets of a quadratic program and its SDP relaxation is given. We comment on these results and present a (partial) generalization to the case of CP relaxations. We finally discuss the formulation of SDP and CP programs as a semi-infinite problem.

Tuesday, 15:30 – 16:30, Room 111

Theoretical Advances 2

Chair: *Marios Kotsonis,* Delft University of Technology, The Netherlands

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Parametric Strategy for Finding Feasible Points in Quadratic Programs

Ridelio Miranda, Universidad de Cienfuegos, Cuba,
Jürgen Guddat, Humboldt University Berlin, Germany,
Sira Allende, Universidad de La Habana, Cuba

We introduce a parametric strategy for the calculation of a feasible point of a non-convex set which is defined by the intersection of a polyhedron and a quadratic function. The strategy consist on the embedding of the original set in a family of one-parametric optimization problems $P(t)$, which will be solved using pathfollowing method and jumps. The problem $P(t)$ is formulated such that from the solution of $P(t)$ for $t = 1$ it is easy to obtain a solution for the defined problem. Finally we present an illustrative example for the application of the strategy and the application to the solution of quadratic programming problems.

An SQP Method for Worst-Case Robust Optimal Control Problems

Frank Schmidt, Chemnitz University of Technology, Germany

We consider the worst-case scenario for optimal control problems with uncertain parameters, i.e. $\min_{u \in U_{\text{ad}}} \max_p f(u,p)$. This results in an infinite dimensional bilevel optimization problem. The existence of a solution is shown. Moreover for a convex-concave function f the problem is reformulated into a mathematical program with complementarity constraints and an SQP method is utilized to solve it.

Overcoming Computational Complexity in Nonlinear Optimization

Sadik Olaniyi Maliki, Ebonyi State University Abakaliki, Nigeria

In this work we show how to overcome computational complexity when dealing with nonlinear optimization problems. We consider in particular a nonlinear objective function involving four variables to be maximized subject to four nonlinear equality constraints.

We employ the method of Lagrange multipliers. The first order optimality conditions provide us with the critical values of the problem, while the second order condition is given by the so called Bordered Hessian Matrix. In order to determine the nature of the critical points and because of the large size of the matrix, the numerics is implemented with MathCAD software which proves to be very efficient.

Wednesday, 9:00 – 10:30, Room 001

Applications 1

Chair: *Lialia Nikitina,* Fraunhofer Institute for Algorithms and Scientific Computing, Germany

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Parametric Shape Optimization for Aircraft Design

Michiel Straathof, Delft University of Technology, The Netherlands

This work will explain the application of a novel parametrization technique to the optimization of aircraft shapes. This Class-Shape-Refinement Transformation (CSRT) technique combines an analytical function (class function), a set of Bernstein polynomials (shape function) and a B-spline (refinement function) and can be used to model various aircraft components. It allows for both local and global control of the shape and therefore forms a very efficient and intuitive way of mathematically describing aircraft parts. A parametric study will be presented that shows the behavior of the shape as a function of a number of different parameters, such as total number of shape variables and Bernstein/B-spline coefficient ratio. The CSRT method was used to approximate a typical aircraft wing and the results showed a very non-linear relationship between the number of shape variables and the error of the approximation, expressed in terms of a correlation factor. This behavior and the methodology behind the approximation process will be thoroughly investigated and explained in the forthcoming paper. Additionally, optimization results will be presented that show that the CSRT method was successfully coupled to different aerodynamic flow solvers. The objective function of the optimization runs was the lift-to-drag ratio, but in principle any objective function could be used as long as its input follows from the aerodynamic analysis. It will be shown that the optimization algorithm is capable of completely removing the shock wave on a wing in typical cruise conditions.

Parametric Optimization in Aerospace Engineering Using Interval Analysis

Hui Yu, Durk Steenhuizen, Delft University of Technology, The Netherlands

Optimization algorithms based on interval analysis are presented to solve parametric optimization problems that are arising in the field of aerospace engineering, including airfoil shape optimization, aircraft arrival trajectory optimization and so on. In such optimization problems, there are always system parameters that fall into a small region of interest and design variables that vary to give different values to the cost function.

