International Conference on Bilevel Optimization

August 8-11, 2023
University of Southampton
Highfield Campus, Southampton, UK

Conference Book

University of Southampton

Contents

Welcome address

On behalf of the program and organization committee as well as the University of Southampton, we welcome you to the International Conference on Bilevel Optimization.

It is our pleasure to provide a conference of 4 invited plenary talks, 19 invited or contributed sessions, comprising 63 talks, a summer school of 2 lectures, and a poster competition of 6 posters merely dedicated to the topic of bilevel optimization in its numerous different flavors. We also would like to take this opportunity to, academically, bid farewell to Stephan Dempe, a pioneer in bilevel optimization, our PhD supervisor, and friend, whose tremendous contributions enriched the field over the last 30 years and who officially retired in October 2022.

During the conference, almost 90 delegates from 20 countries all over the world will learn about recent developments in theoretical, algorithmic, numerical, and applied bilevel optimization, discuss current and upcoming challenges, and, hopefully, revive old and coin new scientific collaborations. The above numbers clearly indicate the importance of bilevel optimization as a seminal and shining subfield of mathematical programming.

We would like to express our sincere appreciation to the volunteers who enabled us to make this conference possible. Particularly, we acknowledge the activities of the program committee, session organizers, and session chairs who set up a fine scientific program. Our sincere thanks go to the members of the organization committee and everyone involved in the local organization – the Faculty of Social Sciences Events and Maths FOS teams as well as our PhD student helpers – for the many weeks of work. Finally, we acknowledge financial support by diverse sponsors which, among others, made the awarding of travel grants and prizes for the poster competition possible.

We wish you all a pleasant and memorable conference with open-minded and fruitful discussions.

Patrick Mehlitz & Alain B. Zemkoho
Cottbus & Southampton, August 2023

List of sponsors

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Useful information

- Venue
  The conference will mainly take place at Highfield Campus of the University of Southampton with the summer school hosted in building B2A - Annex and the main conference hosted in building B100 - Centenary Building. For the visit of the SeaCity Museum and the conference dinner at Leonardo Royal Hotel Grand Harbor, we have to leave the Highfield Campus.

- Registration desk
  Participants are kindly asked to pick up their conference bag comprising, among other helpful things, the conference badge, a digital version of the conference booklet, as well as bus and dinner tickets at the registration desk.

  - August 8th: 08:00 - 10:30, B2A - Foyer (Level 2)
  - August 8th: 17:00 - 19:00, B38 - The Arlott Bar (Welcome reception)
  - August 9th: 08:00 - 10:45, B100 - Foyer (Level 4)

- Welcome reception
  We are happy to host a welcome reception on August 8th, 17:00 - 19:00, at B38 - The Arlott Bar which serves as a first get-together of the participants. Some drinks will be available there. The registration desk also opens during welcome reception.

- Contributed talks
  Contributed talks are scheduled to last 25 minutes including questions. There are PCs available in each of the lecture rooms, so speakers are asked to bring their talks saved on a USB flash drive and to put the presentation onto the available computers (PhD student helpers will assist you). Please, arrive at least 10 minutes before your session starts.

- Poster session
  The poster session will take place on August 10th, 16:30 - 17:45, in room B100/4013. All delegates are encouraged to join the session and to inspect the 6 contributed posters dealing with different aspects of bilevel optimization. Contributors are encouraged to put their posters up by 09:00 in the morning.

  We are happy to announce that the best 3 posters are awarded with a prize kindly sponsored by DAS Ltd. Once during the poster session, each of the contributors will be given a 5 minutes time slot to present their poster in front of the poster prize committee. A discussion of about 5 minutes will follow. The winners will be announced at the end of the conference.

- Coffee breaks
  On August 8th, the coffee breaks are hosted in B2A - Foyer (Level 2). From August 9th to August 11th, we scheduled the coffee breaks in B100 - 4013/Foyer (Level 4). On August 10th and August 11th, some welcome refreshments will be provided from 08:30 to 09:00 at B100 - Foyer (Level 4).

- Lunch breaks
  The conference fee includes a daily lunch for all participants which will be served in B38 - Terrace Restaurant. Use the entrance marked with a black arrow in the map of Highfield Campus.

- Accommodation at Glen Eyre Halls
  If you have booked to stay in the Glen Eyre Complex, you will be staying specifically in the Chamberlain Halls located at the following address:
  Chamberlain Halls, Glen Eyre Road, Southampton SO16 3UD
  Main reception telephone number: +44 (0)23 8059 8004
  However, your breakfast will be served in served in B38 - Terrace Restaurant according to the following schedule:

  - August 8th: 07:30 - 08:00
  - August 9th: 08:15 - 08:45
  - August 10th: 08:15 - 08:45
  - August 11th: 08:15 - 08:45

  Anyone staying the evening of Friday, August 11th, will collect a packed breakfast from the service station in B100 on Friday. These will be delivered and available from the afternoon refreshment service.

  Further important onboarding information:

  - *Check in* – You can check in after 15:00, please proceed to Chamberlain reception/Post room between 15:00 - 19:00. If you are arriving after 19:00, please, go to the 24-hour-reception which is on the other side of the road.
  - *Check out* – Please, return your key fob to Chamberlain reception/Post room no later than 09:30 in the morning.
  - *Car parking* - There is limited car parking on the Glen Eyre site – in particular outside of Chamberlain. If you are bringing a car to site and needing to park (not just drop off and pick up), you require a permit. These will be issued on check-in and guests will be required to provide registration number and contact details. This permit is for halls only, it will not work on Highfield Campus.
  - *Road closure* – Please, be aware of the current partial closure of Glen Eyre Road. Pedestrian routes have been maintained, however, there is no vehicle access from Burgess Road, and guests should be directed via the Avenue A33. For anyone arriving from Southampton (via M27), this will add a good 5-10 minutes on the regular journey.

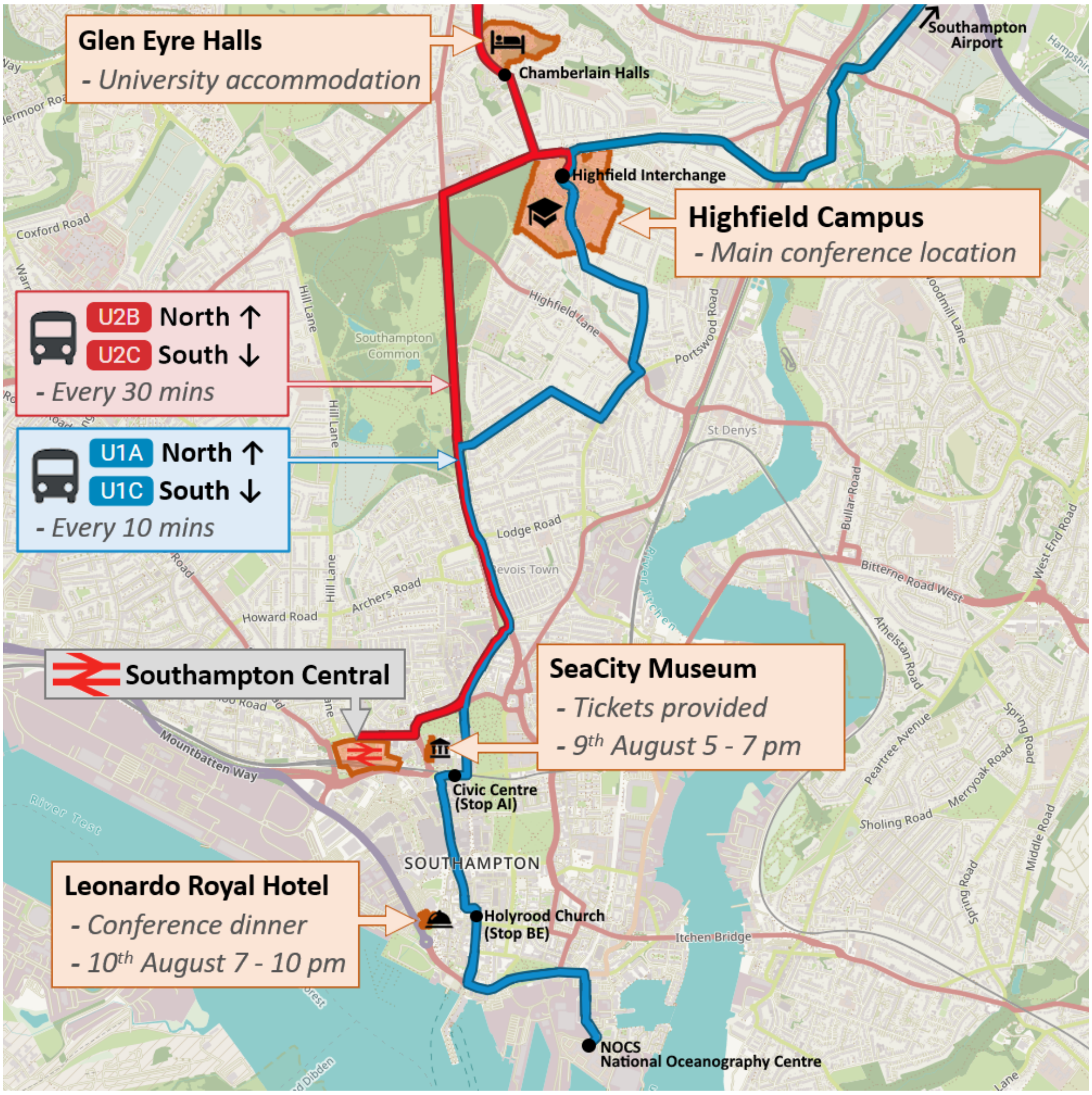
- Visit SeaCity Museum
  On August 9th, you may join us for a visit of Southampton SeaCity Museum. We meet at 17:00 directly at the museum. You may take the U1C bus from Highfield Interchange (Highfield Campus) to go there. Tickets are covered by the fee.

- Conference dinner
  The conference dinner takes place at Leonardo Royal Hotel Grand Harbor on August 10th and starts at 19:00. You may take the U1C bus from Highfield Interchange (Highfield Campus) to go there. In the case where you registered for the dinner, you may find a dinner ticket among your conference material. Please, bring this dinner ticket to the dinner.

- Updates of the schedule
  We aim to guarantee that the digital version of the booklet as well as the conference webpage (https://www.bilevelconference2023.org/schedule) provide up-to-date versions of the schedule. Additionally, the daily conference program will be available in short form at the venue.

Spotting Southampton

We first look at a macroscopic view of Southampton. Most of the conference talks and events will take place on Highfield Campus. For all other venues, bus tickets are provided in your conference bag.



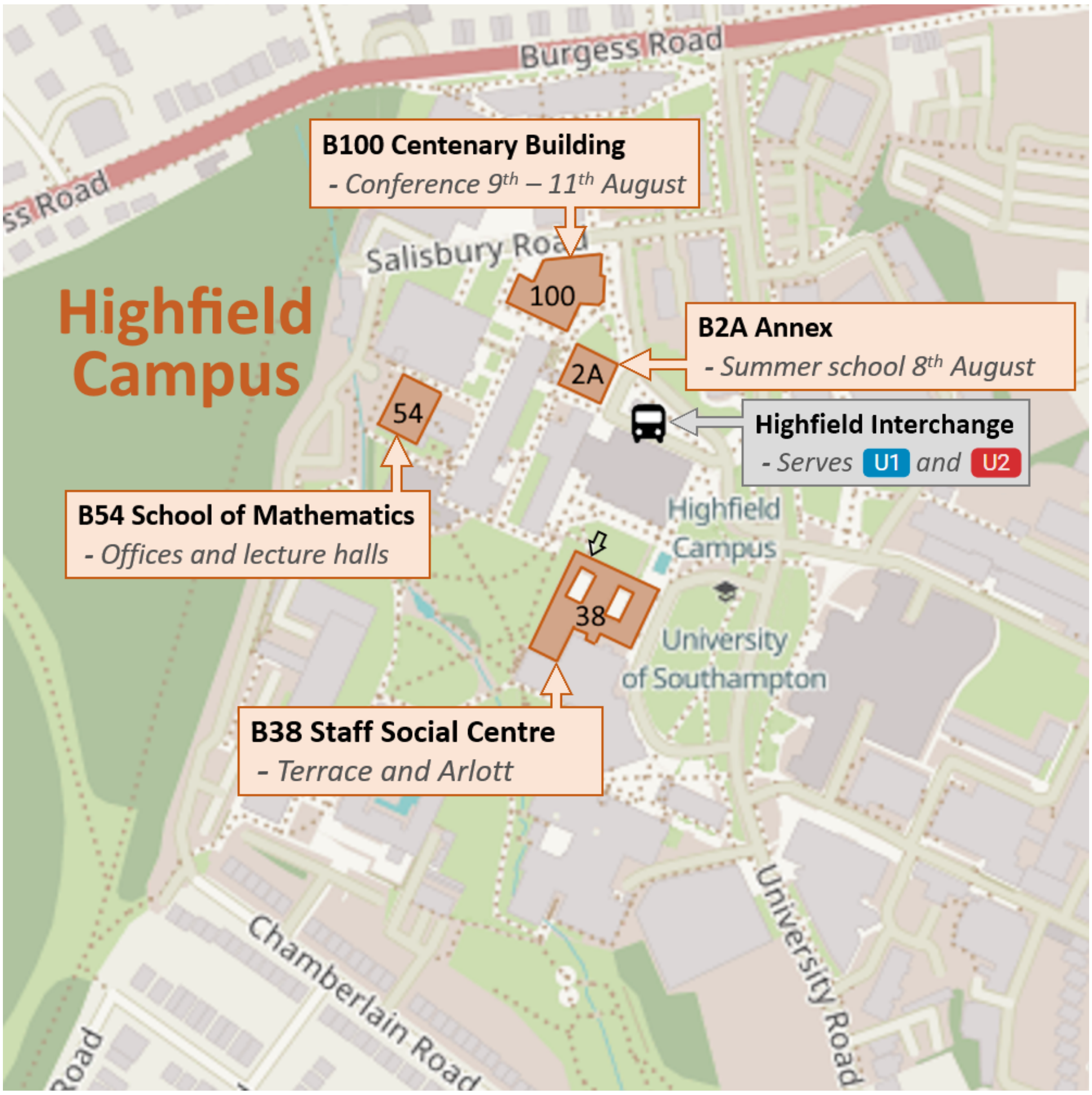
- On August 9th, the final talk concludes at 16:00. Delegates will then be ushered to the Highfield Interchange, where we will catch the U1C bus for a 20 minutes journey to Civic Center (Stop AI). The SeaCity Museum tickets are valid from 17:00, and the museum is a 2 minute walk from this stop.

