An exact approach for aggregated formulations

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THE PROGRAM

ISMP

BERLIN

2012
1. How many navigable road kilometers do TomTom maps cover worldwide?
   A) 34.8 million  
   B) 42.0 million  
   C) 68.9 million

2. What is the total length of the entire Berlin road network?
   A) 5,200 km  
   B) 6,300 km  
   C) 7,400 km

3. What was the total distance travelled in Berlin by TomTom users reporting anonymously speed data from January until March 2012?
   A) 2,483,178 km  
   B) 5,205,726 km  
   C) 7,738,423 km

4. How many traffic jams does TomTom HD Traffic detect and broadcast in a typical afternoon rush hour in Berlin?
   A) 26  
   B) 85  
   C) 120

5. How long did an average driver with a daily commute of 30 minutes free-flow travel time spend in traffic jams in Berlin in 2011?
   A) 35 hours  
   B) 69 hours  
   C) 83 hours

6. In which hour of the week is traffic slowest going west on Straße des 17. Juni in front of the TU Berlin main building?
   A) Mondays @ 17:00-18:00  
   B) Tuesdays @ 17:00-18:00  
   C) Fridays @ 16:00-17:00

7. The plots below show average jam lengths (Y-axis) over time (X-axis) on the entire German Autobahn network. Which one of the plots depicts a Thursday, which one a Friday and which one a Saturday?
   A)  
   B)  
   C)  

Quiz forms can be found in the conference bag. Quiz results will be announced at the TomTom Minisymposium Wednesday, 22 Aug, 13:15-14:45, H104.

Looking for a job at e.g. TomTom Berlin: http://tomtom.jobs
WELCOME TO ISMP 2012

On behalf of the ISMP 2012 Organizing Committee, the Technische Universität Berlin, and the Mathematical Optimization Society, I welcome you to ISMP 2012, the 21st International Symposium on Mathematical Programming.

The symposium covers all theoretical, computational, and practical aspects of mathematical optimization. With roughly six-hundred invited and contributed sessions, fifteen invited state-of-the-art lectures, five history lectures, totaling well over seventeen-hundred presentations, this is by far the largest ISMP so far. Roughly two-thousand participants from more than sixty countries all over the world will learn about the most recent developments and results and discuss new challenges from theory and practice. These numbers are a clear indication of the importance of Mathematical Optimization as a scientific discipline and a key technology for future developments in numerous application areas.

Berlin is an exciting city that has experienced dramatic political, economical and social changes within the past 25 years. The opening ceremony of ISMP 2012 will take place at the Konzerthaus on the historic Gendarmenmarkt which is considered one of the most beautiful squares in Europe. The conference dinner will take place at the Haus der Kulturen der Welt ("House of the Cultures of the World") located in the Tiergarten park with a beer garden on the banks of the Spree river and a view on the German Chancellery. I hope that you will also find the time to take a look around Berlin on your own, to obtain a feeling for the vibrant life style, and to explore the many attractions of this wonderful city.

Finally, I would like to express my sincere appreciation to all of the many volunteers who made this meeting possible. I wish to acknowledge, in particular, the members of the program committee, the cluster chairs, and the many session organizers for setting up the scientific program. My sincere thanks go to the members of the organizing committee and everyone involved in the local organization – the system administrators, secretaries, student assistants, PhD students, and postdocs – for the many days, weeks and even months of work.

I wish you all an enjoyable and memorable ISMP 2012 in Berlin.

Berlin, August 2012

Martin Skutella
THANKS TO OUR SPONSORS

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The opening ceremony takes place on Sunday, August 19, 18:00, at the “Konzerthaus am Gendarmenmarkt”.

Chair: Günter M. Ziegler
Musical accompaniment: Berliner Sibelius Orchester
Conducted by Vinzenz Weissenburger

Welcome addresses
- Martin Skutella
  (Organizing Committee Chair)
- Nicolas Zimmer
  (Permanent Secretary for Economics, Technology and Research of the State of Berlin)
- Paul Uwe Thamsen
  (First Vice President of the Technische Universität Berlin)
- Philippe Toint
  (Chair of the Mathematical Optimization Society)

Awards
- Dantzig Prize for original research which by its originality, breadth and depth, is having a major impact on the field of mathematical optimization
- Lagrange Prize for outstanding works in the area of continuous optimization
- Fulkerson Prize for outstanding papers in the area of discrete mathematics
- Beale-Orchard-Hayes Prize for excellence in computational mathematical programming
- Tseng Lectureship for outstanding contributions in the area of continuous optimization, consisting of original theoretical results, innovative applications, or successful software development
- Tucker Prize for an outstanding doctoral thesis: Announcement of the three finalists

Reception
The opening ceremony is followed by a reception with a magnificent view on Gendarmenmarkt.
OVERVIEW OF EVENTS

Registration
- Sunday, August 19, 15:00–18:00
  Konzerthaus Berlin
  (Gendarmenmarkt, 10117 Berlin)
- Monday, August 20, 07:00–18:30
  Main Building of TU Berlin
  (Straße des 17. Juni 135, 10623 Berlin)
- Tuesday through Friday, August 21–24, 7:30 – 18:30
  Main Building of TU Berlin
  (Straße des 17. Juni 135, 10623 Berlin)
- From Monday through Friday, the central activities like registration etc. will take place in the Main Building of the TU Berlin (Straße des 17. Juni 135). The conference office and the information desk are located in the lobby of the Main Building.
  For a detailed map of the campus and the buildings please see page 25.
- Airport Registration Service: From Friday, August 17, 14:00, through Sunday, August 19, 16:00, ISMP 2012 would like to welcome you at the Berlin airports TXL and SXF.
  Find more details on how to obtain this service on the ISMP 2012 webpage (http://ismp2012.mathopt.org).

Opening Ceremony and Reception
Sunday, August 19, 18:00, at the Konzerthaus am Gendarmenmarkt, featuring symphonic music by the Berliner Sibelius Orchester; followed by a reception with beverages and some fingerfood (see 3).
  Please consult the ISMP Berlin Guide for instructions on how to get to the Konzerthaus.

Awards
During the opening ceremony, the following prizes will be awarded: Dantzig Prize, Lagrange Prize, Fulkerson Prize, Beale-Orchard-Hayes Prize, and Tseng Memorial Lectureship. Moreover, the Tucker Prize finalists will be announced.
  The Tucker Prize will be awarded during the Tucker Prize Session on Monday at 10:30 in room MA 041 (Math Building) followed by presentations by the finalists.
  The Tseng Memorial Lecture will take place on Tuesday at 17:00 in room H 0105 (Main Building).

Plenary and Semi-Plenary Lectures
Featured state-of-the-art lectures are given by 15 distinguished speakers. (See page 8.)

Historical Lectures
Five special history lectures are scheduled reporting on work of Euler, Leibniz, Weierstrass, Minkowski, and the inventor of the electronic computer Konrad Zuse. (See page 16.)

Parallel Sessions
More than 1700 talks are given in almost 600 invited and contributed sessions. See program on page 30 and, in more detail, on page 74.
  All alterations in the scientific program and other important information for participants will be announced on a message board near the information desk in the lobby of the Main Building.

Conference Dinner
The conference dinner will take place on Wednesday, August 22, 19:00, at the Haus der Kulturen der Welt ("House of the Cultures of the World") located in the Tiergarten park with a beer garden on the shores of the Spree river and a view on the German Chancellery.
  Tickets are 40 € and can be purchased at the ISMP registration desk.
  Please consult the ISMP Berlin Guide for instructions on how to get to the Haus der Kulturen der Welt.

Receptions
- Monday, August 20, 18:00
  Informal welcome reception at TU Berlin with soft drinks, beer and pretzels.
- Friday, August 24, 18:00
  Farewell gathering at TU Berlin with beverages and snacks.

MOS Business Meeting
The business meeting of the Mathematical Optimization Society (MOS) will take place on Tuesday, August 21, at 18:15 in room H 0105.
REGISTRATION AND GENERAL INFORMATION

Registration. Your registration fee includes admittance to the complete technical program and most special programs.

The following social/food events are also included: Opening ceremony including reception on Sunday evening, welcome reception on Monday evening, farewell gathering on Friday evening, and all morning and afternoon coffee breaks.

The Wednesday evening conference dinner requires a separate payment of 40 €.

Badges required for conference sessions. ISMP badges must be worn at all sessions and events. Attendees without badges will be asked to go to the registration desk to register and pick up their badges.

All attendees, including speakers and session chairs, must register and pay the registration fee.

Conference dinner tickets. The Wednesday evening conference dinner is open to attendees and guests who registered and paid in advance for tickets. The tickets are included in your registration envelope. There may be a limited number of tickets available on site. Go to the ISMP registration desk to inquire. Tickets are 40 €.

Questions and information. The organizers, staff of the conference desk, and the student assistants will be identifiable by colored name tags and orange T-shirts. Please contact them if you have any questions.

Do not hesitate to inquire about all necessary information concerning the conference, orientation in Berlin, accommodation, restaurants, going out, and cultural events at the information desk which is located in the lobby of the Main Building.

Getting around by public transport. The conference badge allows you to use all public transport in and around Berlin (zone ABC) during the symposium from August 19 to August 24. In order to identify yourself, you need to carry along your passport or national ID card. Please refer to the ISMP Berlin Guide for more information on public transport in Berlin.

Internet access. If your home university participates in eduroam and you have an account, you can directly connect to eduroam WiFi at TU Berlin.

Otherwise, for using the WiFi network in the TU Berlin, eduroam guest accounts will be provided to you. You will receive the username and password with your registration. To access the WiFi network, you will need to install certificates to connect to eduroam which can be found on the ISMP USB flash drive or downloaded at the first login. In case of problems, please contact the WiFi helpdesk which is located in the lobby of the Main Building.

Snacks and coffee breaks. Coffee, tea, and beverages are served during all breaks in the Main Building [H] and the Mathematics Building [MA]. Moreover, various cafeterias are located in the Main Building [H] and Mathematics Building [MA].

Food. The Mensa of the TU Berlin offers plenty of opportunities for lunch at moderate prizes. In the vicinity of the TU Berlin, there are also many different restaurants from fast food to gourmet restaurants. For the daily lunch break, please consult the Restaurant Guide (leaflet) for a list of nearby cafeterias and restaurants. Moreover, a selection of nice restaurants, cafés, pubs, bars etc. in different neighborhoods of Berlin can be found in the ISMP Berlin Guide.

You find both guides in your conference bag and on the ISMP USB flash drive.

Cloakroom. Participants are asked to look carefully after their wardrobe, valuables, laptops and other belongings for which the organizers are not liable. You will find a cloakroom in the Main Building.

ISMP Berlin Guide. You want to experience Berlin as Berliners do? Valuable information that you might find useful during your stay can be found in the ISMP Berlin Guide in your conference bag and on the ISMP USB stick. Getting around, sightseeing, and going out are some of the topics covered. And, of course, you can find a great collection of restaurants, cafés, bars, pubs etc.

Messages. The best way for people to reach you is to contact you directly at your hotel. Please leave your hotel phone number with your colleagues and family members. For urgent messages, call the ISMP registration desk: +49 (0)30 31421000. Registration staff will transcribe the message and post it on the message board located near registration.

