Online-Workshop

ASIP-2021

Applications of Semi-Infinite Optimization

May 20 & 21, 2021

Division Optimization of Fraunhofer ITWM
&
Chair for Continuous Optimization at IOR, KIT

Programme – Abstracts – Participants

Aim of the Workshop

Semi-infinite optimization, i.e., the solution of optimization problems with infinitely many constraints (SIP), has been intensively studied over the last decades. The progress of computer technology has enhanced SIP methodology significantly. On the one hand, solution methods for this problem class have been increasingly developed and refined. On the other hand, high-dimensional problems, as they often occur in practice, have become numerically tractable. As a result, the range of possible applications has evolved considerably and semi-infinite optimization has been increasingly applied to practical problems in recent years.

In addition to the standard applications of semi-infinite optimization such as model approximation, design centering, robust optimization, and optimal control, SIP techniques have been recently used in machine learning, design of experiments, coverage issues and mixed stochastic-robust optimization. Thereby, SIP methods have been applied in application areas such as product portfolio optimization and process engineering.

The two-day workshop provides the opportunity to discuss and promote the use of semi-infinite optimization in practice with outstanding international scientists and application experts.

Yours sincerely,

Prof. Dr. Karl-Heinz Küfer
(Fraunhofer ITWM, Kaiserslautern)

Prof. Dr. Oliver Stein
(Karlsruhe Institute of Technology KIT)

Programme

Thursday, 20th May 2021		
Time	**(CEST)**	
9:00	9:30	**Opening:** Prof. Dr. Karl-Heinz Küfer (ITWM), Prof. Dr. Oliver Stein (KIT) (incl. organizational and technical instructions)
		SESSION TH-1 "SIP & Machine Learning" **Session chair: Karl-Heinz Küfer**
9:30	10:15	**Semi-infinite Optimization in Machine Learning** Prof. Dr. Süreyya Akyüz, Bahçeşehir University Istanbul, Turkey
10:15	10:30	**Semi-infinite optimization for shape-constrained regression** Dr. Jochen Schmid, Fraunhofer ITWM
10:30	10:45	**Obtaining Optimal Experimental Designs via Semi-Infinite Optimization and Gaussian Process Regression** Philipp Seufert, Fraunhofer ITWM
10:45	11:00	Coffee break (in socializing tool)
		SESSION TH-2 "SIP & Optimization under Uncertainties I (Robust Optimization)" **Session chair: Alexander Mitsos**
11:00	11:45	**Non, je ne regrette rien** Prof. Dr. Ralf Werner, University of Augsburg
11:45	12:15	**On the epigraphical reformulation of uncertain multiobjective optimization problems** Dr. Ernest Quintana, TU Ilmenau
12:15	12:30	**The concept of inverse robustness and a semi-infinite solution approach** Holger Berthold, Fraunhofer ITWM
12:30	13:30	Lunch*
		SESSION TH-3 "SIP & Optimal Control I / Engineering" **Session chair: Ralf Werner**
13:30	14:15	**Contingency Screening for Power Grids Using Existence-Constrained Semi-Infinite Programs** Prof. Dr. Alexander Mitsos, RWTH Aachen
14:15	14:45	**Semi-Infinite Programming yields Optimal Disturbance Model for Offset-Free Nonlinear Model Predictive Control** Dr. Adrian Caspari, RWTH Aachen
14:45	15:15	**Designing optimal product portfolios with semi-infinite programming** Dr. Helene Krieg, Fraunhofer ITWM
15:15	15:45	Coffee break (in socializing tool)
		SESSION TH-4 "SIP Methods I - Variational Principles" **Session chair: Sürreya Akyüz**
15:45	16:15	**On semi-infinite reformulations for equilibrium selection** Prof. Dr. Oliver Stein, Karlsruhe Institute of Technology KIT
16:15	16:45	**Algorithms for generalized Nash games in semi-infinite optimization** Prof. Dr. Giancarlo Bigi, University of Pisa, Italy
16:45	17:15	**Ekeland type variational principle for set-valued maps in quasi-metric spaces with applications** Dr. Pradeep Kumar Sharma, University of Delhi, India
17:15	17:45	Closing break (in socializing tool)
19:30	22:00	**Virtual social event (speakers only, sponsored by Division Optimization, Fraunhofer ITWM)**