- On August 10th, the poster competition concludes at 17:45. Again, delegates will depart from Highfield Interchange on the U1C. This time we will stop at Holyrood

Church (Stop BE) for the 19:00 dinner at the Leonardo Royal Hotel Grand Harbor.

- The U1 drawn in blue on the map serves all stops every 10 minutes between 05:35 and 19:45. It continues less frequently and serves fewer stops between 19:45 and 01:00.
- The U2 drawn in red on the map serves all stops approximately every 30 minutes between 07:47 and 19:25.
- Note that Southampton busses have different suffixes when travelling north (e.g. U1A) than when travelling south (e.g. U1C).

We now zoom in on Highfield Campus. All university buildings have both a name and number. The summer school (August 8th) will take place in building 2 Annex (B2A). The conference talks (August 9th to 11th) will be in building 100 Centenary (B100). Meal and social activities will be hosted in building 38 Staff Social Centre (B38). We also point out the location of the Highfield Interchange for all bus routes that pass though campus.



For an interactive map of all campus buildings, please, use this link: https://maps.soton.ac.uk/.

Short program

August 8th

Room 08:00 – 08:30	B2A - Foyer (Level 2) **Welcome & registration**
Room Lecture 08:30 – 10:00	B2A - 2077 **Bilevel optimization algorithms and models for contemporary energy challenges (I)** **Anjos**
10:00 – 10:30	**Coffee break**
Lecture 10:30 – 12:00	**Bilevel optimization algorithms and models for contemporary energy challenges (II)** **Anjos**
12:00 – 13:15	**Lunch break**
Lecture 13:15 – 14:45	**Bilevel optimization in machine learning (I)** **Pontil/Grazzi**
14:45 – 15:15	**Coffee break**
Lecture 15:15 – 16:45	**Bilevel optimization in machine learning (II)** **Pontil/Grazzi**
Room 17:00 – 19:00	B38 - The Arlott Bar **Welcome reception & registration**

August 9th

Room 08:00 – 09:00	B100 - Foyer (Level 4) **Welcome & registration**		
Room 09:00 – 09:15	B100 - 4011 **Opening**		
Plenary 09:15 – 10:15	B100 - 4011, Chair: Zemkoho **Dempe**		
10:15 – 10:40	**Coffee break**		
Room Session 10:40 – 12:20	B100-5013 **Bilevel optimization and applications (I)** Chair: Galé	B100 - 5015 **Nash equilibria in Stackelberg games** Chair: Zemkoho	B100 - 5017 **Mixed-integer bilevel optimization (I)** Chair: Coniglio
10:40 – 11:05	Hengeler Antunes	Steffensen	Furini
11:05 – 11:30	Albornoz	Bigi	Thürauf
11:30 – 11:55	Smeulders	Ceparano	Messina
11:55 – 12:20	Suvak	Caruso	Moriggia
12:20 – 13:30	**Lunch break**		
Session 13:30 – 14:45	**Robustness in bilevel optimization** Chair: Fliege	**Newton-type methods in bilevel optimization** Chair: Ye	**Mixed-integer bilevel optimization (II)** Chair: M. Schmidt
13:30 – 13:55	Henke	Fischer	Coniglio
13:55 – 14:20	Schneider	Mefo Kue	Beck
14:20 – 14:45	Kovács	Jolaoso	Neto
14:45 – 15:00	**Coffee break**		
Plenary 15:00 – 16:00	B100 - 4011, Chair: M. Schmidt **Ljubić**		
17:00 – 19:00	**Visit SeaCity Museum**		

August 10th

Room Session 09:00 – 10:15	B100-5013 **Complementarity-based bilevel optimization** Chair: Dutta	B100 - 5015 **Bilevel optimization in infinite dimensions** Chair: Dempe	B100 - 5017 **Metaheuristics for bilevel optimization** Chair: Anjos
09:00 – 09:25	Kreimeier	Khalil	Alves
09:25 – 09:50	Upandyay	Mehlitz	Camacho-Vallejo
09:50 – 10:15	Laha	Valkonen	Galé
10:15 – 10:40	**Coffee break**		
Session 10:40 – 12:20	**Bilevel optimization and applications (II)** Chair: Thürauf	**Bilevel optimization in machine learning (I)** Chair: Coniglio	**Mixed-integer bilevel optimization (III)** Chair: Ljubić
10:40 – 11:05	Cerulli	Dunn	Horländer
11:05 – 11:30	Labbé	Ward	Ley
11:30 – 11:55	Anjos	Li	Blom
11:55 – 12:20	Rodrigues	Qian	Weninger
12:20 – 13:30	**Lunch break**		
Session 13:30 – 15:10	**Bilevel optimization and applications (III)** Chair: Labbé	**Bilevel optimization in machine learning (II)** Chair: Fliege	**Algorithmic nonlinear bilevel optimization** Chair: Mehlitz
13:30 – 13:55	Jacquet	Grazzi	Suonperä
13:55 – 14:20	Wiertz	Benfield	Xu
14:20 – 14:45	Mukherjee	Sinha	Käming
14:45 – 15:10	Mastin	Salehi	Zemkoho
15:10 – 15:30	**Coffee break**		
Plenary 15:30 – 16:30	B100 - 4011, Chair: Ljubić **M. Schmidt**		
Room 16:30 – 17:45	B100 - 4013 **Poster competition**		
19:00 – 22:00	**Conference dinner**		

August 11th

Room Session 09:00 – 10:15	B100-5013 **Semi-infinite optimization** Chair: Fliege	B100 - 5015 **Multiobjective bilevel optimization** Chair: Mehlitz
09:00 – 09:25	Seidel	Hoff
09:25 – 09:50	Poursanidis	Mao
09:50 – 10:15	Schwientek	
10:15 – 10:40	**Coffee break**	
Session 10:40 – 11:30	**Beyond bilevel optimization** Chair: Anjos	**Bilevel parameter learning** Chair: Coniglio
10:40 – 11:05	Dutta	Bucarey
11:05 – 11:30	Burtscheidt	Molan
11:30 – 13:00	**Lunch break**	
Plenary 13:00 – 14:00	B100 - 4011, Chair: Mehlitz **Ye**	
Room 14:00 – 14:15 14:15 – 14:30	B100 - 4011 **Awarding ceremony poster competition** **Closing**	

Invited speakers

Summer school lecturers

Miguel F. Anjos, University of Edinburgh

Miguel F. Anjos holds the Chair of Operational Research at the School of Mathematics, University of Edinburgh, U.K., and is Schöller Senior Fellow at the University of Erlangen-Nürnberg, Germany. He previously held faculty positions at Polytechnique Montreal, the University of Waterloo, and the University of Southampton. He is the Founding Academic Director of the Trottier Institute for Energy at Polytechnique Montreal. His accolades include an Inria International Chair, a Canada Research Chair, the NSERC-Hydro-Quebec-Schneider Electric Industrial Research Chair, a Humboldt Research Fellowship, and the Queen Elizabeth II Diamond Jubilee Medal. He is a Fellow of EUROPT and of the Canadian Academy of Engineering. The research interests of Miguel are in the theory, algorithms and applications of mathematical optimization. He is particularly interested in the application of optimization techniques to problems in the areas of power systems, smart energy grids and facility layout. He has published four books and more than 100 scientific articles.

Massimiliano Pontil, Italian Institute of Technology

Massimiliano Pontil is P.I. of the Computational Statistics and Machine Learning research unit at Italian Institute of Technology (IIT), professor at University College London (UCL), and member of the UCL Centre for Artificial Intelligence. He is an ELLIS Fellow and co-director of ELLIS Unit Genoa, a joint effort of IIT and University of Genoa. He has been active in machine learning research for over twenty years, working on theory and algorithms, including the areas of kernel methods, multitask and transfer learning, online learning, sparse estimation, and statistical learning theory. Recent interests include meta-learning, algorithm fairness, hyperparameter optimization, and learning with partial feedback. He received a best paper runner up at ICML 2013 and served as an Area Chair at NeurIPS, ICML, COLT, and action editor for the Journal of Machine Learning Research.

Riccardo Grazzi, Italian Institute of Technology

Riccardo Grazzi recently completed his PhD in Computer Science at University College of London (UCL) and the Italian Institute of Technology (IIT) under the supervision of Massimiliano Pontil. During his PhD, he was an intern at Amazon AWS Berlin under the supervision of Matthias Seeger. Previously, he completed his Master and Bachelor degree in computer engineering at University of Florence. His main research focus is on bilevel optimization in machine learning. In particular, he is interested in the quantitative study of efficient gradient based bilevel optimization algorithms.

Plenary speakers

Stephan Dempe, Technical University Bergakademie Freiberg

Stephan Dempe is a leading expert in the field of bilevel optimization. He studied mathematics at Karl-Marx-Stadt University of Technology (GDR) where he received his diploma degree in 1981. Until 1995 he stayed there and successfully completed his PhD under supervision of Knut Richter as well as his habilitation in the working group of Klaus Beer. Based on research stays at the Belorussian State University Minsk (USSR) in 1982 and at the Leningrad State University (USSR) in 1988, Stephan gained international scientific expertice. After a short academic stay in Leipzig (Germany) he was appointed full professor at Technical University "Bergakademie" Freiberg (Germany). Stephan authored, coauthored, or edited approximately 150 papers, book chapters, and books mostly concerned with theoretical and numerical issues in mathematical bilevel optimization. During his long career, Stephan supervised 18 PhD students. He retired in autumn 2022.

Ivana Ljubić, ESSEC Business School

Ivana Ljubić received her PhD in computer science at Vienna University of Technology, where she has been supervised by Petra Mutzel and Ulrich Pferschy, in 2004 and her habilitation in operations research at the University of Vienna in 2013. She stayed at the University of Vienna as an associate professor until 2015. Since 2015 Ivana is employed at ESSEC Business School in Paris, where she has been promoted to a full professor of operations research in 2016. Her academic career is adorned with several international research stays in Chile, France, Germany, Italy, and the Unites States. Her research has been published in more than 100 papers and book chapters, and focuses on diverse topics of operations research including applications of bilevel optimization and the development of exact methods for discrete bilevel optimization.

Martin Schmidt, University of Trier

Martin Schmidt studied mathematics at the Leibniz University Hannover (Germany) and received his diploma in 2008. Afterward, he got his PhD at the Leibniz University Hannover in 2013 under the supervision of Marc Steinbach. In 2018, Martin became a junior professor at the Friedrich-Alexander-University Erlangen-Nürnberg (Germany). In 2019, he moved to Trier, where he is now a full professor for nonlinear optimization. Martin wrote approximately 100 papers and book chapters dealing with diverse aspects of continuous and mixed-integer optimization with a special emphasis on bilevel optimization and applications addressing energy markets.

Jane J. Ye, University of Victoria

Jane J. Ye is a professor at the University of Victoria (British Columbia, Canada) working in the areas of nonsmooth optimization and variational analysis with a strong focus on bilevel optimization and its applications. She received her bachelor degree in mathematics back in 1982 from the Xiamen University (Fujian, China) before moving to the Dalhousie University Halifax (Nova Scotia, Canada) in 1984 where she completed her PhD in 1990 under supervision of Michael A. H. Dempster. Afterwards, Jane became a postdoctoral fellow at the Univerersité de Montréal (Québec, Canada) under supervision of Francis H. Clarke. In 1992, she moved to the University of Victoria (British Columbia, Canada) for an assistant professorship which has been turned into a full professorship in 2002. Jane received the Krieger-Nelson Prize of the Canadian Mathematical Society in 2015. She authored or coauthored more than 100 papers and book chapters dealing with the theoretical and numerical treatment of continuous optimization problems. Her special interest lies in complementarity-type and bilevel optimization.

Special issue in Optimization

We are organizing a special issue in the journal *Optimization* to celebrate the outstanding contribution of Stephan Dempe to the field of bilevel optimization. All delegates are encouraged to submit a paper to contribute to this special issue by March 31st, 2024.

The associated call-for-papers addresses the growing research interest in optimization from the theoretical as well as from the application point of view. The objective of this special issue of *Optimization* is to present advances in different areas of mathematical optimization, especially in those areas covered by the research of Stephan Dempe, including theoretical, numerical, as well as application topics related to (optimistic and pessimistic) bilevel optimization, hierarchical optimization, Stackelberg games, min-max optimization, equilibrium- and complementarity-constrained optimization, robust optimization, semi-infinite optimization, and optimization under uncertainty.

Guest editors:

Mehlitz, Patrick	BTU Cottbus-Senftenberg (GER)
Morgan, Jacqueline	University of Naples Federico II (ITA)
Tammer, Christiane	MLU Halle-Wittenberg (GER)
Ye, Jane J.	University of Victoria (CAN)
Zemkoho, Alain B.	University of Southampton (GBR)

More details on how to submit your paper for the special issue can be found on the webpage of the journal (https://think.taylorandfrancis.com/special_issues/optimization-journal-mathematical-programming).