You can also contact colleagues attending the meeting using this message board. Please check the board periodically to see if you have received any messages.
SOCIAL PROGRAM

Monday, August 20, 14:00–16:00
Discover the historic heart of Berlin
Every street in the center of Berlin has history, much of it no longer visible: On this walk you will meet the ghosts and murmurs of Prussians and Prussian palaces, Nazis and Nazi architecture, Communists and real, existing socialist architecture, as well as visit some sites of the present.
Meetingpoint: Book store “Berlin Story”, Unter den Linden 40 [near S ‘Unter den Linden’, Bus 100, 200].
Tickets: 15 EUR
Groupsize: min 5; max 25
Booking Deadline: August 13
Pre-booking requested at info@stattreisenberlin.de

Tuesday, August 21, 14:00–16:00
Where was the Wall
Berlin: the heart of the cold war. So little is left. Walking the former “deathstrip” between Checkpoint Charlie and Potsdam Square, listen to the stories of how a city was violently split in 1961, how one lived in the divided city, how some attempted to escape from the east, how the wall fell in 1989, and memory today.
Meetingpoint: Underground Station Stadtmitte, on the platform of the U6 [not of the U2!]. End: Potsdamer Platz
Tickets: 15 EUR
Groupsize: min 5; max 25
Booking Deadline: August 13
Pre-booking requested at info@stattreisenberlin.de

Wednesday, August 22, 14:00–16:00
Where was the Wall
Berlin: the heart of the cold war. So little is left. Walking the former “deathstrip” between Checkpoint Charlie and Potsdam Square, listen to the stories of how a city was violently split in 1961, how one lived in the divided city, how some attempted to escape from the east, how the wall fell in 1989, and memory today.
Meetingpoint: Underground Station Stadtmitte, on the platform of the U6 [NOT of the U2!] End: Potsdamer Platz
Tickets: 15 EUR
Groupsize: min 5; max 25
Booking Deadline: August 13
Pre-booking requested at info@stattreisenberlin.de

Thursday, August 23, 14:00–16:00
Potsdam – Residence of Frederic the Great
To many outside Germany Potsdam, where the Prussian Kings lived, symbolized Prussia; one spoke of a battle between Potsdam and Weimar for the German soul. But what was Potsdam really? A city of the military, certainly, but also a city of immigrants; a city defined by the court, yes, but also much, more.
Meetingpoint: Potsdam, Alter Markt, Obelisk, close to Potsdam-Hauptbahnhof (S7; RB)
Tickets: 18 EUR
Groupsize: min 5; max 25
Booking Deadline: August 13
Pre-booking requested at info@stattreisenberlin.de

For the booking of further individual tours you may check the website of the tour operator StattReisen Berlin GmbH at www.stattreisenberlin.de.
You can book most of the tours in various languages for mini groups from 120 EUR.
**SPEAKER AND CHAIR INFORMATION**

**Speaker guidelines**

Audio-visual services. All session rooms will be equipped with a computer projector with VGA input. Please follow these guidelines to ensure a successful presentation:
- Please bring your laptop to your session. We strongly recommend that you pre-arrange with other speakers in your session to ensure that at least one of you brings a laptop which can be connected to the computer projector.
- Please bring a power adapter which can be connected to the German grid. We recommend that you do not attempt to run your presentation off the laptop battery.
- If your notebook does not provide a standard VGA port to connect to the beamer, please have the required adapter at hand (e.g., Mini DisplayPort or dvi to VGA).
- Please arrive at your session at least 15 minutes before it begins. All presenters in a session should set up and test the connection to the projector before the session begins.
- We encourage speakers to have at hand a USB flash drive with a copy of their presentation.
- If you need an overhead projector for your talk, please contact the registration office on arrival. Overhead projectors will only be available in exceptional cases.

Presentation guidelines. The room and location of your session are listed on page 30 ff. and in detail on page 74 ff. Please arrive at your session at least 15 minutes early for technical set-up and to check in with the session chair.

Time your presentation to fit within the designated time span of 25 minutes, leaving enough time for audience questions and change of speaker.

There will be a speakers’ preparation room available in the Main Building in room H 1036. Student assistants will provide support for the handling of the computer projectors.

Program information desk. If you have general questions about the meeting or questions about your own presentation, stop by at the Program Information Desk located in lobby of the Main Building. We ask Session Chairs to notify the Information Desk about any last-minute changes or cancellations; these changes will be posted outside the meeting rooms.

Assistance during your session. If you have a problem in your session room related to technical needs or any other requests, please contact one of the student assistants wearing an orange T-shirt.

**Session chair guidelines**

The role of the Chair is to coordinate the smooth running of the session and introduce each speaker. The chair begins and ends each session on time. Each talk lasts 25 minutes plus 5 minutes for discussion and change of speaker. Please stick to the order of talks and times announced in the program.
A polymatroid is a polytope associated with a submodular function. It's not often one can write a sentence that contains at least three words designed to scare small animals and little children, but there it is. Polymatroids will be familiar to students of optimization because of their attractive properties. Less well known is that these useful creatures are to be found lurking in the roots of auction theory. In this talk, I will describe how they arise and give examples of why they are useful in auction theory.

Rakesh Vohra is the John L. & Helen Kellogg Professor of Managerial Economics and lapsed math programmer. He occupies himself with the usual obligations of a faculty member … sitting and thinking and, when required, standing and professing. He thinks mostly about pricing, auctions and the design of markets. He professes on the same but with less success.

Modern probability theory, whose foundation is based on the axioms set forth by Kolmogorov, is currently the major tool for performance analysis in stochastic systems. While it offers insights in understanding such systems, probability theory is really not a computationally tractable theory. Correspondingly, some of its major areas of application remain unsolved when the underlying systems become multidimensional: Queueing networks, network information theory, pricing multi-dimensional financial contracts, auction design in multi-item, multi-bidder auctions among others. We propose a new approach to analyze stochastic systems based on robust optimization. The key idea is to replace the Kolmogorov axioms as primitives of probability theory, with some of the asymptotic implications of probability theory: the central limit theorem and law of large numbers and to define appropriate robust optimization problems to perform performance analysis. In this way, the performance analysis questions become highly structured optimization problems (linear, conic, mixed integer) for which there exist efficient, practical algorithms that are capable of solving truly large scale systems. We demonstrate that the proposed approach achieves computationally tractable methods for (a) analyzing multiclass queueing networks, (b) characterizing the capacity region of network information theory and associated coding and decoding methods generalizing the work of Shannon, (c) pricing multi-dimensional financial contracts generalizing the work of Black, Scholes and Merton, (d) designing multi-item, multi-bidder auctions generalizing the work of Myerson. This is joint work with my doctoral student at MIT Chaithanya Bandi.

Dimitris Bertsimas is currently the Boeing Leaders for Global Operations Professor of Management and the co-director of the Operations Research Center at the Massachusetts Institute of Technology. He has received a BS in Electrical Engineering and Computer Science at the National Technical University of Athens, Greece in 1985, a MS in Operations Research at MIT in 1987, and a PhD in Applied Mathematics and Operations Research at MIT in 1988. Since 1988, he has been in the MIT faculty. His research interests include optimization, stochastic systems, data mining, and their applications. In recent years he has worked in robust optimization, health care and finance. He is a member of the National Academy of Engineering and he has received several research awards including the Farkas prize, the SIAM Optimization prize and the Erlang Prize.
All derivative free methods rely on sampling the objective function at one or more points at each iteration. Direct search methods (developed by Dennis, Torczon, Audet, Vicente and others) rely on sample sets of defined configuration, but different scales. Model-based DFO methods (developed by Powell, Conn, Scheinberg, Toint, Vicente, Wild and others) rely on building interpolation models using sample points in proximity of the current best iterate. Constructing and maintaining these sample sets has been one of the most essential issues in DFO. Many of the existing results have been summarized in a book by Conn, Scheinberg, Vicente, where all the sampling techniques considered for deterministic functions are deterministic ones. We will discuss the new developments for using randomized sampled sets within the DFO framework. Randomized sample sets have many advantages over the deterministic sets. In particular, it is often easier to enforce “good” properties of the models with high probability, rather than the in the worst case. In addition, randomized sample sets can help automatically discover a good local low dimensional approximation to the high dimensional objective function. We will demonstrate how compressed sensing results can be used to show that reduced size random sample sets can provide full second order information under the assumption of the sparsity of the Hessian. We will discuss new convergence theory developed for the randomized models where we can, for instance, show that as long as the models are “good” with probability more than ½ then our trust region framework is globally convergent with probability 1 under standard assumptions.

Katya Scheinberg is an associate professor in the Industrial and Systems Engineering Department at Lehigh University. A native from Moscow, she earned her undergraduate degree in operations research from the Lomonosov Moscow State University in 1992 and then received her PhD in operations research from Columbia in 1997. Scheinberg was a Research Staff Member at the IBM T. J. Watson Research center for over a decade, where she worked on various applied and theoretical problems in optimization, until moving back to Columbia as a visiting professor in 2009 and later on to Lehigh. Her main research areas are related to developing practical algorithms (and their theoretical analysis) for various problems in continuous optimization, such as convex optimization, derivative free optimization, machine learning, quadratic programming, etc. Scheinberg has also published a book in 2008 titled, Introduction to Derivative Free Optimization, which is co-authored with Andrew R. Conn and Luis N. Vicente. She is currently the editor of Optima, the MOS newsletter, and an associate editor of SIAMOPT.

At the heart of the Graph Minors project of Robertson and Seymour lies a deep theorem saying that every graph $G$ with no minor isomorphic to a fixed graph $H$ has a certain structure. The structure can then be exploited to deduce far-reaching consequences. The exact statement requires some explanation, but roughly it says that there exists an integer $k$ depending on $H$ only such that $G$ has a tree-decomposition into pieces, each of which has a $k$-near embedding in a surface $S$ that does not embed $H$. Here a $k$-near embedding means that after deleting at most $k$ vertices the graph can be drawn in $S$ without crossings, except for $k$ local areas of non-planarity, where crossings are permitted, but the graph is constrained in a different way, again depending on the parameter $k$. I will explain the theorem and its applications, and then will discuss recent work: a much simpler proof and a variation on the theorem, which adds some restrictive assumptions, but is much easier to state and to apply. Part of this is joint with Ken-ichi Kawarabayashi and Paul Wollan, and part is joint with Sergey Norin.

Robin Thomas received his PhD from Charles University in Prague, formerly Czechoslovakia, now the Czech Republic. He has worked at the Georgia Institute of Technology since 1989. Currently he is Regents’ Professor of Mathematics and Director of the multidisciplinary PhD program in Algorithms, Combinatorics, and Optimization. In 1994 and 2009 he and his coauthors won the D. Ray Fulkerson prize in Discrete Mathematics.
Tuesday

**Tseng memorial lecture lecture**

**Tue.17:00.H0105**

TBA

**Tseng memorial lecture**

Chair Sven Leyffer

This lecture will be given by the prize winner of the Tseng Memorial Lectureship. The prize was established in 2011 and will be awarded for the first time during the opening ceremony of ISMP 2012.

**Semi-plenary lecture**

**Tue.17:00.H1058**

Rekha R. Thomas

**Lifts and factorizations of convex sets**

Chair Martin Skutella

A basic strategy for linear optimization over a complicated convex set is to try to express the set as the projection of a simpler convex set that admits efficient algorithms. This philosophy underlies all lift-and-project methods in the literature which attempt to find polyhedral or spectrahedral lifts of complicated sets. Given a closed convex cone $K$ and a convex set $C$, there is an affine slice of $K$ that projects to $C$ if and only if a certain “slack operator” associated to $C$ can be factored through $K$. This theorem extends a result of Yannakakis who showed that polyhedral lifts of polytopes are controlled by the non-negative factorizations of the slack matrix of the polytope. The connection between cone lifts and cone factorizations of convex sets yields a uniform framework within which to view all lift-and-project methods, as well as offers new tools for understanding convex sets. I will survey this evolving area and the main results that have emerged thus far.