In interval analysis, discrete numbers are replaced by closed finite intervals of arbitrary size. Interval algebra is used to transform traditional discrete value functions and operations into their interval counterparts. Because of the logical induction that is used in interval algebra, treating an interval mathematically is analogous to treating each individual number in the interval's set. By applying interval analysis to optimization, the whole domain of design variables can be split into a finite number of sub-intervals. By applying interval algebra the interval containing the optimum is found and reduced in size until the required accuracy is obtained. Because interval algebra in effect considers every number in the design variable domain, the found optimum is always the global optimum to the given optimization problem. In the full paper, the principles of such algorithms will be presented and an example will be given to demonstrate their applicability.

In certain optimization problems, some system parameters may vary between specified lower and upper bounds. With conventional optimization algorithms, it is impossible to cover all the possibilities of these parameters that are enclosed by the lower and upper bounds because the number of the sampled points is always limited. With interval-related optimization algorithms, however, each of such parameters can be represented by an interval with the specified lower and upper bounds as its infimum and supremum. In the process of optimization, these intervals remain constant while the interval for the design variables are split and eliminated until the global minimum value of the cost function is returned. Two simple examples about airfoil shape optimization and aircraft arrival trajectory optimization will be given in the full paper.

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Investigation of Surrogate Model Based Structural Design Optimization

Qian Xu, Horst Baier, Erich Wehrle, Xinxue Xu, University of Technology, Munich, Germany

The most attractive advantage of surrogate model (or metamodel) for engineers is that it can greatly release computation expense for solving large iterations of FEM or CFD simulators of system response. The essential ambitions of surrogate modeling are high efficiency and accuracy. To achieve this goal, efforts are made in three aspects.

One is adaptive sampling strategy aims at minimize sample size and maximize information from existed samples. Second is optimizing metamodels to get the best goodness of fit. One way is to choose the best surrogate methods from Kriging, Radial Basis Function (RBF), Artificial Neural Networks (ANN), Support Vector Machine (SVM), and corresponding variants of them, also to find the best combination of sampling and modeling strategy. Another is to optimize metamodel parameters, which is called hyperparameter optimization. The third is to develop a good Surrogate Based Design Optimization (SBDO) frame. There are three basic approaches: sequential, adaptive optimization and direct sampling. Besides, a proper loop can be designed, where low fidelity and high fidelity metamodels can be used interactively to balance time and computer expense with model accuracy.

In this paper a Probability of Improvement and Indirect Gradient enhanced adaptive sampling strategy is designed. Different metamodels are tested and compared to validate the strategy and to search for a good combination as a solution. Numerical tests are carried out on different problem sizes ranging from smaller scale mathematical test functions over midsize to larger size structural optimization problems like an aircraft wing design optimization problem, which provide vigorous proof of the efficiency of the designed strategies.

Wednesday, 10:45 – 12:15, Room 001

Semi-infinite Optimization

Chair: *Miguel A. Goberna*, University of Alicante, Spain

New Formulae for the Subdifferential of the Supremum of an Arbitrary Family of Extended Real-valued Functions

Marco A. López-Cerdá, Alicante University, Spain
Michel Volle, University of Avignon, France

We provide new formulae for the subdifferential of the supremum of an arbitrary family of extended real-valued functions, in terms of the approximate subgradients of 'well chosen convex combinations of the data functions'. The data functions are neither convex nor lower semicontinuous, but in this approach we assume that the supremum of the second conjugates of the data functions is proper and coincides with the second conjugate of the supremum function. Some applications of the main formula are provided. In particular, new formulas are given for the subdifferential of the closed convex hull of an extended real-valued function, as well as for the corresponding set of minimizers. We also get a generalization of a well-known formula established by Hiriart Urruty and Phelps.

Polyhedral Cells of a Voronoi Diagram

Ina Voigt, Anadeo Consulting GmbH, Germany
Stephan Weis, University of Erlangen-Nürnberg, Germany

We identify a cell of a Voronoi diagram, i.e. a nearest neighbor region, with the feasible set of a semi-infinite system. Utilizing a theorem from the theory of semi-infinite programming, we investigate the geometry of a Voronoi cell. We prove that a Voronoi cell of an infinite discrete point set is polyhedral if and only if its corresponding characteristic cone is a polyhedron. This connects computational geometry with semi-infinite optimization.