List of abstracts

Summer school

Bilevel optimization algorithms and models for contemporary energy challenges

Presenter: **Miguel F. Anjos**
Schedule: **Tue, 08:30 - 12:00, B2A - 2077**

The first part of the course will begin with the basic concepts of bilevel optimization. It will then focus on mathematical optimization algorithms for solving bilevel optimization problems. While most attention will be paid to the problems where the functions involved are linear or convex, some aspects of nonconvex problems will be discussed. The second part will present bilevel models that address contemporary challenges in electric energy systems.

Part I: Solving bilevel optimization problems

- I.1 Single-level reformulations
- I.2 Algorithms for linear and convex problems
- I.3 Nonconvex bilevel optimization: What is possible?

Part II: Models for contemporary electric energy challenges

- II.1 Residential demand response and energy storage
- II.2 Multinational carbon-credit market with distinct national strategies
- II.3 Unit commitment under demand uncertainty

Bilevel optimization in machine learning

Presenter: **Massimiliano Pontil, Ricardo Grazzi**
Schedule: **Tue, 13:15 - 16:45, B2A - 2077**

In this lecture, you will learn the challenges in solving bilevel machine learning problems. Popular examples are hyperparameter optimization and meta-learning. The focus will be on explaining efficient gradient based methods that rely only on gradients and Jacobian-vector products and on establishing theoretical quantitative guarantees for such methods.

Part I: Getting started

- I.1 Introduction and outline
- I.2 Machine learning applications overview: hyperparameter optimization, meta-learning, ...
- I.3 Characteristics of bilevel problems in machine learning: large-scale and simple constraints
- I.4 Implicit function theorem and the hypergradient
- I.5 Hypergradient approximation methods, pytorch implementation, and memory/time complexity

Part II: Putting things together

- II.1 Theoretical assumptions: smoothness and strong-convexity/contraction at the lower level
- II.2 Error rates for Approximate Implicit Differentiation (AID) and Iterative Differentiation (ITD)
- II.3 Convergence rates for AID-based inexact (projected) hypergradient descent
- II.4 Relaxing the assumptions: non-smoothness, multiple inner solutions, ...

Plenary talks

Transformation of bilevel optimization problems into single level ones

Presenter: **Stephan Dempe**
Schedule: **Wed, 09:15 - 10:15, B100 - 4011**

Bilevel optimization problems are hierarchical problems where the second (or lower-level) problem is a parametric optimization problem. For solving it, we need to transform it into a single-level problem. This can be realized using various approaches: we can replace the lower-level problem using its Karush–Kuhn–Tucker optimality conditions, apply Lagrange, Wolfe as well as Mond–Weir duality, or formulate a new constraint involving its optimal value function. The presentation deals with relations between the bilevel optimization problem and its single-level transformations, and also properties of the latter problems.

Bilevel optimization under uncertainty

Presenter: **Ivana Ljubić**
Schedule: **Wed, 15:00 - 16:00, B100 - 4011**

Significant algorithmic advances in the field of computational bilevel optimization allow us to solve much larger and also more complicated problems today compared to what was possible two decades ago. This results in more and more challenging bilevel problems that researchers try to solve today. In this talk, we will focus on one of these more challenging classes of bilevel problems: bilevel optimization under uncertainty. We will discuss classical ways of addressing uncertainties in bilevel optimization using stochastic or robust techniques. Moreover, the sources of uncertainty in bilevel optimization can be much richer than for usual, single-level problems, since not only the problem's data can be uncertain but also the (observation of the) decisions of the two players can be subject to uncertainty. Thus, we will also discuss bilevel optimization under limited observability, the area of problems considering only near-optimal decisions, and intermediate solution concepts between the optimistic and pessimistic cases.
The talk is based on joint work with Yasmine Beck and Martin Schmidt.

Matchmaking bilevel and Γ-robust optimization

Presenter: **Martin Schmidt**
Schedule: **Thu, 15:30 - 16:30, B100 - 4011**

Robust optimization is a prominent approach in optimization to deal with uncertainties in the data of the optimization problem by hedging against the worst-case realization of the uncertain event. Doing this usually leads to a multilevel structure of the mathematical formulation that is very similar to what we are used to consider in bilevel optimization. Hence, these two fields are closely related but the study of their combination is still in its infancy. In this talk, we show how branch-and-cut methods can be derived for solving discrete bilevel problems in which the follower tackles uncertainties in a Γ-robust way. Moreover, we discuss structural results showing that the Γ-robust bilevel problem can be solved by solving a polynomial set of nominal, i.e., certain, bilevel problems. By doing so, we generalize the famous result by Bertsimas and Sim for combinatorial optimization to combinatorial bilevel optimization.
The talk is based on joint work with Yasmine Beck and Ivana Ljubić.

Recent developments in solving bilevel optimization problems

Presenter: **Jane J. Ye**
Schedule: **Fri, 13:00 - 14:00, B100 - 4011**

A bilevel optimization problem is a sequence of two optimization problems where the constraint region of the upper-level problem is determined implicitly by the solution set to the lower-level problem. It can be used to model a two-level hierarchical system where the two decision makers have different objectives and make their decisions on different levels of hierarchy. Recently, more and more applications including those in machine learning have been modeled as bilevel optimization problems. In this talk, I will report some recent developments in optimality conditions and numerical algorithms for solving this class of very difficult optimization problems.

Contributed talks

A bilevel optimization model for retailer-consumer interaction in face of time-of-use tariffs

Presenter: **Carlos Henggeler Antunes**
Schedule: **Wed, 10:40 - 11:05, B100 - 5013**

In the electricity retail market, the retailer company aims to determine the optimal time-of-use (ToU) prices to maximize profit resulting from buying electricity in organized (long-term, day-ahead, balancing) markets and selling it to consumers. Therefore, the retailer should consider the consumer's reaction to minimize the electricity bill in face of time varying prices, which may derive from renewable generation availability and grid conditions. This problem is formulated as a bilevel mixed-integer nonlinear programming model in which the retailer is the leader and the consumer is the follower. The retailer's problem involves determining the electricity prices to be set in predefined time slots. The consumer's problem encompasses the integrated optimization of all home energy resources in face of ToU prices, considering re-scheduling appliance operation, charging/discharging of electric vehicle and stationary batteries, managing local generation, and (buying and selling) exchanges with the grid subject to quality of service constraints. The accurate physical modeling of appliance operation to generate effective load scheduling solutions imposes a high computational burden. The bi-level optimization model is presented and algorithmic approaches we have been using to deal with it are outlined, namely different ways to deal with the nonlinearities arising in the leader's and the follower's objective functions.
This talk is based on joint work with Maria João Alves and Inês Soares.

A harvest planning and scheduling problem in a hierarchical food supply chain through a stochastic bilevel program

Presenter: **Víctor M. Albornoz**
Schedule: **Wed, 11:05 - 11:30, B100 - 5013**

This contribution addresses a harvest planning problem in the context of a food supply chain, which integrates the definition of management zones for harvesting, and the coordination between the producer and the wholesaler. The problem is represented through a stochastic bilevel program that allows the representation of the hierarchy between the producer (leader) and a wholesaler (follower). The producer decides planning and scheduling the harvest of each homogeneous management zone into the resulting partition, and the wholesaler decides the amount to be acquired to satisfy demand requirements. At each decision level, a stochastic optimization model is proposed for representing the uncertainty in future crop yields, prices, and demands, using a finite set of scenarios. A reformulation of the bilevel model into a mixed-integer linear program is provided using Karush–Kuhn–Tucker conditions and replacing the nonlinear complementary constraints allowing for the introduction of auxiliary binary variables and a big-M term. This model was applied in a case study for selective harvesting of grapes with data collected from a farm. Our research shows valuable results of the proposed methodology from a set of instances representing the behavior of both decision makers.

Rejection-proof kidney exchange mechanisms

Presenter: **Bart Smeulders**
Schedule: **Wed, 11:30 - 11:55, B100 - 5013**

Kidney exchange programs (KEPs) increase kidney transplantation by facilitating the exchange of incompatible donors. Increasing the scale of kidney exchange programs leads to more opportunities for transplants, and collaboration between transplant organizations (agents) is thus desirable. As agents are primarily interested in providing transplants for their own patients, collaboration requires balancing individual and common objectives. In this talk, we consider ex-post strategic behavior, where agents can modify a proposed set of kidney exchanges. We introduce the class of rejection-proof mechanisms, which propose a set of kidney exchanges such that agents have no incentive to reject them. The problem of finding an optimal rejection-proof solution is naturally modeled as a bilevel integer program. To solve the problem, we formulate a large single-level integer program, with a constraint for each subset of agent's patients/donors. This integer program can be solved through a constraint generation procedure. We also describe heuristic mechanisms that are computationally less demanding. We show rejection-proofness can be achieved at a limited cost for typical instances. Furthermore, our experiments show that the proposed rejection-proof mechanism also removes incentives for strategic behavior in the more traditional ex-ante setting, where agents withhold information about their patients and donors.
This talk is based on joint work with Danny Blom and Frits C. R. Spieksma.

A bilevel optimization approach for poisoning attacks against linear regression

Presenter: **Zeynep Suvak**
Schedule: **Wed, 11:55 - 12:20, B100 - 5013**

Poisoning attacks are widely studied in the field of adversarial machine learning. The attacker that generates poison attacks can access to the training process of a machine learning algorithm and aims to prevent the algorithm from functioning properly by inserting malicious data while training the algorithm. In this work, we study poisoning attacks against linear regression models which target to deteriorate the power of prediction of the attacked regression model. A bilevel optimization problem is developed to model this adversarial process between the attacker generating poisoning attacks and the learner that tries to learn the best predictive regression model. We propose an alternative single-level optimization problem by using the optimality conditions of the learner's problem in the lower level. A commercial solver is used to solve the resulting single-level optimization problem where we generate the whole set of poisoning attack samples at once. Besides, an iterative approach that allows to determine only a portion of poisoning attack samples at every iteration is introduced. The proposed attack strategies are shown to be superior to a benchmark algorithm from the literature by carrying out extensive experiments on two realistic publicly available data sets.

This talk is based on joint work with Miguel F. Anjos, Luce Brotcorne, and Diego Cattaruzza.

Potential multi-leader follower games

Presenter: **Sonja Steffensen**
Schedule: **Wed, 10:40 - 11:05, B100 - 5015**

In this talk, we discuss a particular class of Nash games, where the players group into leaders and followers. Moreover, we consider the case, when the leaders' and/or the followers' game can be described as a potential (generalized) Nash game. This subclass has been introduced by Monderer and Shapley in 1996 and extended to generalized Nash equilibrium problems by Facchinei and colleagues. It has beneficial properties concerning its reformulations, which we will analyze and apply to the setting of multi-leader follower games. We develop necessary and sufficient conditions and derive existence and uniqueness results for this special class of Nash games.

Equilibrium selection via approximation and penalization

Presenter: **Giancarlo Bigi**
Schedule: **Wed, 11:05 - 11:30, B100 - 5015**

The selection of equilibria is a central issue in the management of multi-agent or multi-criteria systems that can be partially controlled. Once the system has been modeled, the selection can be performed through an hierarchical program whose lower level describes the equilibria of the system and the upper level explicitly addresses the selection criterion through a suitable objective function. These hierarchical programs are simpler than more general bilevel structures as the lower-level problems are non-parametric with respect to the upper-level variables. In order to tackle them, suitable approximated versions are introduced. On the one hand, the approximation does not perturb the original (exact) program too much and allows for some additional flexibility in the choice. On the other hand, it allows relying on suitable exact penalty schemes by recovering those regularity conditions that the original problems do not satisfy. These penalization approaches are addressed in detail and their convergence properties are established.

Asymptotic behavior of subgame perfect Nash equilibria in Stackelberg games

Presenter: **Maria Carmela Ceparano**
Schedule: **Wed, 11:30 - 11:55, B100 - 5015**

The study on how equilibria behave when perturbations occur in the data of a game is a fundamental theme, since actions and payoffs may be affected by uncertainty. In this presentation, we investigate the asymptotic behavior of Subgame Perfect Nash Equilibria (SPNEs) in one-leader one-follower Stackelberg games under perturbations both on the action sets and on the payoff functions. So we consider a general sequence of perturbed Stackelberg games satisfying non-restrictive assumptions and we face the question: is the limit of SPNEs (resp. SPNE-outcomes) of the perturbed games an SPNE (resp. an SPNE-outcome) of the original game? In the case of uniqueness of the follower's optimal reaction, the answer is positive both for the SPNEs and for SPNE-outcomes. Instead, in the non-uniqueness case, the answer is positive for the SPNE-outcomes but not for the SPNEs, as shown via an example. However, the issue of how 'far' is the limit of the SPNEs of the perturbed games from an SPNE of the original game is positively addressed. In fact, 'stability-but-for-a-point' holds: an SPNE can be obtained by possibly modifying the limit of SPNEs of the perturbed games at just one point.
This talk is based on joint work with Francesco Caruso and Jacqueline Morgan.

On construction of subgame perfect Nash equilibria in Stackelberg games

Presenter: **Francesco Caruso**
Schedule: **Wed, 11:55 - 12:20, B100 - 5015**

Identifying a Subgame Perfect Nash Equilibrium (henceforth SPNE) of a Stackelberg game could be not a manageable task, especially when the players have a continuum of actions and the followers do not have a unique optimal reaction to each choice of the leader. In this presentation we consider the issue of construction of SPNEs in two-player Stackelberg games by exploiting perturbations of both the action sets and the payoff functions of the leader and of the follower. Since the limit of SPNEs of perturbed games is not necessarily an SPNE of the original game even for classical perturbations, we illustrate how to generate an SPNE from the limit of SPNEs of general perturbed games. This result allows to describe a procedure to find an SPNE that can accommodate various types of perturbations. In fact, under mild assumptions on the data of the original game, we show that perturbations involving the Tikhonov regularization, the Shannon entropy, the proximal regularization and perturbations motivated by altruistic behaviors fit the procedure for constructing an SPNE. The specific SPNE selections associated to such perturbations and their possible behavioral interpretations are also presented.
This talk is based on joint work with Maria Carmela Ceparano and Jacqueline Morgan.