Time	(CEST)	Friday, 21st May 2021
8:30	8:45	**Opening:** Prof. Dr. Karl-Heinz Küfer (ITWM), Prof. Dr. Oliver Stein (KIT)
		SESSION FR-1 "SIP & Optimal Control II / Uncertainties" **Session chair: Oliver Stein**
8:45	9:30	**A Stochastic Maximum Principle for a Markov Regime-Switching Jump-Diffusion Model with Delay and an Application to Finance** Prof. Dr. Gerhard-Wilhelm Weber, Poznan University of Technology, Poland
9:30	10:00	**On the turnpike property for optimal control problems with dynamic probabilistic constraints** Prof. Dr. Martin Gugat, FAU Erlangen-Nürnberg
10:00	10:30	**Adaptive bundle methods for nonlinear robust optimization** Prof. Dr. Michael Stingl, FAU Erlangen-Nürnberg
10:30	10:45	Coffee break (in socializing tool)
		SESSION FR-2 "SIP & Optimization under Uncertainties (Stochastic Optimization)" **Session chair: Gerhard-Wilhelm Weber**
10:45	11:30	**Dealing with Probust Constraints in Stochastic Optimization** PD Dr. René Henrion, WIAS Berlin
11:30	12:00	**An algorithmic approach for solving optimization problems with probabilistic/robust (probust) constraints** Dr. Holger Heitsch, WIAS Berlin
12:00	12:30	**Problem-based scenario generation for two-stage stochastic programs using semi-infinite optimization** Prof. Dr. Werner Römisch, HU Berlin
12:30	13:30	Lunch*
		SESSION FR-3 "SIP Methods II" **Session chair: René Henrion**
13:30	14:00	**A primal-dual algorithm for semi-infinite programming** Dr. Bhagwat Ram, Banaras Hindu University, Varansai, India
14:00	14:30	**A transformation-based discretization method inspired by and applied to gemstone cutting** Dr. Jan Schwientek, Fraunhofer ITWM
14:30	15:00	**A quadratic convergent adaptive discretization method: quADAPT** Dr. Tobias Seidel, Fraunhofer ITWM
15:00	15:30	**Closing:** Prof. Dr. Karl-Heinz Küfer (ITWM), Prof. Dr. Oliver Stein (KIT)
15:30		End of the workshop

* socializing tool will be open, too

Organizational Information and Technical Instructions

The workshop takes place via Microsoft Teams and is in English. **All times are according to Central European Summer Time (CEST).**

You will receive a welcome email with subject "You have been added to a team in Microsoft Teams". Therein, you will be invited to join the "SIP Workshop" team and must accept the invitation by selecting Open Microsoft Teams in the email message before you can access the team and its channels. If you are using MS Teams for the first time, you need to enter a username and password, otherwise you can use your existing credentials.

We recommend to use the desktop app, which can be installed locally on your machine. Download: https://www.microsoft.com/de-de/microsoft-teams/group-chat-software

It is also possible to work with the Microsoft Teams WebApp via browser. However, this is only possible in full functionality with the browsers Microsoft Edge or Google Chrome - video conferencing does not work with all other browsers!

The talks will take place in the *channel "Plenum – Talks"*. On Thursday, May 20, we are already online from 8.30 CEST in MS Teams.