On Topological Properties of Min-Max Functions

Dominik Dorsch, Hubertus Th. Jongen, Vladimir Shikhman, RWTH Aachen University, Germany

We examine the topological structure of the upper-level set M^{max} given by a min-max function φ. It is motivated by recent progress in Generalized Semi-Infinite Programming (GSIP). Generically, M^{max} is proven to be the topological closure of the GSIP feasible set. We formulate two assumptions (Compactness Condition CC and Sym-MFCQ) which imply that M^{max} is a Lipschitz manifold (with boundary). The Compactness Condition is shown to be stable under C^0-perturbations of the defining functions of φ. Sym-MFCQ can be seen as a constraint qualification in terms of Clarke's subdifferential of the min-max function φ. Moreover, Sym-MFCQ is proven to be generic and stable under C^1-perturbations of the defining functions which fulfill the Compactness Condition. Finally we apply our results to GSIP and conclude that generically the closure of the GSIP feasible set is a Lipschitz manifold (with boundary).

Wednesday, 10:45 – 12:15, Room 111

Applications 2

Chair: *Frank Schmidt,* Chemnitz University of Technology, Germany

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Parametric Optimization of Bulky Data and its Application in Automotive Design

Lialia Nikitina, Igor Nikitin, Tanja Clees, Fraunhofer Institute for Algorithms and Scientific Computing, Germany

One important task in mechanical engineering is to increase the safety of a vehicle and decrease its weight. The safety criteria depend on the thickness of components, while the weight influences fuel consumption, CO_2 emission and production cost. This typical multiobjective optimization task can be solved by formal methods, considering a mapping from the space of design variables to the space of target criteria and identifying its Pareto front. Due to the high computational cost of numerical simulations, the sampling of this mapping is usually very sparse. Using a proper design of experiments and metamodeling, one can replace numerical simulations by interpolated data. Cross-validation methods can control the precision of such representation. Efficient compression methods and rapid interpolation techniques allow to consider distributed optimization criteria, e.g. to interpolate the whole bulky simulation result for detailed inspection of optimal design. Sensitivity of optimization criteria to perturbation of design parameters can be computed and used to study a propagation of uncertainties through the mapping.

The methods described above have been integrated into our design-parameter optimization tool DesParO, which has successfully been applied to a number of real life optimization problems in automotive design. We discuss novel developments, particularly for handling ensembles of bulky simulation results, and demonstrate their efficiency for industrial benchmark cases.

Viscosity Solution of Hamilton-Jacobi-Bellman Equation in Economic Growth Model

Azizul Baten, Anton Abdulbasah Kamil, Universiti Sains Malaysia, Malaysia

The paper studied the stochastic optimization problem in the context of one sector neoclassical growth model with the Cobb-Douglas production function maximizing the expected discounted utility of consumption. We transformed the Hamilton-Jacobi-Bellman equation associated with the stochastic optimization problem so as to reduce the dimension of the state space by changing the variables. By the viscosity solution method, we established the existence of viscosity solution to the transformed Hamilton-Jacobi-Bellman equation.

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Optimal f-divergence Information Measures under Certain Constraint

G. R. Mohtashami Borzadaran, Yahya Mohtashami, Ferdowsi University of Mashhad, Iran

After Shannon (1948), lots of extensions in view of the Shannon entropy are obtained. Among them, information f-divergence measures are often useful for comparing two probability distributions. For a convex function $f : \mathbb{R}^+ \to \mathbb{R}$, the Csiszar f-divergence between two probability distributions $p(.)$ and $q(.)$ is defined as

$$C_f(p,q) = \sum_x q(x) f\left(\frac{p(x)}{q(x)}\right).$$

Most of the famous information measures are special cases of this divergence. We will obtain some properties of C_f in view of the weighted distributions for weights such as order statistics, record values, proportional hazard and reversed proportional hazard rate.

Based on the Shannon entropy idea, Kagan et al. (1973) showed that every probability distribution is the unique maximizer of the relative entropy in an appropriate class of pdf's (or pmf) under certain constraint via a variant of the Lagrange multiplier method. We have achieved under certain constraint the maximizer entropy probability distribution via a Matlab program and extended this to Maximum Renyi entropy also.

We have obtained the distribution that is optimized the f-divergence under the certain constraint and discussed various optimal special cases of this measure such as Kullback Leibler information, χ^2-divergence, total variation, squared perimeter distance, symmetric χ^2-divergence and directed divergence. Finding the optimal measures theoretical and via Matlab programs for various measures and for the most of the famous distributions are also the novelty of this work.