Clique interdiction problems

Presenter: **Fabio Furini**
Schedule: **Wed, 10:40 - 11:05, B100 - 5017**

Given a graph and an interdiction budget k, the Maximum Clique Interdiction Problem asks to find a subset of at most k vertices to remove from the graph so that the size of the maximum clique in the remaining graph is minimized. This problem is a two-player zero-sum Stackelberg game in which the leader interdicts (removes) a limited number of vertices from the graph, and the follower searches for the maximum clique in the interdicted graph. The leader's goal is to derive an interdiction strategy that results in the worst possible outcome for the follower. The problem has applications in many areas, such as crime detection, prevention of outbreaks of infectious diseases, and surveillance of communication networks. We provide several theoretical results concerning the problem complexity, derivation of combinatorial lower bounds, and conditions under which the input graphs can be safely reduced. We propose a single-level integer linear programming formulation of the problem that relies on an exponential family of Clique-Interdiction Cuts. The model is derived from a bilevel formulation of the problem. We give necessary and sufficient conditions under which these cuts are facet-defining. For the separation of these cuts (which requires solving the maximum clique problem), we develop an effective tailored procedure based on a combinatorial branch-and-bound algorithm. Our new approach provides a valuable tool for analyzing the resilience of (social) networks with respect to clique-interdiction attacks, i.e., the decrease of the size of the maximum clique as a function of an incremental interdiction budget level. On a benchmark set of publicly available instances, including large-scale social networks with up to one hundred thousand vertices and three million edges, we show that most can be analyzed and solved to proven optimality within a short computing time.
This talk is based on joint work with Ivana Ljubić, Sébastien Martin, and Pablo San Segundo.

An exact method for nonlinear network flow interdiction problems

Presenter: **Johannes Thürauf**
Schedule: **Wed, 11:05 - 11:30, B100 - 5017**

We study network flow interdiction problems with nonlinear and nonconvex flow models. The resulting model is a max-min bilevel optimization problem in which the follower's problem is nonlinear and nonconvex. In this game, the leader attacks a limited number of arcs with the goal to maximize the load shed and the follower aims at minimizing the load shed by solving a transport problem in the interdicted network. We develop an exact algorithm consisting of lower and upper bounding schemes that computes an optimal interdiction under the assumption that the interdicted network remains weakly connected. The main challenge consists of computing valid upper bounds for the maximal load shed, whereas lower bounds can directly be derived from the follower's problem. To compute an upper bound, we propose solving a specific bilevel problem, which is derived from restricting the flexibility of the follower when adjusting the load flow. This bilevel problem still has a nonlinear and nonconvex follower's problem, for which we then prove necessary and sufficient optimality conditions. Consequently, we obtain equivalent single-level reformulations of the specific bilevel model to compute upper bounds. Our numerical results show the applicability of this exact approach using the example of gas networks.
This talk is based on joint work with Martin Schmidt.

Active learning for generating scenario in stochastic programming

Presenter: **Enza Messina**
Schedule: **Wed, 11:30 - 11:55, B100 - 5017**

Stochastic Programming (SP) is a well-established framework for addressing sequential decision-making problems under uncertainty in which information is iteratively revealed over time and recourse actions can be taken to adjust one's solution to the new information that has become available. What distinguishes stochastic programming from other stochastic modeling approaches is its ability to explicitly model future decisions based on outcomes of stochastic parameters and initial decisions, and the associated costs of these future decisions. This endows SP with a clear hierarchical-optimization aspect, as any optimal decision taken at some stage must be made in anticipation of the recourse actions that will be taken at future stages. The power and flexibility of the stochastic programming approach comes at a price: stochastic programs are usually analytically intractable. Solution techniques for SP problems rely on the representation of the underlying stochastic process, commonly discretized and synthesized in a scenario tree of limited size. Due to this limitation, it is critical to include in the scenario-tree the most informative scenarios in order to avoid over-fitting and to ensure the reliability of the solution. In this talk, we will focus on a scenario generation method based on an Active Learning approach. This iterative process is guided by the optimization of first-stage decisions and by the evaluation of the recourse function of the subsequent stages, leading to more robust and efficient solutions.
This talk is based on joint work with Antonio Candelieri and Xiaochen Chou.

Multivariate second order stochastic dominance constraints for pension fund multistage stochastic models

Presenter: **Vittorio Moriggia**
Schedule: **Wed, 11:55 - 12:20, B100 - 5017**

Multistage stochastic programming models are often adopted in all type of Asset and Liability Management (ALM) problems including long-term asset allocation of pension fund. Recent implementations of such models introduce first order and second order of stochastic dominance constraints to improve the adaptability of an ALM model. In fact, the stochastic dominance constraints ensure that the optimal strategy is able to stochastically dominate a benchmark portfolio. The stochastic dominance allows to compare different portfolios and guarantees the preference of one portfolio to a benchmark portfolio under various utility functions. Most works propose univariate stochastic dominance constraints to guarantee the dominance of the optimal solution, while only few adopt a multivariate approach. In this work, we extend previous results in multivariate stochastic dominance considering alternative types that can be more suitable in a multistage framework. In particular, we propose a goal-based ALM model implemented in the form of multistage stochastic optimization model with second order dominance constraints. As a stress-test, we use the 'safety margin' concept to study the differences among the alternative definition of SSD in terms of economic cost of stochastic dominance constraints.
This talk is based on joint work with Sebastiano Vitali and Miloš Kopa.

The robust bilevel selection problem

Presenter: **Dorothee Henke**
Schedule: **Wed, 13:30 - 13:55, B100 - 5013**

In bilevel optimization problems, two players, the leader and the follower, make their decisions in a hierarchy, and both decisions influence each other. Usually one assumes that both players have full knowledge also of the other player's data. In a more realistic model, uncertainty can be quantified, e.g., using the robust optimization approach: Assume that the leader does not know the follower's objective function precisely, but only knows an uncertainty set of potential follower's objectives, and her aim is to optimize the worst case of the corresponding scenarios. Now the question arises how the computational complexity of bilevel optimization problems changes under the additional complications of this type of uncertainty. We make a step towards answering this question by examining an easy bilevel problem. In the bilevel selection problem, the leader and the follower each select some items, while a common number of items to select in total is given, and each of the two players maximizes the total value of the selected items, according to different sets of item values. We show that this problem can be solved in polynomial time without uncertainty and then investigate the complexity of its robust version. If the item sets controlled by the leader and by the follower are disjoint, it can still be solved in polynomial time in case of a finite uncertainty set or interval uncertainty. Otherwise, the robust problem version becomes NP-hard, even for a finite uncertainty set.

A 3-stage adaptive algorithm for nonlinear robust optimization

Presenter: **Kerstin Schneider**
Schedule: **Wed, 13:55 - 14:20, B100 - 5013**

Robust optimization deals with optimization problems under uncertainty. Two well-known approaches are min-max-regret and adjustable robustness. In adjustable robustness, the idea is that not every decision has to be made right now. Some decisions can be made later when a part of the uncertainty is known. Therefore, the decision variable may depend on some portion of the uncertainty set. This relation can be modeled by an affine linear decision rule. Usually, the objective in adjustable robustness is to optimize for the worst case. On the other hand, in min-max-regret robustness, the objective is to minimize the maximal regret, which is the distance of the objective value for the robust solution in one scenario to the optimal objective value of this scenario. We combine the affine linear decision rule with a min-max-regret ansatz. This gives us the flexibility to adjust our decision according to the realized uncertainty. And, instead of optimizing for an often too conservative worst case, the maximal regret over all scenarios is minimized. The combination results in a bilevel optimization problem. For solving this problem, we present a 3-stage algorithm which uses adaptive discretization of the uncertainty set via two criteria. We prove convergence results for this method and show its application to the problem of making a robust pump operation plan for a drinking water supply system with uncertain water demand.
This talk is based on joint work with Helene Krieg, Dimitri Nowak, and Karl-Heinz Küfer.

Robust bilevel approach to energy management in smart grids

Presenter: **András Kovács**
Schedule: **Wed, 14:20 - 14:45, B100 - 5013**

A plethora of bilevel optimization approaches to demand response management in smart grids has been proposed in the scientific literature. Yet, all classical deterministic approaches assume that the leader is perfectly aware of the decision problem of the follower. This assumption can hardly be satisfied in practice. To overcome this limitation, this talk proposes a robust bilevel programming approach, which assumes that the parameters of the follower are known imperfectly. A robust bilevel model is introduced with uncertainty in the follower's objective function coefficients in the form of polyhedral uncertainty sets. The follower's problem is encoded into a linear problem with the leader's variables appearing as parameters in the bilinear objective. For solving the robust problem, a column-and-constraint generation technique is proposed, which iteratively solves relaxations of the original problem with relevant discrete samples from the original uncertainty set. Experimental results are presented and the possibilities of generalizing the solution method to other robust bilevel problems with similar structure are discussed.
This talk is based on joint work with Tamás Kis and Csaba Mészáros.

An extended local convergence theory for Newton-type methods

Presenter: **Andreas Fischer**
Schedule: **Wed, 13:30 - 13:55, B100 - 5015**

Some classes of nonlinear complementarity systems, like optimality conditions for generalized Nash equilibrium problems, typically have nonisolated solutions. Their reformulation as a constrained or unconstrained system of equations is often done by means of a nonsmooth complementarity function. Degenerate solutions then lead to points where the reformulated system is nonsmooth. Newton-type methods can have difficulties close to solutions that are nonisolated and degenerate. For this case, it is known that the LP-Newton method or a constrained Levenberg—Marquardt method may show local superlinear convergence if the complementarity function is piecewise linear. These results rely on error bounds for active pieces of the reformulation. Using a somewhat different Index Error Bound Condition, we obtain a related result for a complementarity function that is not piecewise linear. To this end, a new convergence framework is developed that allows significantly larger steps. A sophisticated analysis of the constrained Levenberg–Marquardt method shows that local superlinear convergence in the vicinity of a potentially degenerate and nonisolated solution is possible with an R-order of at least 4/3. Moreover, several known local convergence results can be recovered.

Parameter learning in ℓ_2 Tikhonov regularization for inverse problems

Presenter: **Floriane Mefo Kue**
Schedule: **Wed, 13:55 - 14:20, B100 - 5015**

In this talk, we consider the problem of parameter learning in Tikhonov regularization for inverse problems. The learning problem is formulated as a bilevel optimization problem, where the lower-level problem is a Tikhonov regularized problem. We then consider the Karush–Kuhn–Tucker reformulation of the problem and subsequently build a tractable optimization problem by means of properties of the resolvent of an operator. We derive a semismooth Newton method for solving the surrogate problem and then apply the method on a typical inverse problem.

A semismooth Newton-type algorithm for solving pessimistic bilevel optimization problems

Presenter: **Lateef O. Jolaoso**
Schedule: **Wed, 14:20 - 14:45, B100 - 5015**

We consider the pessimistic bilevel optimization problem in which it is assumed that there is no cooperation between the leader and the follower. By means of KKT reformulation, we transform the bilevel optimization problem to a single-level problem and employ the concept of partial calmness to treat the latter problem in order to obtain a more tractable feasible set for the problem. This framework leads to a semismooth system of equations and thus, we develop a semismooth Newton-type algorithm to solve the optimization problem. We study the global convergence properties of the semismooth system and formulate appropriate regularity assumptions which guarantee that a solution of the semismooth system is a local solution of the bilevel optimization problem. We further perform extensive numerical experiments to show that our method is a tractable approach to solve pessimistic bilevel optimization problems.
This talk is based on joint work with Alain B. Zemkoho.

Mixed integer bilevel programming methods for solving pessimistic multi-follower bilevel problems over simplices

Presenter: **Stefano Coniglio**
Schedule: **Wed, 13:30 - 13:55, B100 - 5017**

We investigate pessimistic multi-follower mixed integer bilevel problems with simplicial feasible regions. Such problems arise when looking for an equilibrium in a Stackelberg game with two or more non-cooperating followers who react to the leader's strategy by "agreeing" on playing "the" worst (from the leader's perspective) Nash Equilibrium. We focus on the case where the followers are restricted to pure strategies (for which the lower-level problem is integer). After illustrating different hardness and inapproximability results, we propose a single-level (undecidable) reformulation for the problem. We then investigate the design of exact solution (i.e., equilibrium-finding) algorithms with finite convergence, and propose an exact implicit enumeration algorithm capable of computing the supremum of the problem as well as an α-approximate solution, for any $\alpha > 0$. The viability of our approach is illustrated by extensive experimental results.

Exact methods for discrete min-max problems with a Γ-robust lower level

Presenter: **Yasmine Beck**
Schedule: **Wed, 13:55 - 14:20, B100 - 5017**

Developing solution methods for discrete bilevel problems is known to be a challenging task - even if all parameters of the problem are exactly known. However, many real-world applications of bilevel optimization involve uncertain data. In this talk, we study discrete min-max problems in which the parameters of the lower-level problem may be uncertain. We adopt a Γ-robust approach, present tailored reformulations, and provide two generic branch-and-cut frameworks. Specifically, we study interdiction problems with a Γ-robust follower for which we derive problem-tailored cuts. Finally, we computationally assess the performance of the proposed methods using the example of Γ-robust knapsack interdiction problems.