Rekha Thomas received a PhD in Operations Research from Cornell University in 1994 under the supervision of Bernd Sturmfels. After holding postdoctoral positions at the Cowles Foundation for Economics at Yale University and ZIB, Berlin, she worked as an assistant professor of Mathematics at Texas A&M University from 1995–2000. Since 2000, she has been at the University of Washington in Seattle where she is now the Robert R. and Elaine F. Phelps Endowed Professor of Mathematics. Her research interests are in optimization and computational algebra.
Convexity arises quite naturally in financial risk management. In risk preferences concerning random cashflows, convexity corresponds to the fundamental diversification principle. Convexity is a basic property also of budget constraints both in classical linear models as well as in more realistic models with transaction costs and constraints. Moreover, modern securities markets are based on trading protocols that result in convex trading costs. This talk gives an introduction to certain basic concepts and principles of financial risk management in simple optimization terms. We then review some convex optimization techniques used in mathematical and numerical analysis of financial optimization problems.

Teemu Pennanen is the Professor of Mathematical Finance, Probability and Statistics at King’s College London. Before joining KCL, Professor Pennanen worked as Managing Director at QSA Quantitative Solvency Analysts Ltd, with a joint appointment as Professor of Stochastics at University of Jyväskylä, Finland. His earlier appointments include a research fellowship of the Finnish Academy and several visiting positions in universities abroad. Professor Pennanen’s research interests include financial risk management, financial econometrics, mathematical finance and the development of computational techniques for risk management. He has authored more than 30 journal publications and he has been a consultant to a number of financial institutions including Bank of Finland, Ministry of Social Affairs and Health and The State Pension Fund.

Molecular systems exhibit complicated dynamical behavior that is responsible for its (biological or nanotechnological) functionality. The effective dynamics can be characterized by the switching behavior between several metastable states, the so-called conformations of the system. Therefore, steering a molecular system from one conformation into another one means controlling its functionality. This talk considers optimal control problems that appear relevant in molecular dynamics (MD) applications and belong to the class of ergodic stochastic control problems in high dimensions. It will be demonstrated how the associated Hamilton-Jacobi-Bellman (HJB) equation can be solved. The main idea is to first approximate the dominant modes of the MD transfer operator by a low-dimensional, so-called Markov state model (MSM), and then solve the HJB for the MSM rather than the full MD. The approach rests on the interpretation of the corresponding HJB equation as a nonlinear eigenvalue problem that, using a logarithmic transformation, can be recast as a linear eigenvalue problem, for which the principal eigenvalue and the associated eigenfunction are sought. The resulting method will be illustrated in application to the maximization of the population of alpha-helices in an ensemble of small biomolecules (Alanine dipeptide).

Christof Schütte is a professor in the Mathematics and Computer Science Department at Freie Universität Berlin (FU). He holds a diploma in physics from Paderborn University and a PhD in mathematics from FU. Since 2008, he is the co-chair of the DFG Research Center MATHEON in Berlin and the head of the Biocomputing Group at FU. Christof gave a plenary lecture at ICIAM 2007 in Zurich and was an invited speaker at the 2010 International Congress of Mathematicians in Hyderabad. His research is on modeling, simulation and optimization in the life sciences with a special focus on stochastic multiscale problems in molecular and systems biology and on information-based medicine. He is currently the head of the Innovation Laboratory “Math for Diagnostics” in Berlin.
Modern electricity systems provide a plethora of challenging issues in optimization. The increasing penetration of low carbon renewable sources of energy introduces uncertainty in problems traditionally modeled in a deterministic setting. The liberalization of the electricity sector brought the need of designing sound markets, ensuring capacity investments while properly reflecting strategic interactions. In all these problems, hedging risk, possibly in a dynamic manner, is also a concern. The fact of representing uncertainty and/or competition of different companies in a multi-settlement power market considerably increases the number of variables and constraints. For this reason, usually a trade-off needs to be found between modeling and numerical tractability: the more details are brought into the model, the harder becomes the optimization problem. Both for optimization and generalized equilibrium problems, we explore some variants of solution methods based on Lagrangian relaxation and on Benders decomposition. Throughout we keep as a leading thread the actual practical value of such techniques in terms of their efficiency to solve energy related problems.

Claudia Sagastizábal is on leave from a researcher position at INRIA, in France, and is currently adjunct as a long-term visitor to IMPA, in Rio de Janeiro. After finishing her undergraduate math studies in Argentina, Claudia moved to Paris, where she got her PhD in 1993 and her habilitation degree in 1998, both at the University Paris I Panthéon-Sorbonne. She has taught optimization in Argentina, France, and Brazil and is co-author of the book “Numerical Optimization: Theoretical and Practical Aspects” published by Springer. Claudia has also served in various program committees of international conferences and was elected Council Member-at-large in the Mathematical Optimization Society for the period 2009–2012. In parallel with her academic activities, Claudia has held consulting appointments for companies such as Electricité de France, Gaz de France-Suez, Renault-France, Robert Bosch, Petrobras, and Eletrobras. Her research interests lie in the areas of nonsmooth optimization as well as convex and variational analysis, always driven by real-life applications, with emphasis on the energy sector.

Robert Weismantel was born in 1965 in München, Germany. After studying mathematics at the University of Augsburg, he moved with Martin Grötschel to the Konrad-Zuse-Zentrum für Informationstechnik in Berlin (ZIB) in 1991. From the TU Berlin he received his PhD degree in 1992 and his second PhD degree (Habilitation) in 1995. In the years 1991–1997 he was a researcher at ZIB. From 1998 to 2010 he was a Professor (C4) for Mathematical Optimization at the University of Magdeburg. In 2010, he was elected Full Professor at the Department of Mathematics at ETH Zurich. His main research interest is integer and mixed integer optimization: specifically he was working on primal integer programming, the theory of Hilbert bases, and cutting plane theory. More recently he is working on nonlinear integer optimization. His work has been distinguished with several prizes and honors: His PhD thesis was awarded a Carl Ramsauer Prize. He received the Gerhard Hess Research Prize of the German Science Foundation and IBM–Faculty Awards in 2007 and 2010. He is currently a Co-Editor of Mathematical Programming A.
Sensing and imaging systems are under increasing pressure to accommodate ever larger and higher-dimensional data sets; ever faster capture, sampling, and processing rates; ever lower power consumption; communication over ever more difficult channels; and radically new sensing modalities. This talk will overview the foundations and recent progress on compressive signal processing, a new approach to data acquisition and processing in which analog signals are digitized and processed not via uniform sampling but via measurements using more general, even random, test functions. In stark contrast with conventional wisdom, the new theory asserts that one can combine “sub-Nyquist-rate sampling” with large-scale optimization for efficient and accurate signal acquisition when the signal has a sparse structure. The implications of compressive sensing are promising for many applications and enable the design of new kinds of communication systems, cameras, imagers, microscopes, and pattern recognition systems. Special emphasis will be placed on the pros and cons of the compressive sensing technique.

Richard G. Baraniuk is the Victor E. Cameron Professor of Electrical and Computer Engineering at Rice University. His research interests lie in new theory, algorithms, and hardware for sensing, signal processing, and machine learning. He is a Fellow of the IEEE and AAAS and has received national young investigator awards from the US NSF and ONR, the Rosenbaum Fellowship from the Isaac Newton Institute of Cambridge University, the ECE Young Alumni Achievement Award from the University of Illinois, and the Wavelet Pioneer and Compressive Sampling Pioneer Awards from SPIE. His work on the Rice single-pixel compressive camera has been widely reported in the popular press and was selected by MIT Technology Review as a TR10 Top 10 Emerging Technology for 2007. For his teaching and education projects, including Connexions (cnx.org), he has received the C. Holmes MacDonald National Outstanding Teaching Award from Eta Kappa Nu, Tech Museum of Innovation Laureate Award, the Internet Pioneer Award from the Berkman Center for Internet and Society at Harvard Law School, the World Technology Award for Education, the IEEE-SPS Education Award, and the WISE Education Award.

For many structured data-fitting applications, incremental gradient methods (both deterministic and randomized) offer inexpensive iterations by sampling only subsets of the data. They make great progress initially, but eventually stall. Full gradient methods, in contrast, often achieve steady convergence, but may be prohibitively expensive for large problems. Applications in machine learning and robust seismic inversion motivate us to develop an inexact gradient method and sampling scheme that exhibit the benefits of both incremental and full gradient methods.

Michael P. Friedlander is Associate Professor of Computer Science at the University of British Columbia. He received his PhD in Operations Research from Stanford University in 2002, and his BA in Physics from Cornell University in 1993. From 2002 to 2004 he was the Wilkinson Fellow in Scientific Computing at Argonne National Laboratory. He was a senior fellow at UCLA’s Institute for Pure and Applied Mathematics in 2010. He serves on the editorial boards of SIAM J. on Optimization, SIAM J. on Matrix Analysis and Applications, Mathematical Programming Computation, Optimization Methods and Software, and the Electronic Transactions on Numerical Analysis. His research is primarily in developing numerical methods for constrained optimization, their software implementation, and applications in signal processing and image reconstruction.
Amin Saberi  
**Rounding by sampling and traveling salesman problems**  
Chair Friedrich Eisenbrand

I will talk about a new technique for rounding the solution of linear programming relaxations of combinatorial optimization problems. In particular, I will present new algorithms for symmetric and asymmetric traveling salesman problems, improving the best known approximation ratios for these problems.

Amin Saberi is an Associate Professor and 3COM faculty scholar in Stanford University. He received his B.Sc. from Sharif University of Technology and his PhD from Georgia Institute of Technology in Computer Science. His research interests include algorithms, approximation algorithms, and algorithmic aspects of games, markets, and networks. He is a Frederick Terman Fellow (2005–2010), an Alfred Sloan Fellow (2010–2012), and the recipient of National Science Foundation Career award as well as best paper awards in FOCS 2011 and SODA 2010.

Nikhil Bansal  
**Semidefinite optimization in discrepancy theory**  
Chair Friedrich Eisenbrand

The concept of discrepancy is intimately related to several fundamental topics in mathematics and theoretical computer science, and deals with the following type of question. Given a collection of sets on some elements, color each element red or blue such that each set in the collection is colored as evenly as possible. Recently, there have been several new developments in discrepancy theory based on connections to semidefinite programming. This connection has been useful in several ways. It gives efficient polynomial time algorithms for several problems for which only non-constructive results were previously known. It also leads to several new structural results in discrepancy itself, such as tightness of the so-called determinant lower bound, improved bounds on the discrepancy of the union of set systems and so on. We will give a brief survey of these results, focussing on the main ideas and the techniques involved.

Nikhil Bansal is an Associate Professor in the Department of Mathematics and Computer Science at Eindhoven University of Technology. He obtained his PhD from Carnegie Mellon University in 2003, and worked at the IBM T.J. Watson Research Center until 2011, where he also managed the Algorithms group. His main research interests are the design and analysis of approximation and online algorithms. For his work, he has co-received best paper awards at FOCS 2011, ESA 2011 and ESA 2010, and also IBM Research best paper awards for 2007 and 2010.
Minimization problems with nonsmooth, nonconvex, perhaps even non-Lipschitz regularization terms have wide applications in image restoration, signal reconstruction and variable selection, but they seem to lack optimization theory. On $L_p$ non-Lipschitz regularized minimization, we show that finding a global optimal solution is strongly NP-hard. On the other hand, we present lower bounds of nonzero entries in every local optimal solution without assumptions on the data matrix. Such lower bounds can be used to classify zero and nonzero entries in local optimal solutions and select regularization parameters for desirable sparsity of solutions. Moreover, we show smoothing methods are efficient for solving such regularized minimization problems. In particular, we introduce a smoothing SQP method which can find an affine scaled epsilon-stationary point from any starting point with complexity $O(\epsilon^{-2})$, and a smoothing trust region Newton method which can find a point satisfying the affine scaled second order necessary condition from any starting point. Examples with six widely used nonsmooth nonconvex regularization terms are presented to illustrate the theory and algorithms. Joint work with W. Bian, D. Ge, L. Niu, Z. Wang, Y. Ye, Y. Yuan.