Thursday, 9:00 – 10:00, Room 001

Plenary Jiří Outrata

Chair: *Jane Ye,* University of Victoria, Canada

Dual-space Methods in Analysis and Solution of Equilibrium Problems

Jiří Outrata, Academy of Sciences of the Czech Republic, Czech Republic

The lecture deals with three types of parameterized equilibrium problems governed by generalized equations in which non-polyhedral multifunctions arise. In this way one can model, for instance, discretized contact problems with various types of friction on the contact surface. The main attention is focused on analysis of local behavior of solution maps which assign solution sets of the respective generalized equations to the parameter. To this end we employ standard tools of generalized differential calculus along with some new results, specially tailored to this model. These tools are used to describe the solution maps via the so-called limiting coderivatives. They enable us, among others, to provide characterizations or sharp sufficient criteria for a robust stability of solution sets with respect to the parameter around a reference point. Furthermore they can also be used to compute Clarke's subgradients of composite objectives which may arise in optimization problems, where the considered generalized equations represent an equilibrium constraint. This enables us to compute solutions of these optimization problems via bundle methods in an efficient way. In the application part of the lecture we will use the obtained results to achieve qualitative statements about the Lipschitzian behavior of solutions to a class of variational inequalities with non-polyhedral constraint sets. Moreover, they will be applied to the numerical solution of a 3D shape optimization in a discretized contact problem with Coulomb friction.

Thursday, 10:30 – 12:00, Room 001

Metric Regularity and Genericity

Chair: *Harald Günzel,* RWTH Aachen University, Germany

Metric Regularity of Newton's Iteration

Francisco J. Aragón Artacho, University of Alicante, Spain,
Asen L. Dontchev, National Science Foundation, Ann Arbor, United States of America,
Michaël Gaydu, Michel H. Geoffroy, Université des Antilles et de la Guyane, France,
Vladimir M. Veliov, Vienna University of Technology, Austria

For a version of Newton's method applied to generalized equations with a parameter, we extend the paradigm of the Lyusternik-Graves theorem to the framework of a mapping acting from the pair 'parameter - starting point' to the set of all associated convergent Newton's sequences. Under ample parameterization, the metric regularity of the mapping associated with convergent Newton's sequences becomes equivalent to the metric regularity of the generalized equation mapping.

First and Second-order Characterizations for Metric Subregularity of Smooth Constraint Set Mappings

Helmut Gfrerer, Johannes Kepler University Linz, Austria

Metric subregularity of constraint set mappings (or equivalently, the calmness of the inverse mapping) is an important constraint qualification for ensuring existence of non-degenerate multipliers, exact penalization and for providing error bounds. In this talk we present characterizations of calmness/subregularity. We will see that there are some limitations when using exclusively first-order analysis, which can be bypassed assuming some part of the constraint mapping to be known subregular or by using second-order analysis.

Generic Existence of Solutions in Parametric Optimization

Alexander Zaslavski, The TEchnion-IIT, Israel

In this talk we consider a parametric family of the minimization problems on a complete metric space X with a parameter b which belongs to a Hausdorff compact space B. This parametric family is identified with a complete metric space of functions on $B \times X$. Using the generic approach and the porosity notion we show that for most functions the corresponding minimization problems have a solution for all parameters b from B. These results and their extensions are obtained as realizations of abstract variational principles.

Thursday, 14:00 – 15:30, Room 001

Solution Methods

Chair: *Tim Hoheisel,* University of Würzburg, Germany

Parametric Optimization and Nonsmooth Newton Schemes for Special $C^{1,1}$ Programs

Stephan Bütikofer, Zürich University of Applied Sciences, Switzerland,
Eleftherios Couzoudis, Diethard Klatte, University of Zürich, Switzerland

We consider nonlinear programs with twice continuously differentiable constraints and an objective function f which is the optimal or critical value function of a parametric nonlinear program. Under certain regularity assumptions, f belongs to a special class of $C^{1,1}$ functions. Such models appear e.g. in the context of decomposition procedures, generalized Nash equilibrium problems and other subjects. In the design and convergence analysis of generalized Newton methods for solving this problem, one has to be able to describe the generalized Newton equation or the Gauss-Newton step for path computation in an implementable form. For this we give the representation of certain second-order directional derivatives of f and link results on the sensitivity analysis of parametric nonlinear programs to the computation of Newton schemes and the convergence analysis of a related solution method.