Asymmetry in the complexity of the multi-commodity network pricing problem

Presenter: **José Neto**
Schedule: **Wed, 14:20 - 14:45, B100 - 5017**

The network pricing problem (NPP) is a bilevel optimization problem where the leader sets the prices of some arcs in a network so as to maximize the revenue generated from their use by the followers (commodities) whose routing decisions correspond to shortest paths (depending on the prices set by the leader). We investigate the complexity of NPP with respect to the number of tolled arcs and the number of commodities. Whereas the problem can be solved in polynomial time if the number of tolled arcs is fixed, it becomes NP-hard otherwise even for the case where there is a single commodity. We characterize this asymmetry in the complexity with a novel property named strong bilevel feasibility. An algorithm which is based on this property to generate valid inequalities for NPP is presented, together with numerical results illustrating its performance on instances with a high number of commodities.
This talk is based on joint work with Quang Minh Bui and Margarida Carvalho.

About a constrained abs-smooth solver for single retailer bilevel problems with neutral customers

Presenter: **Timo Kreimeier**
Schedule: **Thu, 09:00 - 09:25, B100 - 5013**

In this talk, we consider the optimal tariff choice of a single retailer and risk-neutral consumers under uncertain wholesale prices. This allows us to address the structure of the bilevel problem faced by a retailer. Using standard KKT theory and a suitable reformulation of the resulting complementarity condition by the max-function, we obtain a constrained single-level nonsmooth optimization problem. To solve this problem we provide a novel solver based on the successive abs-linearization approach for the nonlinear and nonsmooth objective function. The piecewise linear constraints are represented in the so-called abs-linear form – a matrix-vector representation. This allows us to handle them in an inner subproblem by the Constrained Active Signature Method, a solver for constrained piecewise linear optimization problems. The talk concludes with a presentation of first numerical results for examples motivated by the energy market.
This talk is based on joint work with Adrian Schmidt, Ann-Kathrin Wiertz, Andrea Walther, and Gregor Zöttl.

On constraint qualifications for nonsmooth multiobjective mathematical programming problems with complementarity constraints on Hadamard manifolds

Presenter: **Balendu Bhooshan Upadhyay**
Schedule: **Thu, 09:25 - 09:50, B100 - 5013**

In this talk, we consider a class of nonsmooth multiobjective mathematical programming problems with complementarity constraints in the framework of Hadamard manifolds. We will introduce several types of constraint qualifications for such programs and establish relations among them using the properties of the Clarke subdifferential. Moreover, we will also derive Karush–Kuhn–Tucker type necessary optimality conditions employing suitable constraint qualifications.

On quasidifferentiable mathematical programs with complementarity constraints in Banach spaces

Presenter: **Vivek Laha**
Schedule: **Thu, 09:50 - 10:15, B100 - 5013**

The presentation deals with mathematical programs with complementarity constraints involving quasidifferentiable functions defined over a real Banach space. We develop Fritz–John and Karush–Kuhn–Tucker type necessary optimality conditions in terms of quasidifferentials of the functions at an optimal point. As these optimization problems do not satisfy standard constraint qualifications, we provide suitable versions of some constraint qualifications in terms of quasidifferentials. Some sufficient optimality conditions are also examined under generalized convexity assumptions. Some future research possibilities are discussed to accommodate a large class of nonsmooth and nonconvex optimization problems.

Crowd motion paradigm modeled by a bilevel sweeping control problem

Presenter: **Nathalie Khalil**
Schedule: **Thu, 09:00 - 09:25, B100 - 5015**

The talk will concern an optimal crowd motion control problem in which the crowd features a structure given by its organization into two groups (participants) each one spatially confined in a set. The overall optimal control problem consists in driving the ensemble of sets as close as possible to a given point (the "exit") while the population in each set minimizes its control effort subject to its sweeping dynamics with a controlled state-dependent velocity drift. In order to capture the conflict between the goal of the overall population and those of the various groups, the problem is cast in a bilevel optimization framework. A key challenge of this problem consists in bringing together two quite different paradigms: bilevel programming and sweeping dynamics with a controlled drift. Necessary conditions of optimality in the form of a Maximum Principle of Pontryagin are derived. These conditions are then used to solve a simple illustrative example with two participants, emphasizing the interaction between them.
This talk is based on joint work with Tan Cao, Boris S. Mordukhovich, Dao Nguyen, and Fernando L. Pereira.

Demand tracking via inverse optimal control

Presenter: **Patrick Mehlitz**
Schedule: **Thu, 09:25 - 09:50, B100 - 5015**

Given an optimal control problem with a quadratic target-type objective function over a linear differential equation, we are interested in recovering the noised desired state (which represents some kind of *demand* in several practically relevant situations) from given observations (like state-control pairs, obtained from some solver, which are approximately optimal). This results in a model problem of bilevel structure. In the absence of control constraints, the model can be reformulated as a single-level convex optimization problem in many different settings, and as soon as the underlying differential equation is of simple enough structure, the numerical solution of this surrogate problem can be realized without difficulty. This is visualized by means of an example from inverse demand tracking over a tree-shaped transportation network governed by hyperbolic conservation laws. In the presence of control constraints, we make use of the popular value function approach of bilevel optimization to transfer the model into a single-level optimal control problem which is typically not convex. In order to solve the problem to global optimality, we iteratively approximate the value function from above by a piecewise affine function, and the resulting surrogate problem can be tackled by a decomposition approach. Some global convergence results of the associated solution method are presented. Numerical experiments addressing the optimal control of Poisson's equation illustrate the theory.
This talk is based on joint work with Stephan Dempe, Simone Göttlich, Thomas Schillinger, and Gerd Wachsmuth.

Proximal methods for point source localization

Presenter: **Tuomo Valkonen**
Schedule: **Thu, 09:50 - 10:15, B100 - 5015**

This talk concerns the point source localization problem

$$\min_{0\leq\mu\in\mathcal{M}(\Omega)} F(Ax-b)+\|\mu\|_{\mathcal{M}(\Omega)}$$

in the space $\mathcal{M}(\Omega)$ of Radon measures on the domain $\Omega\subset\mathbb{R}^n$. While convex, and therefore in principle easy, the space $\mathcal{M}(\Omega)$ poses challenges for numerical optimization, lacking Hilbert space structure. In fact, the dual formulation of this problem is a semi-infinite program, hence a bilevel program. Practical algorithms also involve two levels of optimization: an inner algorithm to discover points to insert into the support of μ, and an outer algorithm to update the weights of such points. Most such numerical methods presented in the literature for such point source localization problems are based on the Frank–Wolfe conditional gradient method. In this talk, we pose the question: *why are proximal-type methods amenable to this type of problems – or are they?* We answer affirmatively, developing variants of forward-backward splitting, its inertial version, and primal-dual proximal splitting for the problem of interest. Their convergence proofs follow standard patterns. We demonstrate their numerical efficacy.

A comparison of a hybrid meta-heuristic with a deterministic procedure for a bilevel optimization model for electricity dynamic pricing

Presenter: **Maria João Alves**
Schedule: **Thu, 09:00 - 09:25, B100 - 5017**

In this work, two distinct algorithmic approaches are considered to deal with a bilevel mixed-integer optimization problem in electricity retail market: - a hybrid approach combining a particle swarm optimization algorithm to deal with the upper-level problem and an exact solver to tackle the lower-level problem; - a deterministic bounding procedure (DBP) based on an optimal-value- function reformulation. In the problem studied, the retailer (leader) defines dynamic energy prices aiming to maximize profit; the consumers (follower) respond by rescheduling appliance operation to minimize costs while guaranteeing the appropriate levels of quality of service. The consumer's energy decisions affect the retailer's profit. The performance of the two approaches is compared regarding solution quality and computational effort. When the subproblems of DBP do not impose an excessive computational burden, the DBP is able to obtain the optimal solution displaying a much better performance than the hybrid approach. However, when the model becomes more complex (in our case due to the consideration of a thermostatic appliance in the consumer's problem) and the problem size increases (by considering a discretization of the planning period into shorter intervals), the DBP presented several difficulties. The results showed that the hybrid approach can be useful when it is not possible to solve subproblems to optimality, since it could reach solutions competitive or better than the ones of the DBP.
This talk is based on joint work with Carlos Henggeler Antunes and Inês Soares.

An exhaustive review of metaheuristics for bilevel optimization

Presenter: **José-Fernando Camacho-Vallejo**
Schedule: **Thu, 09:25 - 09:50, B100 - 5017**

The inherent complexity of bilevel optimization models limits the development of efficient exact solution methods. Therefore, alternative algorithms are needed, such as heuristics and metaheuristics. In this presentation, we will focus only in metaheuristic algorithms. The design and implementation of effective metaheuristics that produce good-quality solutions in acceptable computational time for bilevel problems has been an active research area. This study aims to review all the published papers devoted to implementing metaheuristics for solving bilevel problems up to December 31th of 2022. A bibliometric analysis is performed to track the evolution of this topic. Also, the journals and authors with more contributions are identified. The specific components of the proposed metaheuristics are described in detail, independent of the inspiration behind the metaheuristics. A detailed analysis of the combination of components is included to determine the more common ones. Also, the manner in which the crucial bilevel aspects of the problem are handled is classified. Particularly, the type of approach considered for designing the metaheuristic is noted (nested, single-level reformulation, co-evolutionary, and biobjective transformation if the metaheuristics assume a unique follower's reaction, the optimistic or pessimistic approaches). A discussion regarding the interesting findings is given and some promising recent approaches are mentioned. This talk is based on joint work with Carlos Corpus and Juan G. Villegas.

A scatter search approach with path relinking for solving bilevel linear programming problems

Presenter: **Carmen Galé**
Schedule: **Thu, 09:50 - 10:15, B100 - 5017**

The linear bilevel programming problem was one of the earliest bilevel programs to be addressed in the literature. Even in this case, it has been proven that these problems are NP-hard, rendering them computationally challenging. Most of the proposed algorithms take advantage of the mathematical properties of the linear bilevel problem to develop procedures specifically tailored to this problem. In this work, a metaheuristic algorithm based on scatter search is developed. Scatter search is a population-based evolutionary method that has been successfully applied to hard optimization problems. This method uses diversification and intensification strategies for searching and has been demonstrated to be effective in a wide range of optimization problems. In the context of bilevel programming, it has been used to tackle specific integer bilevel problems that arise in logistics processes, such as facility location or service pricing. Our objective is to solve general linear bilevel problems using a scatter search heuristic algorithm that makes use of the existence of an extreme point in the problem's polyhedron, which is an optimal solution to the problem. In addition, the metaheuristic integrates a path relinking strategy, which involves exploring paths connecting two given solutions to identify possible better solutions in terms of the upper-level objective function. The construction of these paths takes into account the geometric properties of the optimal solution to the linear bilevel problem. A computational experiment has been conducted to evaluate the effectiveness of the procedure by comparing the results with those obtained by other algorithms on a set of benchmark instances from the literature.
This talk is based on joint work with Herminia I. Calvete, José A. Iranzo, and Manuel Laguna.

Strategic bidding in electricity markets with AC Power Flow market clearing

Presenter: **Martina Cerulli**
Schedule: **Thu, 10:40 - 11:05, B100 - 5013**

In this work, we study the strategic behavior of producers connected to an Alternating Current (AC) electricity network, where the market is regulated by an Independent System Operator (ISO) carrying out the market clearing. We focus on a pay-as-bid AC electricity market in which each producer provides the ISO with a bid used to derive directly its revenues and the market clearing is performed by taking into account the AC power flow constraints. This scenario can be modeled as a multi-leader-single-follower game, and solved seeking the Nash equilibrium, which occurs when each producer can find no alternative bid to improve his/her revenues, assuming that the other producers hold their bids constant. In order to do it, we use a diagonalization method, which solves, at each iteration, several single-leader single-follower problems through a tailored cutting plane algorithm. To benchmark our results, we consider also an unrealistic scenario in which all the producers act together (in a sort of cartel), trying to maximize the sum of their profits. We successfully test the approaches on small-scale instances.
This talk is based on joint work with Claudia D'Ambrosio, Leo Liberti, and Martin Schmidt.

A bilevel approach for mixed-integer quantile minimization problems

Presenter: **Martine Labbé**
Schedule: **Thu, 11:05 - 11:30, B100 - 5013**

We consider mixed-integer linear quantile minimization problems that yield large-scale problems that are very hard to solve for real-world instances. We motivate the study of this problem class by two important real-world problems: a maintenance planning problem for electricity networks and a quantile-based variant of the classic portfolio optimization problem. Then, for these problems, we develop a family of valid inequalities that is obtained by formulating the quantile minimization problem as a bilevel linear optimization problem. We study the computational impact of these inequalities and finally show that their combination with other techniques such as scenario clustering leads to an overall method that can solve the maintenance planning problem on large-scale real-world instances provided by the ROADEF challenge 2020 and that they also lead to significant improvements when solving a quantile-version of the classic portfolio optimization problem.
This is a joint work with Diego Cattaruzza, Matteo Petris, Marius Roland, and Martin Schmidt.

Optimal deployment of electric vehicle charging infrastructure via bilevel optimization

Presenter: **Miguel F. Anjos**
Schedule: **Thu, 11:30 - 11:55, B100 - 5013**

The increase of electric vehicle (EV) adoption in recent years has correspondingly increased the importance of providing adequate charging infrastructure for EV users. For a charging service provider, the fundamental question is to determine the optimal location and sizing of charging stations with respect to a given objective and subject to budget and other practical constraints. One possible objective is to maximize EV adoption as part of a public policy on electric transportation. Alternatively, the objective may be to maximize the profit gained from providing this service, in which case the price of charging is also to be optimized. These problems are fundamentally combinatorial and frequently formulated using mixed-integer linear optimization. In this talk, the focus will be on the use of bilevel optimization in this area, in particular to more accurately capture the interactions between the charging service provider and the EV users.
This talk is based on joint work with Ikram Bouras, Luce Brotcorne, and Alemseged Weldeyesus.