Xiaojun Chen received her PhD degree in Computational Mathematics from Xi’an Jiaotong University, China in 1987 and PhD degree in Applied Mathematics from Okayama University of Science, Japan in 1991. She was a postdoctoral fellow at the University of Delaware, an Australia Research Fellow in the University of New South Wales and a Professor in Hirokaki University, Japan. She joined the Hong Kong Polytechnic University as a Professor in 2007. Her current research interests include nonsmooth nonconvex optimization, stochastic equilibrium problems and numerical approximation methods on the sphere with important applications in engineering and economics. She has published over 80 papers in major international journals in operations research and computational mathematics. Prof. Chen has won many grants as a principal investigator from several government funding agencies and organized several important international conferences. She serves in the editorial boards of five mathematical journals including SIAM Journal on Numerical Analysis.

First-order methods have been advocated for solving optimization problems of large scale. Although they are sometimes the most appropriate techniques, we argue that in many applications it is advantageous to employ second-order information as an integral part of the iteration. This is particularly so when parallel computing environments are available. In this talk, we take a broad view of second-order methods, and center our discussion around three applications: convex L1 regularized optimization, inverse covariance estimation, and nonlinear programming. We note that many efficient methods for these problems can be derived using a semi-smooth Newton framework, which allows us to compare their manifold identification and subspace minimization properties. We propose an algorithm employing a novel active-set mechanism that is of interest in machine learning, PDE-constrained optimization, and other applications. We also discuss dynamic sampling techniques, illustrate their practical performance, and provide work complexity bounds. The talk concludes with some observations about the influence that parallel computing has on large scale optimization calculations.

Jorge Nocedal is a professor in the Industrial Engineering Department at Northwestern University. He holds a B.S. degree in physics from the National University of Mexico and a PhD in applied mathematics from Rice University. Prior to moving to Northwestern, he taught at the Courant Institute of Mathematical Sciences. He is a SIAM Fellow and an ISI Highly Cited Researcher (mathematics category). In 1998 he was appointed Bette and Neison Harris Professor at Northwestern. Jorge was an invited speaker at the 1998 International Congress of Mathematicians in Berlin. His research focuses on the theory, algorithms and applications of nonlinear programming, and he has developed widely used software, including L-BFGS and Knitro. He is currently Editor-in-Chief of the SIAM Journal on Optimization.
Historical lecture

**Horst Zuse**

**The origins of the computer**

Chair Martin Grötschel

Many outstanding scientists and managers were necessary to get the computer to the point of development that we know today. Konrad Zuse (1910–1995) is almost unanimously accepted as the inventor of the first working, freely programmable machine using Boolean logic and binary floating point numbers. This Machine – called Z3 – was finished by Konrad Zuse in May 1941 in his small workshop in Berlin-Kreuzberg. In this presentation the achievements of Charles Babbage (1823), the development of the secret COLOSSUS-Project (UK, 1943), Howard Aiken’s Mark I (USA), and the ENIAC (USA) are outlined. Konrad Zuse’s contributions to computer development are presented, of course, as well, with many surprising pictures and videos. It is not well known that Konrad Zuse founded, in 1949, a computer company that produced 251 computers of a value of 51 Million Euros. It was the first company which produced computers in a commercial way.

Horst Zuse, the oldest of Konrad Zuse’s five children, was born on November 17, 1945 in Hindelang (Bavaria, Germany). He received his PhD degree in computer science from Technische Universität Berlin (TUB) in 1985. From 1975–2010 he was a senior research scientist at TUB. His research interests are information retrieval systems, software engineering, software metrics, computer history and computer architectures. In 1991 he published the book *Software Complexity – Measures and Methods* (De Gruyter Publisher). In 1998 the book *A Framework for Software Measurement* (De Gruyter Publisher) followed. In 1998 he received the habilitation [Privatdozent] in the area of Praktische Informatik (Practical Computer Science), and since 2006 he has been a Professor at the University of Applied Sciences in Senftenberg.

**Eberhard Knobloch**

**Gottfried Wilhelm Leibniz – Universal genius and outstanding mathematician**

Chair Günter M. Ziegler

The universal genius Gottfried Wilhelm Leibniz (1646–1716) contributed to nearly all scientific disciplines and left the incredibly huge amount of about 200,000 sheets of paper that are kept in the Leibniz Library of Hannover. About 4,000 of them regarding natural sciences, medicine, technology have been digitized and are freely available in the internet: http://ritter.bbaw.de. Less than half of them have been published up to now. Hence we know for example – for the time being – only about one fourth of his mathematical production. The lecture will give a short survey of his biography and mainly deal with the following six aspects: 1. Leibniz as an organizer of scientific work: His presidency of the Berlin Academy of Sciences; 2. His rigorous foundation of infinitesimal geometry; 3. Leibniz as the inventor of the differential and integral calculus; 4. His conception of and his contributions to a general combinatorial art (symmetric functions, number theory, insurance calculus); 5. His proposals for engineering improvements in mining; 6. Leibniz’s invention of the first real four-function calculating machine.

Eberhard Knobloch, born in 1943 in Görlitz, Germany, studied mathematics, classical philology, and history of science and technology at Freie Universität Berlin and Technische Universität Berlin. In 1972 he did a PhD in history of science and technology, in 1976 he passed the habilitation for university professors at Technische Universität Berlin. Since 2002 he is professor of history of science and technology at this university and Academy professor at the Berlin-Brandenburg Academy of Sciences and Humanities (BBAW). He is a member of several national and international academies of sciences, president of the International Academy of the History of Science, past president of the European Society for the History of Science, Honorary professor of the Chinese Academy of Sciences. He published or edited more than 300 papers or books on the history of science and technology, he is a member of the editorial boards of sixteen international journals. His main scientific interests concern the history and philosophy of mathematical sciences and Renaissance technology. He is project leader of the A. v. Humboldt research group and the two Leibniz research groups at BBAW.
Wednesday

**Historical lecture**

**Wed.17:00.H1012**

**Günter M. Ziegler**

**Leonhard Euler: Three strikes of a genius**

Chair George Nemhauser

We will explore three of Euler’s genius contributions:
The seven bridges of Königsberg: How a problem of “Recreational Mathematics” led to the creation of Graph Theory.
The Basel problem: A healthy dose of serious numerical computing on the way to a $\zeta(2)$.
The polyhedron formula: Tracing the polyhedron formula from Stockholm to the Berne mountains.

**Günter M. Ziegler,** born in München, Germany, in 1963, got a PhD at MIT in 1987, became a Professor of Mathematics at TU Berlin 1995, and moved to FU Berlin in 2011 as a MATHEON Professor. He became the founding chair of the Berlin Mathematical School in 2006. His interests connect discrete and computational geometry (especially polytopes), algebraic and topological methods in combinatorics, discrete mathematics and the theory of linear and integer programming. He is the author of *Lectures on Polytopes* (Springer 1995) and of *Proofs from THE BOOK* (with Martin Aigner, Springer-Verlag 1998), which has by now appeared in 14 languages. His latest book is *Darf ich Zahlen? Geschichten aus der Mathematik* (Do I count? Stories from Mathematics; English translation to appear). Günter Ziegler’s honors include a Leibniz Prize (2001) of the German Research Foundation DFG, the Chauvenet Prize (2004) of the Mathematical Association of America, and the 2008 Communicator Award of DFG and Stifterverband. He is a member of the executive board of the Berlin-Brandenburg Academy of Sciences, and a member of the German National Academy of Sciences Leopoldina. From 2006–2008 he was the President of the German Mathematical Society DMV. In 2008 he initiated and co-organized the German National Science Year “Jahr der Mathematik” and now directs the DMV Mathematics Media Office and the DMV Network Office Schools–Universities.

**IPCO 2013**

The 16th Conference on Integer Programming and Combinatorial Optimization (IPCO XVI) will take place at the Universidad Técnica Federico Santa María (UTFSM) in Valparaíso, Chile, from March 18 to March 20, 2013. Please note the unusual date.

The main campus of the UTFSM is located in the border between the cities of Valparaíso and Viña del Mar. Valparaíso, located 112 km northwest of Santiago is recognized as one of the most attractive places in Latin America, while Viña del Mar, the “Garden City”, is the tourism capital of Chile.

The IPCO conference is supported by the Mathematical Optimization Society (formerly known as the Mathematical Programming Society). It is held every year, except for those years in which the International Symposium on Mathematical Programming (ISMP) takes place. This conference is a forum for researchers and practitioners working on integer programming and combinatorial optimization. Its aim is to present recent developments in the theory, computation, and applications in these areas.

The program committee is chaired by Michel Goemans, and the organizing committee is chaired by José Correa.

Submission deadline: October 24, 2012

For further details, please visit http://ipco2013.dim.uchile.cl
The work of Karl Weierstrass, the outstanding Berlin mathematician who was one of leading mathematical researchers of the second half of the nineteenth century, had a deep impact on the theory of optimization and on variational calculus. In this talk, we review some aspects of his contributions to the field.

Jürgen Sprekels, born 1948 in Hamburg, Germany, studied mathematics at the University of Hamburg, where he received his PhD in 1975 and his habilitation in 1977. After professorships in Augsburg (1981–88) and Essen (1988–94), he became Full Professor for Applied Analysis at the Humboldt-Universität zu Berlin in 1994. Since 1994 he has been the director of the Weierstrass Institute for Applied Analysis and Stochastics (WIAS) in Berlin, the non-university mathematical research institute that hosts the Secretariat of the International Mathematical Union (IMU) and the German Mathematical Society (DMV). He was also one of the founders of the mathematical research center MATHEON in Berlin. His research focuses on the analysis and optimal control of nonlinear systems of PDEs arising in applications, with an emphasis on hysteresis phenomena, phase transitions, and free boundary problems. He conducted several industrial cooperation projects, in particular, in the growth of semiconductor bulk single crystals. He (co-)authored two research monographs and more than 150 papers in refereed journals and conference proceedings.

Convexity of a set or function is a property that plays an important role in optimization. In this lecture a brief survey of the history of the notion of convexity and, in particular, the role Hermann Minkowski played in it, will be given.