Upper Lipschitz-Continuity Related to Constrained Least-Squares Problems

Andreas Fischer, Roger Behling, Dresden University of Technology, Germany

The problem of solving a nonlinear system of equations and convex inequalities can be reformulated as the minimization of the Euclidean residual of the equations subject to the inequality constraints. The necessary optimality conditions for this minimization problem are equivalent to a generalized equation. The solution set map belonging to the (simply) perturbed generalized equation is considered. Given an error bound condition for the original problem it will be shown that the solution set map is locally upper Lipschitz-continuous. An application of this result to the local analysis of Levenberg-Marquardt methods will be presented as well.

Convergence Results for a Self-dual Regularization of Convex Problems

Alvaro Guevara, Frankfurt University, Germany
Peter Wolenski, Louisiana State University, United States of America

We study a one-parameter regularization technique for convex optimization problems, which has as its main feature its self-duality with respect to the usual convex conjugation. The technique, introduced by Goebel, can be defined for both convex and saddle functions. When applied to the latter, we show that if a saddle function has at least one saddle point, then the sequence of saddle points of the regularized saddle functions converges to the saddle point of minimal norm of the original one. For convex problems with inequality and state constraints, we apply the regularization directly on the objective and constraint functions, and show that, under suitable conditions, the associated Lagrangians of the regularized problem hypo/epi-converge to the original Lagrangian, and that the associated value functions also epi-converge to the original one. Finally, we find explicit conditions ensuring that the regularized sequence satisfies Slater's condition.

Thursday, 14:00 – 15:00, Room 111

Applications 3

Chair: *Michiel Straathof,* Delft University of Technology, The Netherlands

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Optimization of an Array of Plasma Actuators for Drag Reduction

Marios Kotsonis, Michiel Straathof, Delft University of Technology, The Netherlands

In recent years plasma actuators have been applied in several flow control applications. Their robustness and efficiency renders them ideal for applications such as separation control, transition delay and turbulent drag reduction. Plasma actuators consist of two electrodes separated by a dielectric layer. By applying an AC High Voltage between the two electrodes an intense electric field is formed, air is ionized and plasma is formed. Due to collision processes between the plasma and neutral air, momentum is transferred to the flow. This can be macroscopically perceived as spatially distributed body-force acting on the fluid.

This paper deals with the parameterization and optimization of an array of these actuators placed on a flat plate with external turbulent flow. By optimizing the distance between the actuators and the intensity of actuation the near-wall shear stress of the flow is manipulated in such way that the local skin-friction coefficient is reduced. This work involves the numerical investigation of this setup and its coupling to an optimizer. For the flow solution an CFD approach is followed while for implementing the actuator body-force experimental data have been used. The design space consists of the normalized magnitude of the body-force of each actuator as well as their chord wise position. The objective functions are the minimization of the total skin friction coefficient and the local displacement thickness of the boundary layer. Constraints involve the minimum distance between the actuators and maximum power consumption.

Initial results show minimization of skin friction coefficient which lead to friction would drag reduction with relatively moderate increase of displacement thickness which would lead to increase in pressure drag. In projecting the results on a true airfoil flow the gain in skin friction drag appears to be more than the loss in pressure drag.

Multicriteria Optimization and Decision Support for Chemical Plant Design

Richard Welke, Karl-Heinz Küfer, Anton Winterfeld, Fraunhofer Institut für Techno- und Wirtschaftsmathematik ITWM, Germany,
Norbert Asprion, BASF SE, Germany,
Hans Hasse, Technical University of Kaiserslautern, Germany

Due to conflicting objectives and high construction costs of chemical plants, multicriteria optimization has great potential for chemical engineering. Efficient computation of Pareto sets for chemical plants is difficult due to the underlying complex model. Since real-time computation is out of scope, we divide the process into two phases. In a precomputation phase, we generate a reasonable number of Pareto-optimal solutions. In the navigation phase, the chemical engineering expert uses a decision support tool to find a best trade-off among the Pareto-optimal solutions. Here, interpolation allows us to compute intermediate solutions to approximate a continuous Pareto set in moderate time.

Interpolation is not the only way to speed up computations. We show a perspective for additional speed up by integrating model reduction methods combined with rigorous error control into the optimization. As numerical results, we present a study on interpolation error for the multicriteria optimization of a basic distillation process.