On unboundedness and infeasibility of linear bilevel optimization problems

Presenter: **Bárbara Rodrigues**
Schedule: **Thu, 11:55 - 12:20, B100 - 5013**

Bilevel optimization problems are known to be challenging to solve in practice. In particular, the feasible set of a bilevel problem is in general non-convex, even for linear bilevel problems. We are concerned with better understanding the feasible set of linear bilevel programs. Specifically we seek to develop means to identify when a bilevel problem is unbounded or infeasible. In this presentation, we show that extending the well-known High Point Relaxation with lower-level dual information can be relevant to detect when a bilevel problem is infeasible due to unboundedness of its lower-level problem. Moreover, we present a new linear model to detect that the bilevel problem is unbounded in the case when that unboundedness originates from the upper-level variables alone. Finally, we derive sufficient conditions to guarantee bilevel boundedness.
This talk is based on joint work with Miguel F. Anjos.

Bilevel hyperparameter optimization for non-linear support vector machines

Presenter: **Anthony Dunn**
Schedule: **Thu, 10:40 - 11:05, B100 - 5015**

This presentation addresses the problem of hyperparameter selection for non-linear kernel Support Vector Machines (SVMs) using cross-validation and bilevel optimization. While sampling-based strategies such as grid search and random search are commonly used to obtain a satisfactory hyperparameter selection, here we explore the use of bilevel optimization to approximate solutions to the problem of tuning the hyperparameters via cross validation. Previous works in this area have focused on linear kernel SVMs, however, here we focus on the Radial Basis Function (RBF) kernel, a non-linear kernel which is more suitable for many practical domains. We formalize the dual form of the RBF kernel SVM training problem and formulate the bilevel optimization problem for hyperparameter optimization via k-fold cross-validation. Our proposed approach demonstrates promising results.
This talk is based on joint work with Stefano Coniglio, Qingna Li, and Alain B. Zemkoho.

Bilevel optimization for selecting hyperparameters for nonlinear support vector machines

Presenter: **Samuel Ward**
Schedule: **Thu, 11:05 - 11:30, B100 - 5015**

Nonlinear support vector machines are a staple of classification. They require the user to tune specific parameters such as the regularization term and choice of kernel. Traditionally, this tuning has been approximated using cross validation and a grid search but this method scales very poorly with the number of hyperparameters. In this research presentation, we will introduce bilevel optimization and use this framework to model the hyperparameter turning problem. From here, we introduce stationarity concepts and constraint qualifications for bilevel programs. We will conclude with our solution method and numerical experiments.

A fast smoothing Newton method for bilevel hyperparameter optimization in logistic classification

Presenter: **Qingna Li**
Schedule: **Thu, 11:30 - 11:55, B100 - 5015**

Logistic classification is a classical and well-performed learning method in machine learning. A regularization parameter, which significantly affects the classification performance, has to be chosen and this is usually done by the cross-validation procedure. In this talk, we reformulate the hyperparameter selection problem for logistic classification as a bilevel optimization problem in which the upper-level problem minimizes logistic loss of misclassified data points over all the cross-validation folds. The resulting bilevel optimization model is then converted to a KKT system with an extra lower bound constraint. To solve this system, we propose a smoothing Newton method, which is proved to converge to a strict local minimizer of the nonlinear system. Extensive numerical results verify the efficiency of the proposed approach, in particular, compared with other methods.

LP-Newton based global relaxation method for bilevel hyperparameter selection in support vector machines

Presenter: **Yaru Qian**
Schedule: **Thu, 11:55 - 12:20, B100 - 5015**

Support Vector Machines (SVMs) are widely recognized and effective tools for classification tasks, but their performance relies on the selection of appropriate hyperparameters. In this research, our focus is on identifying the optimal value for the regularization hyperparameter, as well as determining the bound constraints of features for the purpose of feature selection in the support vector classification model. Conventional approaches to hyperparameter selection, such as grid search, exhibit limited flexibility in accommodating multiple machine learning objectives and are typically constrained by the number of hyperparameters. To address this challenge, we formulate the problem as a bilevel optimization problem, leveraging T-fold cross-validation. Subsequently, we transform this problem into a mathematical program with linear complementarity constraints (MPCC). Our initial contribution involves proving the MPCC-MFCQ (MPCC-tailored variant of the Mangasarian–Fromovitz constraint qualification) property of the resulting MPCC. Furthermore, we introduce a novel LP-Newton based global relaxation method for solving this problem and provide corresponding convergence results for the method. The advantages of our proposed method are notable. Theoretically, our algorithm does not require additional assumptions for convergence. Numerically, the subproblems encountered in our approach are formulated as linear programming problems, which can be effectively solved by well-established solvers. The numerical results substantiate the superiority of our method over grid search and the global relaxation approach solved by the nonlinear programming solver SNOPT.
This talk is based on joint work with Qingna Li and Alain B. Zemkoho.

Using disjunctive cuts in a branch-and-cut procedure to solve convex integer bilevel programs

Presenter: **Andreas Horländer**
Schedule: **Thu, 10:40 - 11:05, B100 - 5017**

We present a new branch-and-cut method for solving integer bilevel problems with a convex objective function and convex constraints both in the upper and in the lower level. To this end, we generalize the idea of using disjunctive cuts from the literature to separate bilevel-infeasible points. We obtain the cuts by solving a cut generating problem that can be decomposed into a series of smaller subproblems, most of which can be solved in parallel. We prove the correctness of the method and present its applicability by some first numerical results.

A branch-and-bound scheme for a class of partial inverse combinatorial optimization problems

Presenter: **Eva Ley**
Schedule: **Thu, 11:05 - 11:30, B100 - 5017**

We consider partial inverse optimization problems, which are bilevel optimization problems in which the leader aims to incentivize the follower to include a given set of elements in the solution of their combinatorial problem. For solving partial inverse combinatorial optimization problems with only weight increases, we present a new branch-and-bound scheme. In this talk, we focus on the partial inverse shortest path problem with only weight increases. Branching on follower variables, the scheme relies on two different methods that are basically complete inverse shortest path problems on similar graphs, which are known to be solvable in polynomial time. Computational experiments suggest that for dense graphs our branch-and-bound scheme outperforms an MPCC reformulation as well as a decomposition scheme. This talk is based on joint work with Maximilian Merkert.

Generalized interdiction cuts for monotone interdiction games

Presenter: **Danny Blom**
Schedule: **Thu, 11:30 - 11:55, B100 - 5017**

Interdiction games are a special class of adversarial Stackelberg games, in which the leader and the follower make decisions based on a common set of resources. In an interdiction game, the leader is endowed with an interdiction budget, with which they can decide to prohibit certain resources to be used by the follower. Consequently, the follower optimizes their own objective while using only non-interdicted resources. Hence, in order to compute an optimal interdiction strategy, the leader needs to solve a bilevel optimization problem. A typical approach is to rewrite this problem with a single-level reformulation with so-called interdiction cuts for each possible follower solution. The problem can then be solved using a branch-and-cut method that iteratively adds violated interdiction cuts to the model. The effectivity of a single interdiction cut is often rather limited, as such cuts do not incorporate "fallback" options whenever the follower solution suffers from interdictions. In this talk, we focus on the class of *monotone* interdiction games. We introduce two classes of interdiction cuts that incorporate fallback options based on partitioning the set of follower variables. This generalizes variants of interdiction cuts for monotone interdiction games studied in the literature. Furthermore, we provide algorithms for separating violated cuts in a branch-and-cut framework and computationally verify their benefit based on a commonly used test bed of instances.
This talk is based on joint work with Christopher Hojny and Bart Smeulders.

A fast combinatorial algorithm for the bilevel knapsack problem with interdiction constraints

Presenter: **Noah Weninger**
Schedule: **Thu, 11:55 - 12:20, B100 - 5017**

We consider the bilevel knapsack problem with interdiction constraints, a fundamental bilevel integer programming problem. In this problem, there are two knapsacks and n items. The objective is to select some items to pack into the first knapsack such that the maximum profit attainable from packing some of the remaining items into the second knapsack is minimized. Previous exact solution methods for this problem use mixed-integer programming solvers. We present a combinatorial branch-and-bound algorithm which outperforms the current state-of-the-art solution method in computational experiments on 99% of the instances reported in the literature. On many of the harder instances, our algorithm is hundreds of times faster, and it solved 53 of the 72 previously unsolved instances. Our result relies fundamentally on a new dynamic programming algorithm which computes very strong lower bounds. This dynamic program solves a relaxation of the problem from bilevel to $2n$-level where each level only considers whether to pack a single item. The relaxation is easier to solve but approximates the original problem surprisingly well in practice. Our open-source implementation can solve typical instances with $n \leq 1000$, and by using sparse dynamic programming tables, can handle instances with arbitrarily large knapsack capacity if n is small. We also generalize our method to some related problems. We believe that a similar relaxation may be useful for other bilevel problems.
This talk is based on joint work with Ricardo Fukasawa.

A quantization procedure for bilevel pricing problems with an application to electricity markets

Presenter: **Quentin Jacquet**
Schedule: **Thu, 13:30 - 13:55, B100 - 5013**

Electricity retail markets are now open to competition in most countries, and providers are free to design a menu of offers/contracts in addition to regulated alternatives (fixed prices), so that each consumer can select among the vast jungle of offers the one which maximizes his utility. In this work, the choice of a contract is based on the minimization of the invoice (rational choice theory). A standard approach consists in constructing an incentive-compatible menu of contracts, i.e., a menu composed of as many contracts as customers, where each contract is especially adapted to a specific customer, taking his type into account. However, a key problem for electricity providers is to design an optimal menu of offers, maximizing their revenue, under a restriction on the "size" of the menu (number of contracts). Given this size, the problem can be modeled by a bilinear bilevel problem, in the same vein as the product pricing problem, but can be highly difficult to solve for a large number of consumers (followers). We show that the question of limiting the number of offers reduces to an optimal quantization problem, similar to the pruning problem that appeared in the max-plus based numerical methods in optimal control. This problem has been proved to be NP-Hard, and we develop here a new quantization heuristic, which, given an initial menu of contracts, iteratively prunes the less important contracts, to construct an implementable menu of the desired cardinality, while minimizing the revenue loss. We apply this algorithm to solve a pricing problem with price-elastic demand, originating from the electricity retail market. Numerical results show an improved performance by comparison with earlier pruning algorithms.
This talk is based on joint work with Wim van Ackooij, Clémence Alasseur, and Stéphane Gaubert.

A multilevel model of the European entry-exit gas market under market power

Presenter: **Ann-Kathrin Wiertz**
Schedule: **Thu, 13:55 - 14:20, B100 - 5013**

We consider a four-level model of the European entry-exit gas market from the literature. At levels 1 and 4, the welfare-maximizing system operator decides on technical capacities and corresponding booking prices, and organizes gas transport. Gas trade between sellers and buyers is modeled at the market levels 2 and 3. So far, gas sellers have typically been assumed to be competitive in the literature. In contrast, we now focus on a single price-setting firm that sells gas at multiple network locations. This allows us to assess possible welfare losses caused by market power in the entry-exit system. To this end, we compare different degrees of price discrimination. Due to the four-level structure and the nonlinear modeling of gas transport, the problem is highly challenging. To tackle the additional challenge of market power, we study the bilevel problem formed by the new market levels and provide techniques to reformulate it as a concave maximization problem with linear constraints. This allows us to also provide a single-level reformulation of the four-level problem that we solve for several networks and different degrees of price discrimination. Our numerical results indicate that price discrimination has a significant impact on the seller's profit and on the overall welfare. More precisely, in our setup with gas transport on a network, the seller's profit and the overall welfare can decrease with a higher degree of price discrimination.
This talk is based on joint work with Veronika Grimm, Julia Grübel, Martin Schmidt, Alexandra Schwartz, and Gregor Zöttl.

Capacitated single allocation hub interdiction problems: model formulations and solution approaches

Presenter: **Saikat Mukherjee**
Schedule: **Thu, 14:20 - 14:45, B100 - 5013**

Logistics, transportation, and distribution are sensitive aspects of maintaining smooth flows in a network. Hub and Spoke network is an efficient structure where hubs act as facility nodes to the non-hubs, i.e., spoke nodes. Many-to-many industries like e-commerce, telecommunication, and power supply adopt this network. In real-life scenarios, hubs and linking arcs have specific capacities for routing. Uncertain occurrences or interdiction problems may affect critical nodes in this network. Previous literature considered uncapacitated hub and spoke network interdiction problems with single and multiple allocation protocols. In this work, we prepare a bi-level interdiction model, where the interdictor, acting first, compels the decision-maker to decide on the remaining strategies. This model is based on the Stackelberg game between the interdictor and decision-maker considering capacitated network with a single allocation protocol. We prepare formulation and solution approaches for this problem. We also present several model variants based on the branch and cut framework to solve this problem efficiently for large-scale instances.
This talk is based on joint work with Prasanna Ramamoorthy.

Best Response Intersection: an optimal algorithm for interdiction defense

Presenter: **Andrew Mastin**
Schedule: **Thu, 14:45 - 15:10, B100 - 5013**

We define the interdiction defense problem as a game over a set of targets with three stages: a first stage where the defender protects a subset of targets, a second stage where the attacker observes the defense decision and attacks a subset of targets, and a third stage where the defender optimizes a system using only the surviving targets. We present a novel algorithm for optimally solving such problems that uses repeated calls to an attacker's best response oracle. For cases where the defender can defend at most k targets and the attacker can attack at most z targets, we prove that the algorithm makes at most $\binom{k+z}{k}$ calls to the oracle. In application to the direct current optimal power flow problem, we present a new mixed-integer programming formulation with bounded big-M values to function as a best response oracle. We use this oracle along with the algorithm to solve a defender-attacker-defender version of the optimal power flow problem. On standard test instances, we find solutions with larger values of k and z than shown in previous studies, and with running times that are an order of magnitude faster than column and constraint generation.
This talk is based on joint work with Arden Baxter, Amelia Musselman, and Jean-Paul Watson.