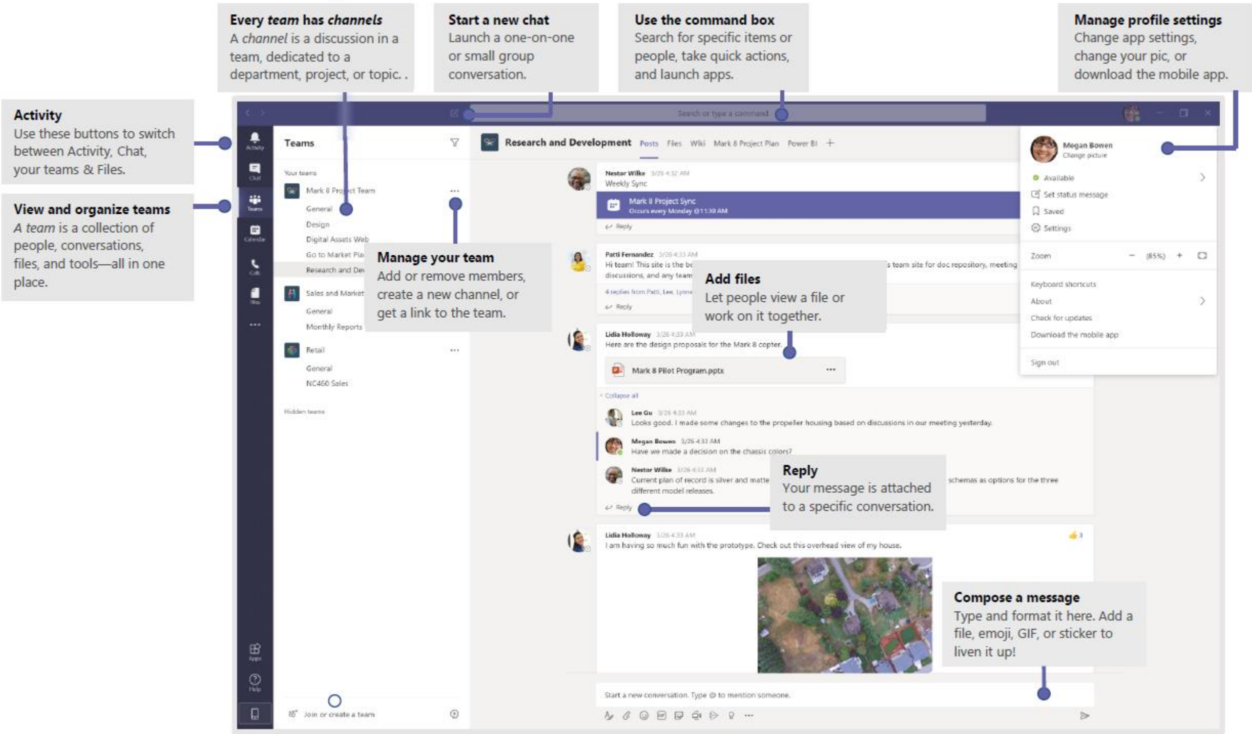
During the coffee breaks there is the possibility to exchange ideas in pairs or in groups or just to make some small talk in the meeting tool Wonder (https://www.wonder.me/). You will receive the link to the coffee break room during the event. Do not forget your coffee or tea! …

Microsoft Teams

Microsoft

Quick Start Guide

New to Microsoft Teams? Use this guide to learn the basics.



Do you have any questions during the workshop? Our organization team is at your disposal all day. Use the chat in the *channel "Reception - Helpdesk"* or write an email. In urgent cases you can also reach them by phone.

Technical issues

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Short CVs of the Invited Speakers and Organizers

Karl-Heinz Küfer is associate professor at Technical University of Kaiserslautern and director of division Optimization at Fraunhofer Institute for Industrial Mathematics (ITWM) at Kaiserslautern. For 20 years his group has been working on decision support systems in industrial branches like logistics, process engineering, production planning, medical treatment planning and operations research in health care. Interactive multi-objective optimization is the key method that has been proven successful to ease compromising between cost and quality measures well suited to the needs of the decision maker.

Oliver Stein is professor for Continuous Optimization at Karlsruhe Institute of Technology (KIT). Already in his doctoral and habilitation theses, first at University of Trier and later at RWTH Aachen University, he dealt with semi-infinite programming. His general research interests are optimization methods and their theoretical foundations. Aside from semi-infinite optimization, this includes robust, parametric, and multi-objective optimization, as well as generalized Nash games, and mixed integer nonlinear programming. He is also lecturer at the Hector School for Engineering and Management and won several teaching awards.

Süreyya Özöğür-Akyüz received her Ph.D. from the Institute of Applied Mathematics, Middle East Technical University, Ankara, Turkey, in 2009. Since then she has been working within the Department of Mathematics of Bahçeşehir University as associate professor. She contributed many multidisciplinary applications of machine learning such as bioinformatics, finance, business analytics, but also involved in theoretical machine learning from an optimization perspective. Her research interests include machine learning, optimization, neuroscience, biomedical applications, and bioinformatics.

René Henrion is deputy head of the research group "Nonlinear Optimization and Inverse Problems" at Weierstrass Institute for Applied Analysis and Stochastics (WIAS) in Berlin. He is additionally lecturer at Humboldt University of Berlin. His research is focused on stochastic optimization, especially chance-constrained programming, nonsmooth, parametric and semi-infinite optimization, as well as multivariate data analysis.