Martin Grötschel, born in Schwelm, Germany in 1948, studied mathematics and economics at Ruhr-Universität Bochum from 1969–1973. He received his PhD (1977) and his habilitation (1981) from Bonn University. He was Full Professor of Applied Mathematics at Augsburg University (1982–1991). Since 1991 he has been Professor at the Institute of Mathematics of Technische Universität Berlin and Vice President of the Zuse Institute Berlin (ZIB). From 2002 to 2008 he served as chair of the DFG Research Center MATHEON. Martin Grötschel was President of the German Mathematical Society DMV 1993–1994, and he has been serving the International Mathematical Union as Secretary since 2007. He is a member of four academies (BBAW, Leopoldina, acatech, NAE) and since 2001 in the executive board of BBAW. In 2011 he became chairman of the executive board of the Einstein Foundation Berlin. His scientific honors include the Leibniz, the Dantzig and the Fulkerson Prize and four honorary degrees. His main areas of scientific interest are discrete mathematics, optimization and operations research with a particular emphasis on the design of theoretically and practically efficient algorithms for hard combinatorial optimization problems occurring in practice.
LIST OF CLUSTERS AND CLUSTER CHAIRS

- **Approximation and online algorithms**  
  Organizer: Leen Stougie, David P. Williamson
- **Combinatorial optimization**  
  Organizer: Jochen Könemann, Jens Vygen
- **Complementarity and variational inequalities**  
  Organizer: Michael C. Ferris, Michael Ulbrich
- **Conic programming**  
  Organizer: Raphael Hauser, Toh Kim Chuan
- **Constraint programming**  
  Organizer: Michela Milano, Willem-Jan van Hoeve
- **Derivative-free and simulation-based optimization**  
  Organizer: Luís Nunes Vicente, Stefan Wild
- **Finance and economics**  
  Organizer: Thomas F. Coleman, Karl Schmedders
- **Game theory**  
  Organizer: Asu Ozdaglar, Guido Schäfer
- **Global optimization**  
  Organizer: Christodoulos A. Floudas, Nikolaos V. Sahinidis
- **Implementations and software**  
  Organizer: Tobias Achterberg, Andreas Wächter
- **Integer and mixed-integer programming**  
  Organizer: Andrea Lodi, Robert Weismantel
- **Life sciences and healthcare**  
  Organizer: Gunnar W. Klau, Ariela Sofer
- **Logistics, traffic, and transportation**  
  Organizer: Marco E. Lübbecke, Georgia Perakis
- **Mixed-integer nonlinear programming**  
  Organizer: Sven Leyffer, François Margot
- **Multi-objective optimization**  
  Organizer: Jörn Fliege, Johannes Jahn
- **Nonlinear programming**  
  Organizer: Philip E. Gill, Stephen J. Wright
- **Nonsmooth optimization**  
  Organizer: Amir Beck, Jérôme Bolte
- **Optimization in energy systems**  
  Organizer: Alexander Martin, Claudia Sagastizábal
- **PDE-constrained optimization and multi-level/multi-grid methods**  
  Organizer: Matthias Heinkenschloss, Michael Hintermüller
- **Robust optimization**  
  Organizer: Aharon Ben-Tal, Dimitris Bertsimas
- **Sparse optimization and compressed sensing**  
  Organizer: Ben Recht, Michael Saunders, Stephen J. Wright
- **Stochastic optimization**  
  Organizer: Shabbir Ahmed, David Morton
- **Telecommunications and networks**  
  Organizer: Andreas Bley, Mauricio G. C. Resende
- **Variational analysis**  
  Organizer: René Henrion, Boris Mordukhovich

### ICCOPT 2013

ICCOPT 2013, The Fourth International Conference on Continuous Optimization, will take place in Lisbon, Portugal, from July 27 to August 1, 2013. ICCOPT is a recognized forum of discussion and exchange of ideas for researchers and practitioners in continuous optimization, and one of the flagship conferences of the Mathematical Optimization Society.

ICCOPT 2013 is organized by the Department of Mathematics of FCT, Universidade Nova de Lisboa, in its Campus de Caparica, located near a long beach, 15 minutes away by car (and 30 by public transportation) from the center of Lisbon, on the opposite side of the river Tagus.

ICCOPT 2013 includes a Conference and a Summer School. The Conference (July 29 – August 1) will count with the following Plenary Speakers:

- Paul I. Barton (MIT, Massachusetts Inst. Tech.)
- Michael C. Ferris (Univ. Wisconsin)
- Yurii Nesterov (Univ. Catholique de Louvain)
- Yinyu Ye (Stanford Univ.)

and the following Semi-plenary Speakers:

- Amir Beck (Technion, Israel Inst. Tech.)
- Regina Burachik (Univ. South Australia)
- Sam Burer (Univ. Iowa)
- Coralia Cartis (Univ. Edinburgh)
- Michel De Lara (Univ. Paris-Est)
- Victor DeMiguel (London Business School)
- Michael Hintermüller (Humboldt-Univ. Berlin)
- Ya-xiang Yuan (Chinese Academy of Sciences)

The Summer School (July 27–28) is directed to graduate students and young researchers in the field of continuous optimization, and includes two courses:

- Summer Course on Sparse Optimization and Applications to Information Processing (July 28, 2013), by Mário A. T. Figueiredo (Technical Univ. Lisbon and IT) Stephen J. Wright (Univ. Wisconsin)

There will be a paper competition for young researchers in Continuous Optimization (information available from the website below).

The three previous versions of ICCOPT were organized respectively in 2004 at Rensselaer Polytechnic Institute (Troy, NY, USA), in 2007 at McMaster University (Hamilton, Ontario, Canada), and in 2010 at University of Chile (FCFM, Santiago, Chile).

The meeting is chaired by Luís Nunes Vicente (Organizing Committee) and Katya Scheinberg (Program Committee) and locally coordinated by Paula Amaral (Local Organizing Committee).

The website is [http://eventos.fct.unl.pt/iccopt2013](http://eventos.fct.unl.pt/iccopt2013)
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CAMPUS MAP

- **Ernst-Reuter-Platz**
- **Underground Station 'Ernst-Reuter-Platz'**
- **Math Building (MA)**
- **Main Building (H)**
- **Mensa**

**Orientation**

- **Bus 245**
- **Bus 245, M45, X9**

- **5 min walk to Urban Rail Station 'Tiergarten'**
- **5 min walk to Train Station/Urban Rail Station 'Zoologischer Garten'**
FLOOR PLANS

Ground floor

Main entrance

1st floor

2nd floor

3rd/4th floor

Ladies toilet
Gents toilet
Elevator
Stairs

Main Building

Straße des 17. Juni
## Daily events and sessions

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<td>Airport Registration Service</td>
<td>Airports Tegel and Schönefeld</td>
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<td><strong>Saturday, August 18</strong>&lt;br&gt;Saturday, August 18</td>
<td>00:00–23:59</td>
<td>Airport Registration Service</td>
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<td><strong>Sunday, August 19</strong>&lt;br&gt;Sunday, August 19</td>
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<td>09:00–17:00</td>
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<td>09:00–09:50</td>
<td>Plenary Lecture: Rakesh Vohra</td>
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<td>10:00–10:30</td>
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<td>10:30–12:00</td>
<td>Technical Sessions (Mon.1)</td>
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<td>13:15–14:45</td>
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<td>Semi-Plenary Lecture: Katya Scheinberg</td>
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<td><strong>Tuesday, August 21</strong>&lt;br&gt;Tuesday, August 21</td>
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<td>18:15–</td>
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<td>07:30–18:30</td>
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<td>07:30–18:30</td>
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**Special session: Tucker session** [Organizer: Daniel Ralph] [p. 74]
Tucker awards ceremony: Presentation by Tucker Prize Finalist

**Approximation and online algorithms: Approximation in routing and others** [Organizers: Sylvia Boyd and David Shmoys] [p. 74]
Hyung-Chan An: Improving Christofides’ algorithm for the s,t-path TSP
Frans Schalekamp: On the integrality gap of the subtour LP for the 1,2-TSP
David Shmoys: A primal-dual approximation algorithm for min-sum single-machine scheduling problems

**Combinatorial optimization: Combinatorial optimization in chip design I**
Igor Markov: A primal-dual Lagrange optimization for VLSI global placement
Markus Struyna: Quadratic and constrained placement in chip design: global flows and local realizations
Ulrich Brenner: Fractional versus integral flows: A new approach to VLSI legalization

**Combinatorial optimization: Triangulations** [Organizer: Lionel Pournin] [p. 74]
Lionel Pournin: The flip-graph of the 4-dimensional cube is connected
Felix Schmiedl: Gromov-Hausdorff distance of finite metric spaces

**Combinatorial optimization: Rational convex programs and combinatorial algorithms for solving them** [Organizer: Vijay Vazirani] [p. 75]
Vijay Vazirani: Rational convex programs
Kamal Jain: Eisenberg-Gale markets: Algorithms and game theoretic properties
Gagan Goel: A perfect price discrimination market model, and a rational convex program for it

**Combinatorial optimization: Matching** [p. 75]
Sigrd Knust: Scheduling sports tournaments on a single court based on special 2-factorizations
Mizuho Takamatsu: Matching problems with delta-matroid constraints
Michael Kapralov: On the communication and streaming complexity of maximum bipartite matching

**Combinatorial optimization: Combinatorial optimization in railways I** [Organizer: Ralf Borndörfer] [p. 75]
Jun Imaizumi: A column generation approach for crew rostering problem in a freight railway company in Japan
Thomas Schlechte: Recent developments in railway track allocation
Steffen Weider: A rapid branching method for the vehicle rotation planning problem

**Combinatorial optimization: Scheduling algorithms I** [Organizer: Nikhil Bansal] [p. 76]
Sigrid Knust: Scheduling sports tournaments on a single court based on special 2-factorizations
Mizuho Takamatsu: Matching problems with delta-matroid constraints
Michael Kapralov: On the communication and streaming complexity of maximum bipartite matching

**Complementarity and variational inequalities: Optimization and equilibrium models in energy systems** [Organizer: Jong-Shi Pang] [p. 76]
Steven Gabriel: A new method for MPECs with a natural gas application
Yuqiu Fan: A stochastic variational inequality model for estimating traffic demand based on random link flow observations
Yanfeng Ouyang: Biofuel supply chain design under competitive agricultural land use and feedstock market equilibrium

**Conic programming: Geometry and duality in convex programming** [Organizer: Gabor Pataki] [p. 76]
Hayato Waki: Computation of facial reduction algorithm
Vera Roshchina: Partition and complementarity in multifold conic systems
Osman Guler: Efficient first-order methods for convex programming

**Conic programming: Applications of semidefinite optimization** [Organizer: Miguel Anjos] [p. 77]
Henry Wolkowicz: Taking advantage of degeneracy in cone optimization with applications to sensor network localization and molecular conformation
Philipp Hungerländer: Semidefinite optimization approaches to some facility layout problems
Manuel Vieira: Relationships between minimal unsatisfiable subformulas and semidefinite certificates of infeasibility

**Constraint programming: Constraint-based scheduling** [Organizer: Petr Välimä] [p. 78]
Andre Cire: MDD propagation for disjunctive scheduling
Philipp Laborie: Conditional interval variables: A powerful concept for modeling and solving complex scheduling problems

**Finance and economics: Applications of stochastic programming to finance and insurance** [Organizer: Giorgio Consiglii] [p. 78]
Andrea Consiglio: Convex lower bounding to generate multi-asset, arbitrage-free, scenario trees
Nalan Gulpinar: Robust investment decisions for asset liability management
Giorgio Consigli: Institutional asset-liability management for a large P&C insurance company