Bilevel optimization with a lower-level contraction: optimal sample complexity without warm-start

Presenter: **Riccardo Grazzi**
Schedule: **Thu, 13:30 - 13:55, B100 - 5015**

We analyze a general class of bilevel problems, in which the upper-level problem consists in the minimization of a smooth objective function and the lower-level problem is to find the fixed point of a smooth contraction map. This type of problems includes instances of meta-learning, equilibrium models, hyperparameter optimization and data poisoning adversarial attacks. Several recent works have proposed algorithms which warm-start the lower-level problem, i.e., they use the previous lower-level approximate solution as a staring point for the lower-level solver. This warm-start procedure allows one to improve the sample complexity in both the stochastic and deterministic settings, achieving in some cases the order-wise optimal sample complexity. However, there are situations, e.g., meta learning and equilibrium models, in which the warm-start procedure is not well-suited or ineffective. In this work we show that without warm-start, it is still possible to achieve order-wise (near) optimal sample complexity. In particular, we propose a simple method which uses (stochastic) fixed point iterations at the lower-level and projected inexact gradient descent at the upper-level, that reaches an ϵ-stationary point using $O(\epsilon^{-2})$ and $\tilde{O}(\epsilon^{-1})$ samples for the stochastic and the deterministic setting, respectively. Finally, compared to methods using warm-start, our approach yields a simpler analysis that does not need to study the coupled interactions between the upper-level and lower-level iterates.

Stackelberg games for adversarial machine learning

Presenter: **David Benfield**
Schedule: **Thu, 13:55 - 14:20, B100 - 5015**

Adversarial machine learning concerns the situation where data miners face attacks from active adversaries. In particular, the underlying distribution of the data used by the data miner to train machine learning models is vulnerable to significant changes made by the adversary. The interactions between the data miner and the adversary can be modeled as a game between two players. While many game theoretic models exist, some of these assume that the players act simultaneously. However, in the case of adversarial learning, a perhaps more appropriate assumption is that players can observe their opponent's actions before making their own. For example, spam email senders might probe an email filter by sending test emails before deploying their final products. Furthermore, the amount of information available to each player can drastically influence their decision process. We present a Stackelberg game model where players act sequentially and which restricts the availability of information. In this Stackelberg model, the two players are each assigned a role of either the leader, who acts first, or the follower, who acts second. This gives us two possible approaches to modeling our adversarial scenario, depending on who takes on these roles. Focusing on the case where the data miner takes the role of the leader, we explore how pessimistic bilevel optimization can be used to model adversarial learning scenarios before developing and testing a solution method.
This talk is based on joint work with Alain B. Zemkoho, Vuong Phan, and Stefano Coniglio.

A bilevel-driven local search approach for hyperparameter tuning in machine learning

Presenter: **Ankur Sinha**
Schedule: **Thu, 14:20 - 14:45, B100 - 5015**

Hyperparameter optimization is a computationally demanding task as it involves training multiple machine learning models and selecting the best model based on validation performance. We formulate the hyperparameter optimization problem as a bilevel program where the lower-level optimization represents minimization of training loss and the upper-level optimization represents minimization of validation loss. The lower-level variables are the model parameters and the upper-level variables are the hyperparameters. Any feasible solution to this problem represents a valid machine learning model for a given set of hyperparameters. We propose a hyper local search technique to improve validation performance by searching for better machine learning hyperparameters and model parameters. The hyper local search is motivated by the bilevel steepest descent approach and we show that with some assumptions the problem can be reduced to a linear program. The hyper local search has been integrated with various sampling-based hyperparameter tuning methods, such as grid search, random search, Tree-structured Parzen Estimator, and Quasi-Monte Carlo Sampler. We conduct experiments using two commonly used datasets - MNIST and CIFAR-10, and also demonstrate the usefulness of the approach in transfer learning scenarios. The empirical results confirm that the proposed approach effectively refines the hyperparameters and model parameters of the model leading to improved performance on the target task.
This talk is based on joint work with Satender Gunwal.

Inexact algorithms for bilevel learning

Presenter: **Mohammad Sadegh Salehi**
Schedule: **Thu, 14:45 - 15:10, B100 - 5015**

Estimating hyperparameters is a long-standing problem in variational regularization methods. We consider the case where hyperparameters are learned using bilevel learning, which leads to a nested optimization problem. However, due to the numerical methods employed for solving the lower-level problem and the computational cost associated with obtaining highly accurate solutions, the exact computation of gradients with respect to hyperparameters is infeasible. This necessitates the use of methods relying on approximate lower-level solutions and gradients. In this talk, we present an analysis of hypergradient estimation and its error bound. We introduce an inexact backtracking line search within a dynamic framework that adaptively determines the required accuracy of both the lower-level solution and hypergradient estimate. Our line search ensures sufficient decrease and convergence in the exact function while only having access to the inexact components. We specifically validate the empirical performance of this framework within the variational regularization context. Furthermore, we conduct comprehensive numerical comparisons to evaluate and compare the effectiveness of different methods on an image denoising problem.

Preconditioned proximal-type methods for bilevel optimization

Presenter: **Ensio Suonperä**
Schedule: **Thu, 13:30 - 13:55, B100 - 5017**

Bilevel problems have been traditionally solved through either treating the inner problem as a constraint, and solving the resulting Karush–Kuhn–Tucker conditions using a Newton-type solver; or by trivializing the inner problem to its solution mapping. The latter approach in principle requires near-exact solution of the inner problem for each outer iterate. Moreover, an adjoint equation typically needs to be solved to calculate the differential of the inner problem solution mapping. Recently, intermediate approaches have surfaced that solve the inner problem and occasionally the adjoint as well to a low precision, and still obtain some form of convergence. In this talk, we discuss the linear convergence of methods based on taking interleaved steps of proximal-type methods on both the inner and outer problem, and computationally cheap steps for the adjoint. We demonstrate numerical performance on imaging applications.
This talk is based on joint work with Tuomo Valkonen.

A smoothing gradient-based augmented Lagrangian method for constrained bilevel programs

Presenter: **Mengwei Xu**
Schedule: **Thu, 13:55 - 14:20, B100 - 5017**

Based on the novel augmented Lagrangian method of multipliers for optimization problems with inequality constraints, we propose a smoothing gradient-based augmented Lagrangian method for bilevel programs, where the lower-level problems involve inequality constraints. Gradient-based methods are effective in handling the bilevel programs with unconstrained lower-level problems. By using the augmented Lagrangian method, we propose a family of smoothing functions to approximate the solution mapping of the lower-level problem with inequality constraints, which is Lipschitz continuous under suitable conditions. The bilevel problem can be approximated by a sequence of single-level problems by substituting the smoothing functions for the lower-level solution mapping into the upper-level problem. We combine the gradient-based method with the augmented Lagrangian method for solving the resulting constrained problem. We show that any accumulation point of the iteration sequence generated by the algorithm is a Clarke stationary point of the bilevel problem or a Bouligand stationary point if an additional verifiable condition holds. Preliminary numerical experiments illustrate our theoretical results.

Value function-based relaxation for bilevel optimization

Presenter: **Isabella Käming**
Schedule: **Thu, 14:20 - 14:45, B100 - 5017**

We consider the lower-level value function reformulation (LLVF) of the standard optimistic bilevel programming problem. The value function constraint included in this reformulation typically behaves very badly, since it causes, for example, that standard constraint qualifications are violated at each feasible point. An approach to avoid such issues is to consider a corresponding relaxed problem. To obtain the relaxed problem, the value function constraint is relaxed by allowing a deviation $\epsilon > 0$ from the optimal value of the lower level problem. This relaxed problem behaves quite differently and standard constraint qualifications may be satisfied in its feasible points. Moreover, there exist several numerical algorithms in the literature that can be used to compute stationary points of the relaxed problem. From a theoretical point of view, it is therefore interesting to investigate under which conditions a sequence of stationary points of the relaxed problem converges to a stationary point of (LLVF) when the relaxation parameter ϵ is iteratively sent towards zero. In this talk, such a condition is presented.
This talk is based on joint work with Andreas Fischer and Alain B. Zemkoho.

Scholtes relaxation method for pessimistic bilevel optimization

Presenter: **Alain B. Zemkoho**
Schedule: **Thu, 14:45 - 15:10, B100 - 5017**

When the lower-level optimal solution set-valued mapping of a bilevel optimization problem is not single-valued, we are faced with an ill-posed problem, which gives rise to the optimistic and pessimistic bilevel optimization problems, as tractable algorithmic frameworks. However, solving the pessimistic bilevel optimization problem is far more challenging than the optimistic one; hence, the literature has mostly been dedicated to the latter class of the problem. The Scholtes relaxation has appeared to be one of the simplest and efficient ways to solve the optimistic bilevel optimization problem in its Karush–Kuhn–Tucker (KKT) reformulation or the corresponding more general mathematical program with complementarity constraints (MPCC). Inspired by such a success, this work studies the potential of the Scholtes relaxation in the context of the pessimistic bilevel optimization problem. To proceed, we consider a pessimistic bilevel optimization problem, where all the functions involved are at least continuously differentiable. Then assuming that the lower-level problem is convex, the KKT reformulation of the problem is considered under the Slater constraint qualification. Based on this KKT reformulation, we introduce the corresponding version of the Scholtes relaxation algorithm. We then construct theoretical results ensuring that a sequence of global/local optimal solutions (resp. stationarity points) of the aforementioned Scholtes relaxation converges to a global/local optimal solution (resp. stationarity point) of the KKT reformulation of the pessimistic bilevel optimization. The results are accompanied by technical results ensuring that the Scholtes relaxation algorithm is well defined. In this talk, we will provide a brief overview of the results of this work, as well as some numerical results on the implementation of the Scholtes relaxation for computing C-stationary points. This talk is based on joint work with Imane Benchouk, Lateef O. Jolaoso, and Khadra Nachi.

Combining transformations and a quadratically convergent adaptive discretization method to solve generalized semi-infinite optimization problems

Presenter: **Tobias Seidel**
Schedule: **Fri, 09:00 - 09:25, B100 - 5013**

Especially in geometric tasks like the optimal usage of gemstones, semi-infinite constraints can be used to describe subset and separation conditions in a general form. Unfortunately, the simple description of the problems has its price. A semi-infinite problem is often harder to solve than a finite non-linear problem. Nevertheless, different strategies have been developed to solve these problems. A classic approach, which is easy to implement, is based on discretizing the semi-infinite index set and solving a sequence of resulting finite problems. In this talk, we show that the classical and widely used adaptive discretization algorithm of Blankenship and Falk generally leads to a slow convergence rate. Using the bilevel structure, we developed a new way to choose discretization points adaptively. The resulting algorithm guarantees a quadratic rate of convergence under standard regularity assumptions. We focus on the extension of this method to the generalized semi-infinite case using a transformation. We present results showing that all properties of the standard semi-infinite case can be transferred. Moreover, we will show that suitably chosen transformations can even improve the convergence properties of the method.

Semi-infinite optimization for shape-constrained regression

Presenter: **Miltiadis Poursanidis**
Schedule: **Fri, 09:25 - 09:50, B100 - 5013**

Shape-constrained regression is an active subfield of informed machine learning that aims to incorporate shape constraints into regression problems. Shape constraints, such as boundedness, monotonicity, or convexity, restrict the shape of the regression function over the entire domain. Shape-constrained regression problems can be formulated as semi-infinite optimization problems that are typically convex. In our work, we propose an adaptive discretization algorithm for convex semi-infinite optimization with the following properties: first, the algorithm terminates at a feasible point whose value deviates from the optimal value of the problem only by a preset error bound. For general semi-infinite optimization problems, the best possible precision of the approximate solution can be arbitrarily bad. Second, the algorithm terminates after a finite number of iterations, and we provide an upper bound on the number of iterations. Third, the discretizations performed by the algorithm are considerably smaller thanks to an exchange-type procedure. Fourth, all occurring finite optimization subproblems in our algorithm need to be solved only approximately. Moreover, strict feasibility is the only assumption made on the feasible set and it can easily be verified for a given shape-constrained polynomial regression problem. In the end, we apply the algorithm to a real-world example from quality prediction in manufacturing.
This is a joint work with Jochen Schmid.

Computing T-optimal designs via two-stage semi-infinite programming and adaptive discretization

Presenter: **Jan Schwientek**
Schedule: **Fri, 09:50 - 10:15, B100 - 5013**

When modeling real processes, often several different models fit. For being able to distinguish, or *discriminate*, which *model* is best suited, one is often interested in so-called *T-optimal designs*. These consist of the points, where the two models deviate most, under the condition that the models are fitted best on those points to each other. Thus, this is a max-min (bilevel) optimization problem. Firstly, these problems were solved by dedicated descent methods, which are very robust, but only converge slowly. Later, techniques from semi-infinite optimization have been applied either linearizing the inner parameter estimation problem or refining a discretization of the parameter space. While the former approach leads to performant, but unreliable algorithms, the latter requires the solution of the estimation problem to global optimality which is time-consuming. If one considers a finite number of candidate design points instead, a numerically well tractable linear semi-infinite optimization problem (LSIP) arises. Since, this yields only an approximate solution of the original problem, we propose an algorithm which alternately and adaptively refines discretizations of the parameter as well as of the design space and, thus, solves a sequence of LSIPs. We prove convergence of our method and show by means of discrimination tasks from chemical engineering that our approach is stable and can outperform the known methods.
This talk is based on joint work with David Mogalle, Philipp Seufert, Michael Bortz, and Karl-Heinz Küfer.