Alexander Mitsos is a Full Professor (W3) in RWTH Aachen University, and the Director of the Laboratory for Process Systems Engineering (AVT.SVT). He also has a joint appointment at Forschungsentrum Juelich where he is a Director of IEK-10 Energy Systems Engineering. Mitsos received his Dipl-Ing from University of Karlsruhe in 1999 and his Ph.D. from MIT in 2006, both in Chemical Engineering. Mitsos' research focuses on optimization of energy and chemical systems and development of enabling numerical algorithms.

Gerhard-Wilhelm Weber is professor at Poznan University of Technology at Faculty of Engineering Management. He received his Ph.D. at RWTH Aachen University, before he later obtained his habilitation for his research about generalized semi-infinite optimization at TU Darmstadt. His interests are various, including financial mathematics, nonlinear optimization, optimal control, operational research, but also bioinformatics, and environmental modeling.

Ralf Werner is professor for Mathematics of Economics at Augsburg University since 2012. Before he became a professor in 2010 at Munich University of Applied Sciences, he worked for more than ten years as Financial Engineer and Risk Analyst in the financial industry. Among other interests, his current work consists of machine learning for life insurance, nested Monte Carlo methods, robust multi-criteria optimization, and stochastic optimization.

Abstracts of Talks

TH-1, 9:30 - 10:15 (CEST)

Semi-infinite Optimization in Machine Learning

Süreyya Akyüz, Bahçeşehir University Istanbul, Turkey

There is a great interplay between optimization and machine learning where optimization is in the core of machine learning models. For instance, building a learning model for a given training instances takes place by minimizing the error function. As learning from data becomes more difficult task with the increase in size of data and because of the complexity nature of real world problems, advanced and special optimization models are required to obtain reliable performances close to exact values. Semi-infinite programming is one of the inspiring optimization methods across semi-definite programming in machine learning applications. It was first used in multiple kernel learning models to speed up the original semi-definite model. Then it was generalized to infinite kernel learning by semi-infinite programming.

In this talk, semi-infinite optimization models arise in machine learning problems will be discussed. As the nature of data is heterogeneous in real world, kernel function, which defines the similarity of data points, require to express heterogeneity in terms of simple convex combination. This leads to additional variables, coefficients of corresponding kernel functions, to be determined simultaneously with other constraints like maximum margin principle. The overall model with these constraints can be modelled as multiple kernel learning and later in general as infinite kernel learning using semi-infinite optimization. Experimental validation with various data sets will be discussed at the end of the talk.

TH-1, 10:15 - 10:30

Semi-infinite optimization for shape-constrained regression

Jochen Schmid, Fraunhofer Institute for Industrial Mathematics (ITWM) Kaiserslautern, Germany

In this talk, we present a regression method which enhances the predictive power of models by exploiting expert knowledge on the shape of the model. Important types of shape constraints are monotonicity or convexity constraints. Incorporating such shape constraints is particularly beneficial when the available data sets are sparse. We set up the regression subject to the considered shape constraints as a semi-infinite optimization problem and use adaptive discretization algorithms for its solution. It turns out that, in manufacturing applications with their typically sparse data, the predictive power of the models obtained with our semi-infinite optimization method is generally superior to those obtained with alternative monotonization methods from the literature.

TH-1, 10:30 - 10:45

Obtaining Optimal Experimental Designs via Semi-Infinite Optimization and Gaussian Process Regression

Philipp Seufert, Fraunhofer Institute for Industrial Mathematics (ITWM) Kaiserslautern, Germany

In general, optimal experimental design (OED) tasks are mixed-integer nonlinear problems, which -- as is well known -- are difficult to solve to global optimality. By means of a relaxation and the Kiefer-Wolfowitz Equivalence Theorem one can transfer the OED problem into a semi-infinite one. We use an adaptive discretization approach to solve the resulting SIP. While the discretized SIP problem, the weight optimization, is a convex problem and can even be formulated as a semi-definite problem (under the usual design criteria), the lower level problem is generally non-convex. Moreover, the lower level objective function is only given implicitly. In order to prevent time-consuming evaluations, we adaptively approximate the lower level objective function using Gaussian process regression and determine the maximum point of the surrogate for refining the discretization. With this modification we can efficiently compute locally optimal continuous designs even for high-dimensional input spaces. We have proven convergence of this approach and have obtained promising results on real-world problems from chemical engineering.