Thursday, 16:00 – 17:00, Room 001

Plenary Andreas Wächter

Chair: *Georg Still,* University of Twente, The Netherlands

Large-Scale Nonlinear Optimization with Inexact Step Computations

Andreas Wächter, IBM TJ Watson Research Center, United States of America

Interior point methods have shown to be very efficient in solving large-scale nonlinear optimization problems with up to millions of variables. In most cases, the predominant part of the computation time is spent in solving sparse linear systems to obtain the search directions. In certain applications, such as problems involving discretized 3D PDEs in the constraints, a direct factorization of the matrix leads to a lot of fill-in, resulting in excessive computation time.

In those circumstances, algorithms that can make use of inexact solutions of the linear systems computed by iterative linear solvers can be much more efficient. While ensuring convergence of inexact Newton methods is straight-forward when solving nonlinear systems of equations, the possible presence of nonconvexity and degeneracy in an optimization problem require special attention. We present an algorithm that uses carefully designed termination tests for the inexact linear solver, so that global convergence can be proved under mild assumptions.

The practical performance of the method is demonstrated on 3D PDE-constrained optimization examples. The algorithm is implemented in the Ipopt open-source optimization framework, using the Pardiso linear solver library.

In collaboration with Frank Curtis, Johannes Huber, and Olaf Schenk.

Friday, 9:00 – 10:30, Room 001

MPECs and Related Topics 3

Chair: *Stephan Dempe,* Technical University Bergakademie Freiberg, Germany

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On Problems of Structural Optimization with Singular Stiffness Matrices

Wolfgang Achtziger, University of Erlangen-Nürnberg, Germany,
Christoph Schürhoff, Dortmund University of Technology, Germany

We consider a simple class of mathematical programs arising in the field of structural optimization and material optimization. The central equations in these programs are the (usual) equilibrium conditions linking the control (resp. design) variables with the state variables in a finite element context. Contrary to standard formulations, in our applications the stiffness matrix may become singular (and will be singular at an optimizer). This causes the break-down of known constraint qualifications, standard numerical solution algorithms etc. The talk briefly addresses a few typical situations. Nevertheless, certain continuity properties can be proved for the relation of design and state variables when the stiffness matrix becomes singular. These results may be used to prove that standard optimality conditions hold at optimizers although a constraint qualification is not satisfied.

Mathematical Programs with Vanishing Constraints

Tim Hoheisel, Christian Kanzow, University of Würzburg, Germany

A mathematical program with vanishing constraints (MPVC) is an optimization problem with important applications in the field of topology optimization. Due to the combinatorial nature in the constraints, an MPVC is likely to violate most of the prominent regularity conditions, including the Abadie constraint qualification, e.g. Hence, more problem tailored conditions are investigated. Moreover, an exact penalty result is stated and used to derive necessary optimality conditions. In addition to that, a numerical procedure for the solution of MPVCs that uses regularization ideas is introduced and convergence results are given.

MPVC: Critical Point Theory

Dominik Dorsch, Vladimir Shikhman,, RWTH Aachen University, Germany,
Oliver Stein, Karlsruhe Institute of Technology, Germany

We study mathematical programs with vanishing constraints (MPVC) from a topological point of view. We introduce the new concept of a T-stationary point for MPVC. Under the Linear Independence Constraint Qualification (LICQ) we derive an equivariant Morse Lemma at nondegenerate T-stationary points. Then, two basic theorems from Morse Theory (deformation theorem and cell-attachment theorem) are proved. Outside the T-stationary point set, continuous deformation of lower level sets can be performed. As a consequence, the topological data (such as the number of connected components) then remain invariant. However, when passing a T-stationary level, the topology of the lower level set changes via the attachment of a q-dimensional cell. The dimension q equals the stationary T-index of the (nondegenerate) T-stationary point. The stationary T-index depends on both the restricted Hessian of the Lagrangian and the number of bi-active vanishing constraints. Further, we prove that all T-stationary points are generically nondegenerate. The latter property is shown to be stable under C^2-perturbations of the defining functions. Finally, some relations with other stationarity concepts, such as strong, weak, M-stationarity, are discussed.

Friday, 11:00 – 12:30, Room 001

Generalized Semi-infinite Programming

Chair: *Diethard Klatte,* University of Zürich, Switzerland

Relaxation-based Bounds for GSIPs

Vincent Weistroffer, *Alexander Mitsos,* Massachusetts Institute of Technology, United States of America

Finite formulations are presented for the calculation of lower and upper bounds on the optimal solution value of generalized semi-infinite programs (SIPs). These results built upon the methods developed in [1], which are similar to [2] and based on [3]. The main idea is that a relaxation of the lower-level program results in a restriction of the GSIP and a restriction of the lower-level program leads to a relaxation of the GSIP. Numerical results using the test set in [4] are presented. Global optimization of GSIPs using the bounding scheme is considered. The proposed method performs favorably compared to existing algorithms in several numerical results.