**Game theory: Games in networks** [Organizer: Konstantinos Bimpikis] [p. 79]
Yann Bramoulle: Network games under strategic complementarities
Matthew Elliott: A network centrality approach to coalitional stability
Konstantinos Bimpikis: Competitive marketing strategies over social networks
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<td>Global optimization: Optimization models and methods for computer vision</td>
<td>Vladimir Kolmogorov: Message passing algorithms for MAP-MRF inference, Daniel Cremers: Convex relaxation techniques with applications in computer vision, Katya Scheinberg: Studying effects of various step selection strategies in first order approaches to compressed sensing and other composite optimization problems, Maxim Collins: Random walks based multi-image segmentation: Quasiconvexity results and GPU-based solutions</td>
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<td>Implementations and software: Testing environments for machine learning and compressed sensing</td>
<td>Michael Friedlander: Spot: A linear-operator toolbox for Matlab, Katya Scheinberg: Convex relaxation techniques with applications in computer vision, Dirk Lorentz: Constructing test instances for basis pursuit denoising</td>
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<td>Integer and mixed-integer programming: Column generation and decomposition</td>
<td>Ozgur Ozpeynirci: Allocation of proposals to reviewers to facilitate effective ranking: a branch and price approach, Richard Lusby: A column generation approach for solving the patient admission scheduling problem</td>
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<td>Chuangyin Dang: A fixed-point iterative approach to integer programming and distributed computation, Thomas Rehn: Exploiting symmetry in integer convex optimization using core points, Timm Oertel: Convex integer minimization in fixed dimension</td>
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<td>Antoine Deza: Combinatorial, computational, and geometric approaches to the colourful simplicial depth, Justo Puerto: Ordered weighted average optimization of combinatorial problems, Matthias Köppe: A discretization-free FPTAS for polynomial optimization over the mixed-integer points in a class of polytopes of varying dimension</td>
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<td>Marco Molinaro: Strength of cross cuts, Sanjeeb Dash: On t-branch split cuts for mixed-integer programs, Egon Balas: Cut generating points on the boundary of a lattice-free convex set</td>
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<td>Hugues Richard: Fiona: Automatic correction of sequencing errors in genome sequencing experiments, Marriana D'Addario: DNA sequence design, Iman Hajirasouliha: Next-generation sequence characterization of complex genome structural variation.</td>
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<td>Logistics, traffic, and transportation: Facility location and p-median problems</td>
<td>Sergio García Quiles: On the p-median problem with uncertainty in the cost matrix, Vincius Xavier: Solving the Fermat-Weber location problem by the hyperbolic smoothing approach, Haldun Sural: The dynamic p-median problem with relocation</td>
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<td>Nonsmooth optimization: Constrained variational inequalities</td>
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  - Stefan Canzar: Transcriptome reconstruction using delayed column generation
  - Tobias Marschall: CLEVER: Clique-enumerating variant finder

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**Logistics, traffic, and transportation: TomTom routing and traffic research: Data, models and algorithms**

- **Organizer:** Heiko Schilling

  - Felix König: Crowd-sourcing in navigation – How selfish drivers help to reduce congestion for all

  **H 0104**

**Logistics, traffic, and transportation: Math programming in supply chain applications**

- **Organizer:** Pavithra Harsha

  - Maxime Cohen: Designing consumer subsidies with industry response for green technology adoption

  **H 0106**

**Logistics, traffic, and transportation: New algorithms for new pricing models**

- **Organizer:** Hamid Nazerzadeh

  - Ashish Goel: Reputation and trust in social networks

  **H 0111**

**Mixed-integer nonlinear programming: Structured MINLP and applications**

- **Organizer:** Noam Goldberg

  - Luis Briceño-Arias: Optimal continuous pricing with strategic consumers

  **MA 041**

**Mixed-integer nonlinear programming: Topics in mixed-integer nonlinear programming II**

- **Organizer:** Jacek Gondzio

  - Melissa Calinescu: Optimal resource allocation in survey designs

  **MA 042**

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- **Shashi Mishra: On constraint qualifications in multiobjective optimization problems with vanishing constraints**

  - Ingrida Steponavice: On robustness for simulation-based multiobjective optimization

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**Nonlinear programming: Regularization techniques in optimization II**

- **Organizer:** Jacek Gondzio

  - Stefania Bellavia: Regularized Euclidean residual algorithm for nonlinear least-squares with strong local convergence properties

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- **Makoto Yamashita: An approach based on shortest path and connectivity consistency for sensor network localization problems**

  - Amirhossein Sadoghi: Piecewise monotonic regression linear programs

  **H 0129**

**Nonsmooth optimization: Applications of nonsmooth optimization**

- **Ann-Brith Strömberg: Lagrangian optimization for inconsistent linear programs**

  - Michael Patriksson: Nonlinear continuous resource allocation – A numerical study

  **H 1012**

**Optimization in energy systems: Robust aspects of optimization in energy management**

- **Organizer:** Wim van Ackooij

  - Adilson Xavier: The continuous multiple allocation p-hub median problem solving by the hyperbolic smoothing approach: Computational performance

  **MA 549**

**Optimization in energy systems: Stochastic optimization applied to power systems**

- **Organizer:** Sara Lumbereras

  - Santiago Cerisola: Approximations of recourse functions in hydrothermal models: Numerical experiences

  **MA 550**

**PDE-constrained optimization and multi-level/multi-grid methods: Optimization applications in industry IV**

- **Organizer:** Dietmar Hömberg

  - Hans Josef Pesch: Direct versus indirect solution methods in real-life applications: Load changes of fuel cells

  - Chantal Landry: Modeling of the optimal trajectory of industrial robots in the presence of obstacles

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Florian Bruns: Robust load planning of trains in intermodal transportation  
Pierre-Louis Poirion: Robust optimal sizing of an hybrid energy stand-alone system |
|       |         |          | Sparse optimization and compressed sensing: Efficient first-order methods for sparse optimization and its applications (Organizer: Shiqian Ma) | Shiqian Ma: An alternating direction method for latent variable Gaussian graphical model selection  
Zhaosong Lu: Sparse approximation via penalty decomposition methods  
Donald Goldfarb: An accelerated linearized Bregman method |
|       |         |          | Stochastic optimization: Scenario generation in stochastic optimization (Organizer: David Papp) | David Papp: Generating moment matching scenarios using optimization techniques  
Teemu Pennanen: Tractability of stochastic programs  
Jitamitra Desai: A mathematical programming framework for decision tree analysis |
|       |         |          | Stochastic optimization: Large-scale stochastic programming (Organizer: Mihai Anitescu) | Andreas Grothey: Multiple-tree interior point method for stochastic programming  
Miles Lubin: Parallel and distributed solution methods for two-stage stochastic (MI)LPs  
Werner Roemisch: Are quasi-Monte Carlo methods efficient for two-stage stochastic programs? |
|       |         |          | Telecommunications and networks: Length bounded trees (Organizer: Markus Leitner) | Ivana Ljubic: Layered graph models for hop constrained trees with multiple roots  
Markus Leitner: New models for the diameter constrained steiner tree problem  
Andreas Bley: Capacitated facility location with length bounded trees |
|       |         |          | Variational analysis: Structural properties in variational analysis (Organizer: Stephen Robinson) | Boris Mordukhovich: Second-Order variational analysis and stability in optimization  
Adrian Lewis: Active sets and nonsmooth geometry  
Shu Lu: Confidence regions and confidence intervals for stochastic variational inequalities |
|       |         |          | Variational analysis: Equilibrium problems: Formulations and methodologies (Organizer: Patrizia Daniele) | Patrizia Daniele: General financial models: Methodologies and suggestions for the recovery  
Giovanni Crespi: Minty variational principle in set optimization  
Tina Wakolbinger: A variational inequality formulation of economic network equilibrium models with nonlinear constraints |
|       |         |          | Approximation and online algorithms: Randomized rounding algorithms in mathematical programming (Organizer: Maxim Sviridenko) | Viswanath Nagarajan: Thresholded covering algorithms for robust and max-min optimization  
Barna Saha: The constructive aspects of the Lovász Local Lemma: finding needles in a haystack  
Aravind Srinivasan: Dependent rounding and its applications |
|       |         |          | Combinatorial optimization: Knapsack and bin packing (Organizer: Maxim Sviridenko) | Alantha Newman: A counterexample to Beck's three permutations conjecture  
Paolo Detti: The bounded sequential multiple knapsack problem  
Joachim Schauer: Knapsack problems with disjunctive constraints |
|       |         |          | Combinatorial optimization: Graph coloring (Organizer: Maxim Sviridenko) | Noriyoshi Sukegawa: Lagrangian relaxation and pegging test for clique partitioning problems  
Jakub Marecek: Semidefinite programming relaxations in timetabling and matrix-free implementations of augmented Lagrangian methods for solving them |
|       |         |          | Combinatorial optimization: Competitive and multi-objective facility location (Organizer: Maxim Sviridenko) | Vladimir Beresnev: Algorithms for discrete competitive facility location problem  
Yury Kochetov: A local search algorithm for the (r | p)-centroid problem on the plane  
Marta Pascoal: A path-based method for multicriteria metaheuristics |
|       |         |          | Combinatorial optimization: Heuristics III (Organizer: Maxim Sviridenko) | Polina Kononova: Local search heuristic for the buffer-constrained two-stage multimedia scheduling problem  
Beyzanur Cayir: A genetic algorithm for truck to door assignment in warehouse routing problems |
|       |         |          | Combinatorial optimization: Polyhedra in combinatorial optimization (Organizer: Maxim Sviridenko) | Shungo Koichi: A note on ternary semimodular polyhedra  
Aleksandr Maksimenko: The common face of some 0/1 polytopes with NP-complete nonadjacency relations  
Shanfei Li: The polyhedral relationships between the capacitated facility location polytope and its knapsack and single-node flow relaxations |

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| 15:15 | Wednesday | H 3010   | Economic model and equilibrium models with nonlinearities (Organizer: Maxim Sviridenko) | Franz Halbstreit: A variational inequality formulation of resource allocation problems with nonconvexity  
Andreia Prado: A consequent vector equilibrium model in cost optimization  
Timo Wolsey: A variational inequality formulation of a nonsmooth optimization problem with nonlinearities |
|       |         |          | Linear algebra: Singular values and condition numbers and their applications | Christian Numer: Singular values and condition numbers  
Ole Frejinger: Geometric and non-smooth geometry  
Karsten Schürmann: matrices and condition numbers in applications of convex optimization |
|       |         |          | Variational analysis: Generalized convexity and quasiconvexity (Organizer: Maxim Sviridenko) | Jia Li: Generalized convexity and quasiconvexity  
John Jezowski: Generalized convexity and quasiconvexity in applications of convex optimization  
Glen Taylor: Generalized convexity and quasiconvexity in applications of convex optimization |
|       |         |          | Variational analysis: Generalized convexity and quasiconvexity (Organizer: Maxim Sviridenko) | Jia Li: Generalized convexity and quasiconvexity  
John Jezowski: Generalized convexity and quasiconvexity in applications of convex optimization  
Glen Taylor: Generalized convexity and quasiconvexity in applications of convex optimization |

**Wednesday 15:15–16:45**

**Approximation and online algorithms: Randomized rounding algorithms in mathematical programming (Organizer: Maxim Sviridenko)**