TH-2, 11:00 - 11:45 (CEST)

Non, je ne regrette rien

Ralf Werner, University of Augsburg, Germany

In this presentation, we consider multi-objective decision problems under uncertainty. In the single criteria case, robust optimization methodology can help to identify solutions which remain feasible and of good quality for all possible scenarios. An alternative method is to compare possible decisions under uncertainty against the optimal decision with the benefit of hindsight, i.e. to minimize the (possibly scaled) regret of not having chosen the optimal decision. In this exposition, we extend the concept of regret to the multi-objective setting and introduce a proper definition of multivariate (relative) regret.

While all early attempts in such a setting mix scalarization and modelling efforts, we clearly separate both steps, such that after an optimal decision is taken, "there is nothing to regret". We demonstrate that in contrast to existing approaches, we are not limited to finite uncertainty sets or interval uncertainty, but instead computations remain tractable in important special cases. Tractability here means that we can formulate related convex semi-infinite problems which can be solved with standard (feasible!) SIP methods.

Finally, if time allows, we show that our notion of regret is subject to a subtle caveat. A careful discussion will then show that a slightly improved modelling of regret will then lead to GSIPs instead of ordinary SIPs.

TH-2, 11:45 – 12:15

On the epigraphical reformulation of uncertain multi-objective optimization problems

Ernest Quintana, Technical University of Ilmenau, Germany

In this talk, we consider a solution approach for set-based robust solutions to multiobjective optimization problems under uncertainty. Specifically, we derive a parametric family of (deterministic) semi-infinite multiobjective problems whose solution sets approximate, with desired accuracy, that of the original problem. The tractability of the semi-infinite constraints is also analyzed with tools of Fenchel duality. Our approach generalizes the standard epigraphical reformulation of robust scalar problems to the multiobjective setting.

TH-2, 12:15 – 12:30

The concept of inverse robustness and a semi-infinite solution approach

Holger Berthold, Fraunhofer Institute for Industrial Mathematics (ITWM) Kaiserslautern, Germany

In the past, a lot of methods were developed to deal with uncertain optimization problems. While the uncertainty definition of such problems need to be given, the literature on how to define a suitable uncertainty set is rather sparsely. In this talk, we describe an approach of how to improve a given reference solution to find a solution that covers a largest uncertainty set possible while staying close to the reference solution w.r.t. the objective value. We develop a generic concept and provide a comparison to existing robustness concepts.

Afterwards we will reduce the introduced inverse robust optimization problem by appropriate parametrizations of the uncertainty sets to a generalized semi-infinite optimization problem and illustrate the concepts by a small example.

TH-3, 13:30 - 14:15 (CEST)

Contingency Screening for Power Grids Using Existence-Constrained Semi-Infinite Programs

Alexander Mitsos, RWTH Aachen University, Germany

We consider the problem of categorizing contingencies in power grids under uncertainty in order to support the provision of (n-1)-reliability. Following previous work (Fliscounakis et al. in IEEE Transactions on Power Systems 28(4):4909-4917, 2013), our aim is to categorize contingencies according to the preventive control actions that are required to guarantee nominal operation of a power grid under uncertainty and optimal corrective control actions. This problem formulation results in an existence-constrained semi-infinite program (ESIP), which is akin to an adjustable robust optimization problem. As a power grid model, we employ the DC power flow approximation together with disjunctive models for load distribution, bus merging and splitting, and phase shifting transformers (Djelassi et al. in Power Systems Computation Conference, 2018). Due to the lack of rigorous algorithms for the solution of ESIPs, prior considerations of the categorization problem were limited to solving a feasibility problem. In contrast, our recently proposed algorithm for the global solution of ESIPs absent convexity assumptions (Djelassi and Mitsos in Journal of Optimization Theory and Applications, submitted 2019) enables the solution of the categorization problem.

In the talk we first discuss the ESIP algorithm. We specialize the algorithm for the contingency categorization problem and perform a contingency screening on a large-scale power grid instance, where we solve the categorization problem for each member of a set of contingencies. We discuss the information that can be gained from categorization of contingencies as well as the tractability of the proposed approach for large-scale contingency screenings.