A global solver for optimistic semivectorial bilevel problems

Presenter: **Daniel Hoff**
Schedule: **Fri, 09:00 - 09:25, B100 - 5015**

In semivectorial bilevel optimization one considers an optimization problem, the upper-level problem, which contains a solution set of a multiobjective optimization problem, the lower-level problem, as a constraint. Within this talk, we follow the optimistic approach, i.e., we choose the weakly efficient points of the lower-level problem that are most suitable for the upper-level objective function. As a next step, we replace the weak efficiency map of the lower-level problem by using its optimal value function and obtain the so-called value function reformulation. Based on that, we present a global solver for optimistic semivectorial bilevel problems. The proposed branch-and-bound method refines suitable partitions until the approximations of the value function, and thus the lower and upper bound on the minimal value, are sufficiently close.
This talk is based on joint work with Gabriele Eichfelder.

Value functions of bilevel optimization with multiobjective lower-level problems in infinite-dimensional Banach spaces

Presenter: **Weihao Mao**
Schedule: **Fri, 09:25 - 09:50, B100 - 5015**

The study of bilevel optimization problems involving multiobjective lower-level problems in infinite-dimensional Banach spaces has widespread applications across various fields. One crucial aspect when addressing these problems is the examination of continuity and subdifferentials of the value function. Many regular conditions and properties have been proposed to characterize solution maps of the lower-level problem for value functions. However, these conditions are challenging to verify or do not hold in most infinite-dimensional Banach spaces due to the absence of interior points in the ordering cones of these spaces. This talk employs the theory of generating spaces of convex sets to investigate conditions and properties that can yield local Lipschitz continuity and enable subdifferential calculations in infinite-dimensional Banach spaces.

Simple bilevel programming: theory and algorithms

Presenter: **Joydeep Dutta**
Schedule: **Fri, 10:40 - 11:05, B100 - 5013**

In this talk we shall discuss the theory and algorithms for the simple bilevel programming problem. The simple bilevel programming problem seeks to minimize a convex function over the solution set of another convex optimization problem. Symbolically this is given as

$$\min f(x), \quad \text{subject to} \quad x \in \arg\min_C g,$$

where f and g are a convex functions and C is a convex set. Our first step would be to show that the difficulties that we see in the usual bilevel programming problem are carried over into this simpler structure too and also in order to motivate we shall introduce the algorithm for this problem due to Solodov, which is the first algorithm for this problem to the best of our knowledge. Then we shall discuss the theoretical developments associated with this particular class of problem which is now becoming very important in many applications. We will end the talk by introducing few more algorithms associated with the simple bilevel problem by using different assumptions on the problem data, mainly the assumption of differentiability or the lack of it.
This talk is based on joint work with Stephan Dempe, Nguyen Dinh, and Tanushree Pandit.

On the existence of solutions in bilevel stochastic linear programming with integer variables

Presenter: **Johanna Burtscheidt**
Schedule: **Fri, 11:05 - 11:30, B100 - 5013**

Stochastic bilevel problems arise from the interplay between two decision makers on different levels of hierarchy where the lower level problem is entered by a random vector. In our context, we add lower-level integrality constraints to a bilevel stochastic linear program where the right-hand side of the lower-level constraint system is affected by the leader's choice as well as the realization of some random vector. Based on that the upper-level goal function in the optimistic setting lacks lower semicontinuity and the existence of an optimal solution cannot be guaranteed under standard assumptions. Assuming that only the follower decides under complete information, we employ a special class of risk measures to assess the upper-level outcome. Confining the analysis to the cases where the lower-level feasible set is finite, we provide sufficient conditions for Hölder continuity of the leader's risk functional and draw conclusions about the existence of optimal solutions. Finally, we examine qualitative stability with respect to perturbations of the underlying probability measure. Considering the topology of weak convergence, we prove joint continuity of the objective function with respect to both the leader's decision and the underlying probability measure.
This talk is based on joint work with Matthias Claus.

Non-convex optimization methods for finding regret-minimization predictions

Presenter: **Víctor Bucarey**
Schedule: **Fri, 10:40 - 11:05, B100 - 5015**

Optimization problems often involve unknown parameters; a commonly applied approach to circumvent this issue is to use observations of these parameters and predict them before optimizing. One important property of this "Predict, then Optimize" framework is that it optimizes prediction error, which may not necessarily yield the best decisions under parameter uncertainty. As an alternative, Elmachtoub and Grigas (2021) proposed the "Smart Predict, then Optimize" framework to generate prediction models that minimize decision error instead. Here, a prediction model is designed by minimizing a "regret" function which captures the error of making a sub-optimal decision due to an inaccurate prediction. The resulting problem can be formulated as a pessimistic bilevel optimization problem which is inherently non-convex; Elmachtoub and Grigas thus propose a convex surrogate to obtain tractability. In this talk, we focus on solution methods for the exact non-convex pessimistic bilevel optimization problem. We reformulate the problem as a quadratically-constrained problem and show an extensive computational study in shortest-path instances comparing different solution methods, both existing and new.
This talk is based on joint work with Sophia Calderón and Gonzalo Munoz.

Learning the follower's objective in sequential bilevel games

Presenter: **Ioana Molan**
Schedule: **Fri, 11:05 - 11:30, B100 - 5015**

Bilevel problems model the hierarchical interaction between two decision makers in which the follower's problem appears as a constraint in the leader's problem. In many practical situations, some parts of the follower's problem may not be explicitly known by the leader. In this talk, we consider lower-level problems having quadratic objective functions with only partially known coefficients. We present two inverse optimization methods to learn the unknown objective function. The first method is based on the multiplicative weights update (MWU) algorithm and the second one is similar to an inverse KKT method known in literature. We analyze the convergence of the MWU-based method and show the applicability of both approaches using the examples of bilevel knapsack and pricing problems.
This talk is based on joint work with Martin Schmidt and Johannes Thürauf.

Posters

An evolutionary approach to pessimistic bilevel optimization problems

Presenter: **Margarita Antoniou**
Schedule: **Thu, 16:30 - 17:45, B100 - 4013**

When dealing with bilevel optimization, there are two common approaches for making an assumption regarding the lower-level behavior; the optimistic and the pessimistic approach. In the optimistic approach, it is assumed that the lower-level will choose a solution that is favorable for the upper-level, while in the pessimistic approach, it is assumed that the lower-level may choose the solution not favorable to the upper level. There are numerous studies that make use of Evolutionary Algorithms (EAs) to successfully solve bilevel problems. To date, these studies have mostly focused on the optimistic variant of the problem. This work aims to extend the usage of EAs to the pessimistic variant as well. The proposed approach utilizes a nested differential evolution to handle both the upper and the lower level. To ensure convergence to the pessimistic solution, a penalty parameter is used to penalize the lower-level objective based on the values of the upper-level objective. The nested algorithm achieves good convergence accuracy for a number of known test functions, demonstrating the effectiveness of the proposed approach. The findings highlight the potential of using EAs to solve pessimistic bilevel optimization problems.
This poster is based on joint work with Ankur Sinha and Gregor Papa.

On the solution of shape optimization for the Navier–Stokes problem with the stick-slip condition

Presenter: **Vladimír Arzt**
Schedule: **Thu, 16:30 - 17:45, B100 - 4013**

The shape optimization for the Navier–Stokes problem with the stick-slip boundary condition can be modeled as a bilevel problem, where the upper-level optimization task is described as the minimization of a given objective function with respect to the control variables that control the shape of the boundary (the objective function also depends on state variables). The lower-level optimization task is the Navier–Stokes problem with the boundary condition for a given boundary shape described by the control variable. Its solution is the state variables (velocity and pressure). The shape optimization problem can also be modeled as the minimization of the composite function generated by the objective and the control-state mapping (it is a mapping that maps control variables to state variables and is obtained as a solution to the Navier–Stokes problem). It can be shown that this composite function is generally nonsmooth. To solve the nonsmooth optimization problem, we have to use methods that work with the calculus of Clarke. We use the bundle trust method proposed by Schramm and Zowe. In each step of the iteration process, we must find the solution of the state problem, i.e., the Navier–Stokes problem with the stick-slip condition, and compute one arbitrary Clarke subgradient of the nonsmooth composite function. Finite differences are used for the approximation of this subgradient. The state problem contains two nonlinearities. The first caused by the convective term is linearized by Oseen or Newton iterations, and the second caused by the nonlinear stick-slip condition is solved by a semi-smooth Newton method with preconditioned BiCGstab as an inner solver.

A genetic algorithm for bilevel knapsack problems

Presenter: **Shraddha Ghatkar**
Schedule: **Thu, 16:30 - 17:45, B100 - 4013**

Health care projects worldwide are primarily taken care by the country where these are implemented and a central donor agency that aids the funding of these projects. A bilevel knapsack problem has been proposed in the literature to capture the funding mechanism involving two participants – the donor agency (leader) and the recipient country (follower). The cost values of health care projects are the same for both participants, but profit values may be different for them. Both the participants aim to maximize their respective profits. In the upper-level problem, the donor allocates subsidies such that the total subsidy is within her budget and the selected projects are in the optimal solution set of the lower-level recipient problem. In the lower-level problem, there is an external project which is of interest only to the recipient. The recipient is solving a knapsack problem to maximize her profit with the cost subsidized health care projects and the external project. We have proposed a genetic algorithm for the donor-recipient bilevel knapsack problem. The numerical experiments demonstrate effectiveness of the genetic algorithm on realistic instances when compared to solutions given by exact solvers -– an enumerative algorithm and a branching technique, proposed in the literature. The realistic instances are usually large-sized and are computationally expensive for the exact solvers. The solution gaps for the observed instances have improved by 5 to 10% in the experiments performed and hence useful insights can be drawn from these for further development in bilevel knapsack problems.
This poster is based on joint work with Ashwin Arulselvan and Alec Morton.

An inflation and time discount-oriented EOQ model with lot-splitting shipments under trade credit

Presenter: **Tien-Yu Lin**
Schedule: **Thu, 16:30 - 17:45, B100 - 4013**

This research proposes mathematical models that consider uncertain factors, such as inflation rates and trade credit periods, in lot-splitting shipments within the economic order quantity (EOQ) framework. By using a discounted cash flow approach, the objective is to minimize the present value of the annual total relevant cost while examining optimal shipment numbers and order quantities over a finite horizon. The proposed model optimizes under uncertainty for credit period, inflation, and time value of money, providing valuable guidance for decision-making in supply chain management to minimize costs. By incorporating these uncertainties into the model, we developed a two-stage solution procedure to solve a mathematical model with two decision variables - one is a continuous random variable, and the other is an integer-type random variable. We first use optimization theory to convert the two-variable function into a single-variable function, and then develop an algorithm to find an optimal solution. Our analysis highlights the impact of uncertainty on EOQ model decisions, showing the benefits of lot-splitting and ordering cycle extension in high inflation and longer credit periods. The inclusion of optimization under uncertainty into the EOQ models demonstrates that future changes in economic conditions can be anticipated and prepared, leading to improved cost savings and efficiency in supply chain management.

Addressing optimistic bilevel multi-follower problems

Presenter: **Valerio Giuseppe Sasso**
Schedule: **Thu, 16:30 - 17:45, B100 - 4013**

We consider optimistic bilevel multi-follower problems. Specifically, we address problems where the upper-level feasible set is implicitly defined as the set of equilibria of a lower-level Nash Equilibrium Problem. Although this class of mathematical programs encompasses significant real-world applications (e.g. multi portfolio selection problems), there are no available methods for computing stationary points of this nonconvex problem. To tackle the nontrivial structure of a bilevel program in a multiagent setting, we devise an easily implementable scheme based on the sequential convex approximation paradigm. Our proposed algorithm also takes into account the possible inexactness in solving the iteratively generated subproblems, resulting in a realistic analysis. By addressing a relaxed version of the original problem, we are able to prove the feasibility of the generated sequence, and for the first time, we show convergence to stationary points of this complicated framework for our proposed method.

A pessimistic branch and cut algorithm for competing objectives in metabolic engineering

Presenter: **Jose Alexander Vindel-Garduno**
Schedule: **Thu, 16:30 - 17:45, B100 - 4013**

The purpose is to present a new algorithm to solve a hierarchical problem with competing objectives in metabolic engineering to generate risk-averse strategies. The idea to modify a microbe's structure to increase the production of a desired chemical is not new. Methods to alter an organism's structure can be found in the metabolic engineering literature. There are already algorithms to suggest optimistic gene deletions. The literature points to mixed integer bilevel programming and its single-level reformulations as the predominant methodology. However, to the best of our knowledge, there is only one contribution to solving the pessimistic approach. Our proposed methodology is based on a branch and cut (B&C) algorithm. Our algorithm was not just able to reproduce the solutions from the single-level reformulation but in some cases, the algorithm's performance (solving time) was even faster. We expanded our B&C for the pessimistic case by modifying the cuts and found an even better solving time. Thus, our B&C algorithm can suggest strategies within a reasonable solving time both for the pessimistic and optimistic approaches. Hierarchical structures with competing objectives can be found in most research fields. Therefore, presenting our methodology to solve pessimistic bilevel problems has a positive impact as it expands both the literature and the tools available.
This poster is based on joint work with Ashwin Arulselvan and Mahdi Doostmohammadi.

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Nationality shortcuts

AUS	Australia
BEL	Belgium
CAN	Canada
CHN	China
CMR	Cameroon
CZE	Czech Republic
CHI	Republic of Chile
FIN	Finland
FRA	France
GBR	United Kingdom
GER	Germany
HUN	Hungary
IND	India
ITA	Italy
KOR	Republic of Korea
MEX	Mexico
NED	Netherlands
POR	Portugal
SLO	Slovenia
USA	United States of America