**Combinatorial optimization: Knapsack and bin packing (Organizer: Maxim Sviridenko)**

**Combinatorial optimization: Graph coloring (Organizer: Maxim Sviridenko)**

**Combinatorial optimization: Competitive and multi-objective facility location (Organizer: Maxim Sviridenko)**

**Combinatorial optimization: Heuristics III (Organizer: Maxim Sviridenko)**

**Combinatorial optimization: Polyhedra in combinatorial optimization (Organizer: Maxim Sviridenko)**
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| Tuesday: 13:30–15:00 | Combinatorial optimization: Routing in road networks                           | Andrew Goldberg                                                                | Peter Sanders: Advance route planning using contraction hierarchies  
Daniel Delling: Realistic route planning in road networks  
Andrew Goldberg: The hub labeling algorithm  
Wen Chen: A power penalty method for fractional Black-Scholes equations governing American option pricing |
| Tuesday: 15:30–17:00 | Complementarity and variational inequalities: Applications of complementarity | Jong-Shi Pang, Vadam Shmyrev, Sahar Karimi                              | Complementarity and variational inequalities: Applications of complementarity  
Ma 313: Jong-Shi Pang: On differential linear-quadratic Nash games with mixed state-control constraints  
H 3021: Andrew Goldberg: The hub labeling algorithm  
H 3021: Daniel Delling: Realistic route planning in road networks  
H 3021: Wen Chen: A power penalty method for fractional Black-Scholes equations governing American option pricing |
| Tuesday: 13:30–15:00 | Conic programming: First-derivative methods in convex optimization            | Yoel Drori, Clovis Gonzaga, Sahar Karimi                                | Conic programming: First-derivative methods in convex optimization  
H 2036: Clovis Gonzaga: On the complexity of steepest descent algorithms for minimizing quadratic functions  
H 2036: Sahar Karimi: CGSO for convex problems with polyhedral constraints |
| Tuesday: 13:30–15:00 | Conic programming: Conic and convex programming in statistics and signal processing | Defeng Sun, Parikshit Shah, Maryam Fazel                      | Conic and convex programming in statistics and signal processing: IV  
H 2038: Defeng Sun: Finding the nearest correlation matrix of exact low rank via convex optimization  
H 2038: Parikshit Shah: Algorithms for Hankel matrix rank minimization for system identification and realization  
H 2038: Maryam Fazel: Algorithms for Hankel matrix rank minimization for system identification and realization |
| Tuesday: 13:30–15:00 | Constraint programming: Computational sustainability                          | Alan Holland, Sahand Negahban, Maryam Fazel                           | Constraint programming: Computational sustainability  
H 3003A: Alan Holland: Optimising the economic efficiency of monetary incentives for renewable energy investment  
H 3003A: Sahand Negahban: Fast global convergence of composite gradient methods for high-dimensional statistical recovery  
H 3003A: Maryam Fazel: Algorithms for Hankel matrix rank minimization for system identification and realization |
| Tuesday: 13:30–15:00 | Derivative-free and simulation-based optimization                             | Joao Luaro Faco, Sebastian Stich, Anne Auger                           | Derivative-free and simulation-based optimization  
H 3503: Joao Luaro Faco: A continuous GRASP for global optimization with General Linear Constraints  
H 3503: Sebastian Stich: Convergence of local search  
H 3503: Anne Auger: Convergence of adaptive evolution strategies on monotonic Composite and scale-invariant functions |
| Tuesday: 13:30–15:00 | Finance and economics: Management of portfolios and liabilities              | Alberto Martin-Utterra, Nikos Trichakis, Pedro Júdice                | Finance and economics: Management of portfolios and liabilities  
H 3027: Alberto Martin-Utterra: Size matters: Calibrating shrinkage estimators for portfolio optimization  
H 3027: Nikos Trichakis: Fairness in multi-portfolio optimization  
| Tuesday: 13:30–15:00 | Game theory: Network sharing and congestion                                  | Alexandre Bogowski, Cheng Wan, Xavier Zeitoun                         | Game theory: Network sharing and congestion  
H 005: Alexandre Bogowski: Access network sharing between two telecommunication operators  
H 005: Cheng Wan: Coalitions in nonatomic network congestion games  
H 005: Xavier Zeitoun: The complexity of approximate Nash equilibrium in congestion games with negative delays |
| Tuesday: 13:30–15:00 | Game theory: Solving cooperative games                                        | Ping Zhao, Kazutoshi Ando, Pedro Júdice                           | Game theory: Solving cooperative games  
MA 043: Ping Zhao: A mixed-integer programming approach to the determination of a core element for an n-person cooperative game with non-transferable utility  
MA 043: Kazutoshi Ando: Computation of the Shapley value of minimum cost spanning tree games: #P-hardness and polynomial cases  
H 2053: Evrim Dalkiran: RLT-POS: Reformulation-linearization technique-based optimization software for polynomial programming problems  
H 2053: Hong Ryoo: 0-1 multilinear programming & LAD patterns  
H 2053: Spencer Schaber: Convergence order of relaxations for global optimization of nonlinear dynamic systems |
| Tuesday: 13:30–15:00 | Implementations and software: Commercial mathematical programming solvers  | Thorsten Koch, Tobias Achterberg, Eric Phipps                        | Implementations and software: Commercial mathematical programming solvers  
H 0110: Thorsten Koch: Any progress one year after MIPLIB 2010?  
H 0110: Tobias Achterberg: Cover probing for mixed integer programs  
H 0110: Eric Phipps: Support embedded algorithms through template-based generic programming |
| Tuesday: 13:30–15:00 | Implementations and software: Software for large-scale optimization         | Kevin Long, Eric Phipps, Rüdiger Stephan                             | Implementations and software: Software for large-scale optimization  
H 1058: Kevin Long: Sundance: High-level software for PDE-constrained optimization  
H 1058: Eric Phipps: Support embedded algorithms through template-based generic programming  
H 1058: Rüdiger Stephan: Smaller compact formulation for lot-sizing with constant batches |
| Tuesday: 13:30–15:00 | Integer and mixed-integer programming: Scheduling                           | Nelson Hein, Theodore Ralphs, Matthew Galati                         | Integer and mixed-integer programming: Scheduling III  
H 2013: Nelson Hein: Mathematical model of hierarchical production planning  
H 2013: Theodore Ralphs: Dip and DipPy: Towards a generic decomposition-based MIP solver  
H 2013: Matthew Galati: The new decomposition solver in SAS/OR |
H 2032: Marco Löbbecke: A generic branch-price-and-cut solver  
H 2032: Matthew Galati: The new decomposition solver in SAS/OR  
H 2032: Eric Phipps: Support embedded algorithms through template-based generic programming |
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José-María Ucha: Algebraic tools for nonlinear integer programming problems 1: Getting started.  
Maria Isabel Hartillo: Algebraic tools for nonlinear integer programming problems 2: Applications | | H 2033 |
| **Life sciences and healthcare:** Radiation therapy treatment planning | Troy Long: Beam orientation optimization in radiation therapy treatment planning | | | MA 376 |
| **Logistics, traffic, and transportation:** Vehicle and crew planning | Gary Froyland: Robust airline schedule planning, aircraft routing and crew pairing: An integrated scenario-based approach | Elmar Swarat: Modeling and solving a toll enforcement problem  
Guvenç Sahin: Tactical and strategic crew planning problems in railways | | H 0106 |
| **Logistics, traffic, and transportation:** Public transportation | Amin Toosi Vahid: An integer linear programming model for bus rapid transit network design | Weng Hei Tou: A dial-a-ride problem for public transport using electric vehicles  
Marie Schmidt: A new model for capacitated line planning | | H 0111 |
| **Mixed-integer nonlinear programming:** Quadratic integer programming | Christoph Buchheim: Nonconvex underestimators for integer quadratic optimization | | | MA 041 |
| **Mixed-integer nonlinear programming:** Topics in mixed-integer nonlinear programming III | Duan Li: MDP solvers for quadratic programs with cardinality and minimum threshold constraints: A semidefinite program approach | Vikas Sharma: A duality based approach for a class of bilevel programming problems  
Geeta Kumari: Symmetric duality for multiobjective second-order fractional programs | | MA 042 |
| **Multi-objective optimization:** Applications of vector and set optimization | Sonia Radjef: The direct support method to solve a linear multiobjective problem with bounded variables | Andreas Löhne: BENSOLVE – a solver for multi-objective linear programs | | H 1029 |
| **Nonlinear programming:** Line-search strategies | Ernesto G. Birgin: Spectral projected gradients: Reviewing ten years of applications | Sandra Santos: An adaptive spectral approximation-based algorithm for nonlinear least-squares problems | | H 0107 |
| **Nonlinear programming:** Applications of optimization II | Thea Göllner: Geometry optimization of branched sheet metal products | Alina Fedossova: Modeling of transboundary pollutant displacement for groups of emission sources | | H 0112 |
| **Nonsmooth optimization:** Variational methods in optimization | Nina Ovcharova: Second-order analysis of the Moreau-Yosida and the Lasry-Lions regularizations | Pando Georgiev: Global optimality conditions of first order for non-smooth functions in a Banach space | | H 1012 |
| **Optimization in energy systems:** Stochastic programming in energy | Gerardo Perez Valdes: Parallel computational implementation of a branch and fix coordination algorithm | Xiang Li: Stochastic nonconvex MINLP models and global optimization for natural gas production network design under uncertainty  
Lars Hellemo: Stochastic programming with decision dependent probabilities | | MA 549 |
| **Optimization in energy systems:** Stochastic equilibria in energy markets | Golbon Zakeri: Models for large consumer peak shaving and the impact on line pricing | Gauthier de Maere: Modeling market liquidity in restructured power systems by stochastic Nash and generalized Nash equilibrium | | MA 550 |
| **PDE-constrained optimization and multi-level/multi-grid methods:** | Arnd Roesch: Optimal control of a chemotaxis problem | Optimization applications in industry V  
Antoine Laurain: A shape and topology optimization method for inverse problems in tomography  
Stephanie Hokenmaier: Optimization with discontinuities and approximations in process engineering | | MA 415 |
| **Robust optimization:** Applications of robust optimization V | Akiko Takeda: Robust optimization-based classification method | Adrian Sichau: Shape optimization under uncertainty employing a second order approximation for the robust counterpart | | MA 004 |
Sparse optimization and compressed sensing: Structured models in inte
Rodolphe Jenatton: Proximal methods for hierarchical sparse coding and structured sparsity
Minh Pham: Alternating linearization for structured regularization problems
John Duchi: Adaptive subgradient methods for stochastic optimization and online learning

Stochastic optimization: Algorithms and applications for stochastic programming
Zhilin Zhou: A network based model for traffic sensor placement with implications on congestion observation
Ruwei Jiang: Optimization under data-driven chance constraints
Guozin Bayakasan: A sequential bounding method for a class of two-stage stochastic programs

Stochastic optimization: Network design, reliability, and PDE constraints
Olga Mnyudyk: Stochastic network design under probabilistic constraint with continuous random variables.
Zuzana Sabartová: Spatial decomposition for differential equation constrained stochastic programs
Rasool Tahmasbi: Network flow problems with random arc failures

Telecommunications and networks: Local access networks
Stefan Gollowitzer: Capacitated network design with facility location
Mojhe Rezapour: Approximation algorithms for connected facility location with buy-at-bulk edge costs
Ashwin Arulselvan: An incremental algorithm for the facility location problem

Variational analysis: Nonsmooth analysis with applications in engineerin
Alfredo Iusem: The effect of calmness on the solution set of nonlinear equations
Amos Uderzo: On some calmness conditions for nonsmooth constraint systems
Radek Cibulka: Quantitative stability of a generalized equation: Application to non-regular electrical circuits

Variational analysis: Some stability aspects in optimization theory
Abderrahim Hantoute: On convex relaxation of optimization problems
C. H. Jeffrey Pang: First order analysis of set-valued maps and differential inclusions
Vladimir Shikhman: Implicit vs. inverse function theorem in nonsmooth analysis

Thursday 10:30–12:00

Approximation and online algorithms: Approximation algorithms
David Williamson: A dual-fitting $3/2$-approximation algorithm for some minimum-cost graph problems
Naonori Kakimura: Computing knapsack solutions with cardinality robustness

Combinatorial optimization: Optimization and enumeration
Patrice Ossona de Mendez: Large structured induced subgraphs with close homomorphism statistics
Michael Chertkov: Computing the permanent with belief propagation
Amin Coja-Oghlan: Catching the k-NAESAT threshold

Combinatorial optimization: Robust network design
Manuel Kutschka: Robust metric inequalities for network design under demand uncertainty
Daniel Schmidt: Single commodity robust network design: Models and algorithms
Laura Santí: Steiner tree approximation via iterative randomized rounding

Combinatorial optimization: Resource placement in networks
David Johnson: Disjoint path facility location: theory and practice
David Applegate: Using an exponential potential function method to optimize video-on-demand content placement

Combinatorial optimization: Exact algorithms for hard problems
Réal Carbonneau: Globally optimal clusterwise regression by branch and bound optimization with heuristics, sequencing and ending subset
Marzana Fügenschuh: LP and SDP branch-and-cut algorithms for the minimum graph bisection problem: A computational comparison
Adelaide Cerveira: A two-stage branch and bound algorithm to solve truss topology design problems