TH-3, 14:15 - 14:45

Semi-Infinite Programming yields Optimal Disturbance Model for Offset-Free Nonlinear Model Predictive Control

Adrian Caspari, RWTH Aachen

Setpoint tracking without an offset cannot be guaranteed with nonlinear model predictive control (NMPC) in reality, due to disturbances or the omnipresent plant-model mismatch. Offset-free NMPC can solve this issue using a hybrid model comprising a nominal plant model and a disturbance model. The states of both models are estimated to adjust the model during operation. By this interplay of NMPC, state estimation, and hybrid model, the offset is eliminated. The question is as to how to obtain the disturbance model.

We present our recent work about the first systematic approach for disturbance model generation. We tailor disturbance models to satisfy those system theoretical properties which are sufficient for offset-free NMPC. These conditions are embedded in an optimization problem, yielding a generalized semi-infinite program (GSIP), which, after reformulation, gives an SIP. We solve the SIP using a hybrid discretization algorithm.

Two chemical engineering case studies demonstrate the application of the disturbance model generation approach and show that the intended goal is achieved: applying the resulting models yields offset-free tracking.

TH-3, 14:45 – 15:15

Designing optimal product portfolios with semi-infinite programming

Helene Krieg, Fraunhofer Institute for Industrial Mathematics (ITWM) Kaiserslautern, Germany

The design of a product portfolio is one of the most important issues a company has to deal with: It is the task of deciding which and how many products to produce. Satisfying all potential customer demands conflicts with the economic principle of keeping portfolio size small. In technical contexts, the products are machines which often have continuous ranges of operation points. By means of an example from pump industry, we show that these products can be identified with geometrical objects defined by continuous decision variables: the set of operation points at which the machines can be operated. Customer demands usually consist of an operation range, based on which a suitable product is chosen from the portfolio. Yet, there is uncertainty in the customer specification, as the later use of the equipment might be subject to changes. Hence, an optimal product portfolio ideally consists of products that operate not alone in the customer specified set of operation points but in some larger set containing them.

To incorporate satisfaction of customer demands into the design task, we require fulfillment of a set-theoretic constraint. It states that the sets of operation points of a feasible portfolio must contain a given, infinite set of potential customer demand points. At the same time, a quality measure, such as overall efficiency of the portfolio, should be maximized. This set-theoretic formulation of the portfolio design task can be turned into a semi-infinite optimization problem (SIP). Unfortunately, the lower level problem of this SIP is neither smooth nor convex. Our solution approach combines appropriate smoothing with the well-known adaptive discretization technique. The method is shown to converge under harmless requirements on the update of the discretization- and smoothing-based approximating problems. Our numerical examples based on the application of designing an optimal pump portfolio show further that usually, problem size is kept efficiently small.

TH-4, 15:45 – 16:15 (CEST)
On semi-infinite reformulations for equilibrium selection
Oliver Stein, Karlsruhe Institute of Technology KIT, Germany

We consider optimization problems over equilibrium sets of player convex generalized Nash games. The implicit formulation of the equilibrium condition is usually made explicit by the Karush-Kuhn-Tucker approach, leading to a mathematical program with complementarity constraints. Alternatively we propose to reformulate the equilibrium condition by the Nikaido-Isoda approach, or as a quasi-variational inequality. Both reformulations lead to generalized semi-infinite optimization problems.

If the strategy sets are constant polytopes, we show how the (standard) semi-infinite problem problem arising from the variational inequality approach can be treated by a Benders-like algorithm, and we present some preliminary numerical experience.

TH-4, 16:15 – 16:45
Algorithms for generalized Nash games in semi-infinite optimization
Giancarlo Bigi, University of Pisa, Italy

Semi-infinite programs (SIPs) can be formulated as generalized Nash games (GNEPs) with a peculiar structure under mild assumptions. Pairing this structure with a penalization scheme for GNEPs leads to methods for SIPs. A projected subgradient method for nonsmooth optimization and a subgradient method for saddlepoints are adapted to our framework, providing two kinds of the basic iteration for the penalty scheme. A comparison between the two resulting algorithms is outlined as well. Finally, these results and algorithms are exploited to analyse robustness in portfolio selection and/or production planning problems subject to uncertainty in data.