[1] A. Mitsos, P. Lemonidis, C. K. Lee, and P. I. Barton. Relaxation-Based Bounds for Semi-Infinite Programs. SIAM Journal on Optimization, 19(1):77-113. 2008.

[2] C. A. Floudas and O. Stein, The adaptive convexification algorithm: A feasible point method for semi-infinite programming, SIAM Journal on Optimization, 18(4):1187-1208. 2007.

[3] B. Bhattacharjee, W. H. Green Jr. and P. I. Barton, Interval methods for semi-infinite programs, Computational Optimization and Applications, 30(1): 63-93. 2005

[4] P. Lemonidis, Global Optimization Algorithms for Semi-Infinite and Generalized Semi-Infinite Programs, PhD thesis, Massachusetts Institute of Technology, 2008.

General Semi-Infinite Programming: Critical Point Theory

Vladimir Shikhman, *Hubertus Th. Jongen*, RWTH Aachen University, Germany

We study General Semi-Infinite Programming (GSIP) from a topological point of view. Under the Symmetric Mangasarian-Fromovitz Constraint Qualification (Sym-MFCQ) two basic theorems from Morse theory (deformation theorem and cell-attachment theorem) are proved. Outside the set of Karush-Kuhn-Tucker (KKT) points, continuous deformation of lower level sets can be performed. As a consequence, the topological data (such as the number of connected components) then remain invariant. However, when passing a KKT level, the topology of the lower level set changes via the attachment of a q-dimensional cell. The dimension q equals the so-called GSIP-index of the (nondegenerate) KKT-point. Here, the Nonsmooth Symmetric Reduction Ansatz (NSRA) allows to perform a local reduction of GSIP to a Disjunctive Optimization Problem. The GSIP-index then coincides with the stationary index from the corresponding Disjunctive Optimization Problem.

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A New Bi-level Method for GSIP Using Entropic Regularization

Jan Schwientek, Karl-Heinz Küfer, Anton Winterfeld, Fraunhofer Institut für Techno- und Wirtschaftsmathematik ITWM, Germany

We introduce a new numerical solution method for general semi-infinite optimization problems with convex-valued index set mappings. The method is based on the smoothing of the index set mappings via entropic functions resulting in a parameterized *GSIP* and its reformulation as a parametric Stackelberg game. This approach leads to bi-level problems with non-degenerate global solutions of the lower level problems. The solution of the original *GSIP* then amounts to solving these parameterized regular Stackelberg games and driving the regularization parameter to infinity.

Our approach is closely related to the numerical *GSIP* method proposed by Stein and Still (SIAM J. Control Optim. 42:769-788, 2003). We compare both approaches in terms of convergence properties, numerical complexity, and geometric approximation properties. In fact it turns out that a similar modification like the one used by Winterfeld in (Feasible Method for Generalized Semi-Infinite Programming, J. Optim. Theory Appl., 2010) can be applied to the new approach to achieve an inner approximation property.

Finally, we give some numerical examples of two real-world applications: gemstone cutting and radio frequency ablation.

Friday, 14:00 – 15:00, Room 001

Plenary Sven Leyffer

Chair: *Jan-J. Rückmann,* University of Birmingham, United Kingdom

MINOTAUR: A Next-Generation Mixed-Integer Nonlinear Optimization Solver

Sven Leyffer, Argonne National Laboratory, United States of America

Mixed-integer nonlinear optimization problems arise in a range of scientific and operational applications, ranging from the re-ordering of nuclear fuel rods to the design of wireless networks. We present some novel mixed-integer nonlinear optimization applications, and review existing solution techniques.

We present a new package for solving mixed-integer nonlinear optimization problems, called MINOTAUR. MINOTAUR implements a range of branch-and-cut algorithms within a flexible object-oriented framework. We will comment on some software design issues and describe some recent work on tighter integrating nonlinear solvers into a branch-and-cut framework.

Friday, 15:00 – 15:30, Room 001

Closing Session

Chair: *Jan-J. Rückmann,* University of Birmingham, United Kingdom

Farewell

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