TH-4, 16:45 – 17:15
Ekeland type variational principle for set-valued maps in quasi-metric spaces with applicationsoptimization
Pradeep Kumar Sharma, University of Delhi, India

In this talk, we present a fixed point theorem, minimal element theorems, and Ekeland type variational principle for set-valued maps with generalized variable set relations in quasi-metric spaces. These generalized variable set relations are the generalizations of set relations with constant ordering cone, and form the modern approach to compare sets in set-valued optimization with respect to variable domination structures under some appropriate assumptions. In the end, we discuss the application of these variational principles to the capability theory of well-being via variational rationality.

FR-1, 8:45 – 9:30 (CEST)

A Stochastic Maximum Principle for a Markov Regime-Switching Jump-Diffusion Model with Delay and an Application to Finance

Gerhard-Wilhelm Weber, Poznan University of Technology, Poland

We study a stochastic optimal control problem for a delayed Markov regimes-witching jump-diffusion model. We establish necessary and sufficient maximum principles under full and partial information for such a system.

We prove the existence-uniqueness theorem for the adjoint equations, which are represented by an anticipated backward stochastic differential equation with jumps and regimes. We illustrate our results by a problem of optimal consumption problem from a cash flow with delay and regimes. In optimal control, a natural connection with semi-infinite optimization is given by the "flow" of the dynamics. In its stochastic counterpart, the "event" or "scenario", being an element of the probability space, parametrizes the flow. When "delay" enters into the dynamics, (initial) states are replaced by "initial functions" as a flow variable.

FR-1, 9:30 – 10:00

On the turnpike property for optimal control problems with dynamic probabilistic constraints

Martin Gugat, FAU Erlangen-Nürnberg, Germany

The turnpike phenomenon is a structure that is well-known in mathematical economics. We consider systems that are governed by time-discrete dynamics. We study optimal control problems where in the objective function a term of tracking type and a control cost appear.

In addition, the feasible states have to satisfy a conservative probabilistic constraint that requires that the probability that the trajectories remain in a given set F is greater than or equal to a given lower bound. We give sufficient conditions that imply that the optimal expected trajectories converge to the desired state exponentially fast. We consider both static and dynamic optimization problems in the sense of stochastic optimization.

FR-1, 10:00 – 10:30

Adaptive bundle methods for nonlinear robust optimization

Michael Stingl, FAU Erlangen-Nürnberg, Germany

Writing nonlinear robust optimization tasks in minimax form, in principle, bundle methods can be used to solve the resulting nonsmooth problem. However there are a number of difficulties to overcome. First, the inner adversarial problem needs to be solved to global optimality, which is a major challenge in the general nonlinear case. In order to cope with this, an adaptive solution approach is required. A second challenge is that the computation of elements from an ε-neighborhood of the Clarke-subdifferential is in general prohibitive. We show how an existing bundle concept by D. Noll for non-convex problems with inexactness in function values and subgradients can be adapted to this situation. We discuss convergence properties of the resulting method and demonstrate its efficiency by means of robust gas transport problems. In these, the adversarial problem is adaptively solved by mixed integer programming techniques.

FR-2, 10:45 - 11:30 (CEST)

Dealing with Probust Constraints in Stochastic Optimization

René Henrion, Weierstrass Institute for Applied Analysis and Stochastics (WIAS) Berlin, Germany

Introduced some 60 years ago, probabilistic constraints represent nowadays a standard tool of dealing with (finite) random inequality systems within a stochastic optimization problem. Recently, driven by applications in energy management (optimization in gas networks, reservoir control) or in PDE constrained optimization with random state constraints, the extension to the case of continuously indexed inequality systems as they occur in SIP or GSIP has attracted increasing interest. Here, the continuous index could play the role of time or space. Alternatively, it could represent an additional uncertain parameter which in contrast to the given random parameter is not endowed with statistical information and rather treated in a worst case (robust) manner. A typical example is gas network optimization, where one is simultaneously faced with stochastic (e.g. loads at the exits) and non-stochastic (non-measurable friction coefficients in pipes underground) uncertainty. This aspect gave rise to introduce the class of probust (probabilistic/robust) constraints. The talk presents the model, some applications, some basic structural properties including differentiability of the associated probability function as well as some algorithmic ideas.

FR-2, 11:30 – 12:00
An algorithmic approach for solving optimization problems with probabilistic/robust (probust) constraints
Holger Heitsch, WIAS Berlin, Germany

Presented is an adaptive grid refinement algorithm to solve probabilistic optimization problems with infinitely many random constraints. Using a bilevel approach, inequalities that provide most information not in a geometric but in a probabilistic sense are aggregated iteratively. For this conceptual idea convergence can be proven and an adapted implementable algorithm is presented. The efficiency of the approach is shown for a water reservoir problem with joint probabilistic filling level constraints.

FR-2, 12:00 – 12:30
Problem-based scenario generation for two-stage stochastic programs using semi-infinite optimization
Werner Römisch, HU Berlin, Germany

Scenarios are indispensable ingredients for the numerical solution of stochastic programs. We suggest an approach to generate scenarios that makes use of stability estimates based only on problem specific data. For linear two-stage stochastic programs we show that the problem-based approach to optimal scenario generation can be reformulated as best approximation problem for the expected recourse function which in turn can be rewritten as a generalized semi-infinite program. We show that the latter is convex if either right-hand sides or costs are random and can be transformed into a semi-infinite program in a number of cases.

FR-3, 13:30 – 14:00 (CEST)
A primal-dual algorithm for semi-infinite programming
Bhagwat Ram, Banaras Hindu University, Varansai, India

We consider an inexact primal-dual algorithm for semi-infinite programming (SIP) for which it provides general error bounds. We create a new prox function for nonnegative measures for the dual update, and it turns out to be a generalization of the Kullback-Leibler divergence. We show that, with a tolerance for small errors (approximation and regularization error). We show the rate of convergence in terms of the optimality gap and constraint violation. We then use our general error bounds to analyze the convergence and sample complexity of a specific primal-dual SIP algorithm based on Monte Carlo sampling. Finally, we provide numerical experiments to show the performance of this algorithm.

FR-3, 14:00 – 14:30

A transformation-based discretization method inspired by and applied to gemstone cutting

Jan Schwientek, Fraunhofer Institute for Industrial Mathematics (ITWM) Kaiserslautern, Germany

Discretization methods are commonly used for solving standard semi-infinite optimization (SIP) problems. The transfer of these techniques to the case of general semi-infinite optimization (GSIP) problems is difficult due to the variability of the infinite index set. On the other hand, under suitable conditions, a GSIP problem can be transferred into a SIP problem. However, this approach may destroy convexity in the lower level, which is of great importance for the design as well as the performance of numerical algorithms.

We present a solution method for GSIPs with convex lower level problems, which cleverly combines the above mentioned two techniques. It can be shown that the convergence results of discretization methods for SIPs carry over to this approach under suitable assumptions on the transformation. Finally, we demonstrate that our method solves small to medium-sized problems of maximal material utilization in gemstone cutting on a standard PC in reasonable time.

FR-3, 14:30 – 15:00

A quadratic convergent adaptive discretization method: quADAPT

Tobias Seidel, Fraunhofer Institute for Industrial Mathematics (ITWM) Kaiserslautern, Germany

A classical solution approach to semi-infinite programming, which is easy to implement, is based on discretizing the semi-infinite index set. The Blankenship and Falk algorithm adaptively chooses a small set of discretization points. On every iteration, a solution of an approximate problem, based on the current discretization, is calculated. In a second step, the most violated constraint is determined and added to the discretization. We present an example which shows that quadratic convergence is not possible for a minimum of order higher than one.

Motivated by this example we suggest a new adaptive discretization algorithm with guaranteed quadratic convergence. This rate holds even for minima of order higher than one. The key idea is to break the separated scheme of the Blankenship and Falk algorithm and add more information about the lower-level problems to the discretized problems. We develop three main results. First, we present the Quadratic Convergence Theorem, which rigorously establishes quadratic convergence under mild regularity conditions. Second, we show that a limit point is a stationary point, if the iterates are stationary points. Finally, we establish conditions under which, for iterates that are local minima, their limit is a local minimum.

We extend our new method to the case of a variable index-set, and show that the previous results also hold for this case. We compare the Blankenship and Falk algorithm to our new method by considering a series of numerical examples. In these examples, our new method outperforms the Blankenship and Falk algorithm in terms of number of iterations and runtime.

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