Combinatorial optimization: Combinatorial optimization in railways
Ronny Hansmann: Minimal shunting operations for freight train composition
Andreas Bärmann: Approximate robust optimization and applications in railway network expansion
Torsten Klug: An approach for solving the freight train routing problem

Combinatorial optimization: Smoothed analysis of algorithms
Tjark Vredeveld: Smoothed analysis of local search
Tobias Brunsch: Improved smoothed analysis of multiobjective optimization
Kai Plociennik: A probabilistic PTAS for shortest common superstring
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<td>Daniel Dadush: Convex minimization over the integers, Guus Regts: Polyhedra with the integer Carathéodory property</td>
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<td>Logistics, traffic, and transportation: Analysis of decentralized network systems</td>
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<td>• Efficient solutions for non-regular multiobjective problems with inequality-type constraints</td>
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<td>Stefan Stefanov: Convex separable minimization with box constraints</td>
<td>Ganesh Perumal: A decomposition technique for convex optimization problems</td>
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<td>Anna-Laura Wickström: Generalized derivatives of the projection onto the cone of positive semidefinite matrices</td>
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<td>Waltraud Huyer: Minimizing functions containing absolute values of variables</td>
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<td>Capacity of gas transport networks</td>
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<td>Robert Schwarz: Gas network design with integrated optimization of topology and dimensioning</td>
<td>Paul Trodden: MILP-based islanding of large electricity networks using an aggregated model of power flows</td>
<td>Ken McKinnon: An MINLP approach to islanding electricity networks</td>
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<td>Luis A. Fernandez: Optimizing a chemotherapy model for brain tumors by using PDE</td>
<td>Lars Ole Schwen: Modeling flow through realistic, algorithmically generated vascular structures in the liver</td>
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<td>Alexandre D'Aspremont: High-dimensional geometry, sparse statistics and optimization</td>
<td>Fatma Kilinc Karzan: Verifiable sufficient conditions for ě recovery of sparse signals</td>
<td>Anatoli Juditsky: Accuracy guaranties and optimal ě recovery of sparse signals</td>
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<td>Philippe Rigollet: Deviational optimal model selection using greedy algorithms</td>
<td>Sujay Sanghavi: Learning the graph of network cascades</td>
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<td><strong>Stochastic optimization</strong></td>
<td>Decomposition methods for multistage stochastic programs</td>
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<td>Vincent Guigues: Sampling-based decomposition methods for multistage stochastic programs based on extended polyhedral risk measures</td>
<td>Wajdi Tekaya: Risk neutral and risk averse stochastic dual dynamic programming method</td>
<td>Suvrajee Sen: Multi-stage stochastic decomposition</td>
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### Telecommunications and networks: Networks in production, logistics and transport

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**Sabine Büttner:** Online network routing amongst unknown obstacles

**Thomas Werth:** Bottleneck routing games

**Marco Bender:** Online delay management: Beyond competitive analysis

### Telecommunications and networks: Allocation problems

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**Hasan Turan:** Volume discount pricing policy for capacity acquisition and task allocation models in telecommunication with fuzzy QoS Constraints

**Anders Gullhav:** Service deployment in cloud data centers regarding quality of service (QoS) requirements

**Deepak Garg:** Heuristic mathematical models for solving dynamic task assignment problem in distributed real time systems

### Variational analysis: Structure and stability of optimization problems

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**Jan-J Ruckmann:** Max-type objective functions: A smoothing procedure and strongly stable stationary points

**Helmut Gfrerer:** Second-order conditions for a class of nonsmooth programs

**Peter Fusek:** On metric regularity of the Kojima function in nonlinear semidefinite programming

### Variational analysis: Optimization methods for nonsmooth inverse problems in PDEs

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**Barbara Kaltenbacher:** Iterative regularization of parameter identification in PDEs in a Banach space framework

**Christian Clason:** Inverse problems for PDEs with uniform noise

### Thursday 13:15–14:45

#### Approximation and online algorithms: Scheduling, packing and covering

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**Wiebke Höhn:** On the performance of Smith’s rule in single-machine scheduling with nonlinear cost

**Christoph Dürr:** Packing and covering problems on the line as shortest path problems

**Alexander Souza:** Approximation algorithms for generalized and variable-sized bin covering

#### Combinatorial optimization: Cycles in graphs

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**Eva-Maria Sprengel:** An optimal cycle packing for generalized Petersen graphs $P(n, k)$ with $k$ even

**Peter Richter:** A “min-max-theorem” for the cycle packing problem in Eulerian graphs

**Lamia Aoudia:** 4-cycle polytope on a graph

#### Combinatorial optimization: Distance geometry and applications

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**Carilie Lavor:** A discrete approach for solving distance geometry problems related to protein structure

**Pedro Nucci:** Solving the discretizable molecular distance geometry problem by multiple realization trees

**Deck-Soo Kim:** Molecular distance geometry problem: A perspective from the Voronoi diagram

#### Combinatorial optimization: Discrete structures and algorithms II

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**Akiyoshi Shioura:** Computing the convex closure of discrete convex functions

**Naoyuki Kamiyama:** Matroid intersection with priority constraints

**Britta Peis:** Resource buying games

#### Combinatorial optimization: Nonlinear combinatorial optimization

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**Lauri Kettunen:** Cutting algorithms for quadratic combinatorial optimization problems

**Aleks Gorge:** Quadratic cuts for semidefinite relaxation of combinatorial problems

**Marta Vidal:** A new proposal for a lower bound in a generalized quadratic assignment problem applied to the zoning problem

#### Combinatorial optimization: Inverse problems

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**Natalia Shakhlievich:** On general methodology for solving inverse scheduling problems

**Daniele Catanzaro:** An exact algorithm to reconstruct phylogenetic trees under the minimal evolution criterion

**Peter Gritzmann:** On some discrete inverse problems: Combinatorial optimization in discrete and refraction tomography

#### Combinatorial optimization: Combinatorial optimization under uncertainty

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**Xiuli Chao:** Dynamic pricing decision for a monopoly with strategic customers and price adjustment

**Mahdi Noorzadegan:** A branch and cut approach for some heterogeneous routing problems under demand uncertainty

**Zhichao Zheng:** Least square regret in stochastic discrete optimization

#### Complementarity and variational inequalities: Iterative methods for variational inequalities

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**Igor Konnov:** Extended systems of primal-dual variational inequalities

**Alexander Zaslavski:** The extragradient method for solving variational inequalities in the presence of computational errors

**Vyacheslav Kalashnikov:** Finding a conjectural variations equilibrium in a financial model by solving a variational inequality problem

#### Conic programming: Conic relaxation approaches for scheduling and selection problems

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**Karthik Nataraajan:** On theoretical and empirical aspects of marginal distribution choice models

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**Anastasia Bakhtina:** Direct and inverse problems for mathematical models of resource allocation in a multi-scale system.
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Elena Fernandez: A compact formulation for the optimum communication spanning tree problem
Per Olov Lindberg: Updating shortest path subproblem solutions in large scale optimization

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Organizer: René Henrion [p. 223]
Alexey Izmaiov: Strong regularity and abstract Newton schemes for nonsmooth generalized equations
René Henrion: On (co-)derivatives of the solution map to a class of generalized equations

Variational analysis: Variational analysis of optimal value functions and set-valued mappings with applications
Organizer: Mau Nam Nguyen [p. 224]
Messoud Bounkhel: Regularity concepts of perturbed distance functions at points outside of the set in Banach spaces
Sangho Kum: A geometric mean of parameterized arithmetic and harmonic means of convex functions

Variational analysis: Variational methods in inverse problems
Organizer: Elena Resmerita [p. 224]
Esther Klann: A Mumford-Shah type approach for tomography
Mihaela Pricop-Jeckstadt: Genomic selection and iterative regularization methods
Christiane Pöschl: TV-denoising and evolution of sets

Thursday 15:15–16:45

Approximation and online algorithms: Online algorithms
Organizer: Lisa Fleischer [p. 224]
Aleksander Madry: A polylogarithmic-competitive algorithm for the k-server problem
Umang Bhaskar: Online mixed packing and covering
Vahab Mirrokni: Simultaneous adversarial and stochastic approximations for budgeted allocation problems

Combinatorial optimization: Optimization methods for geometric problems
Organizers: Sándor Fekete and Alexander Kröller [p. 225]
Dan Halperin: Multi-objective path optimization in motion planning: From the particular to the general
Chien-Chung Huang: Efficient algorithms for maximum weight matchings in general graphs with small edge weights

Combinatorial optimization: Recent advances in matching algorithms
Organizer: Piotr Sankowski [p. 225]
Manoj Gupta: Fully dynamic maximal matching in O(log n) update time
Chin-Itsh Fujishige: A polynomial-time algorithm for computing an r-ranking of a graph

Combinatorial optimization: Discrete structures and algorithms III
Organizer: Satoru Fujishige [p. 225]
Yusuke Kobayashi: An algorithm for finding a maximum t-matching excluding complete partite subgraphs
Shin-Ichi Tanigawa: Robustness of the minimum weight matching problem under 1-demand

Combinatorial optimization: Arborescences
Organizer: Christian Sommer [p. 226]
Attila Bernáth: Covering minimum cost arborescences
Mario Leston-Rey: Packing entering sets in kernel systems
Mikael Call: A polyhedral analysis of a unique shortest path routing polytope

Combinatorial optimization: Scheduling and network flows over time
Organizer: Martin Groß [p. 226]
Alberto Marchetti-Spaccamela: Universal sequencing on an unreliable machine
Martin Groß: Approximating earliest arrival flows in arbitrary networks
Jan-Philipp Kappmeier: Flows over time with negative transit times and arc release dates

Complementarity and variational inequalities: Algorithms for complementarity and related problems I
Organizer: Evgeny Uskov [p. 226]
Artur Pogosyan: Semismooth Newton-type methods for lifted mathematical programs with complementarity constraints
Evgeny Uskov: Global convergence of augmented Lagrangian methods applied to optimization problems with degenerate constraints, including problems with complementarity constraints
Walter Morris: Efficient computation of a canonical form for a generalized P-matrix

Conic programming: Conic optimization and signal processing applications
Organizer: Anthony Man-Cho So [p. 227]
Sen-Mo Ju: Approximating a KKT point of Schatten p-quasi-norm minimization in polynomial time, with applications to sensor network localization
Wing-Kin Ma: Semidefinite relaxation in wireless communications: Forefront developments, advances and challenges
Yang Yang: Multi-portfolio optimization: A variational inequality approach

Conic programming: Recent developments of theory and applications in conic optimization part I
Organizers: Hayato Waki and Masakazu Muramatsu [p. 227]
Muddappa Gowda: On the nonhomogeneity and the bilinearity rank of a completely positive cone
Masakazu Muramatsu: A perturbed sums of squares theorem for polynomial optimization and its applications
Farid Alizadeh: Some geometric applications of a mixed algebraic sum-of-squares cones
Derivative-free and simulation-based optimization: Recent progress in direct search methods [Organizers: Luís Nunes Vicente and Stefan Wild] [p. 227]  
José Mario Martínez: Inexact restoration method for derivative-free optimization with smooth constraints  
Rohollah Garmanjani: Smoothing and worst case complexity for direct-search methods in non-smooth optimization  

Finance and economics: Modern portfolio optimization [p. 228]  
Süleyman Özekici: Portfolio selection with hyperexponential utility functions  

Finance and economics: Applications in finance [p. 228]  
Jonas Ekblom: Optimal hedging of foreign exchange risk in uncertain cash flows using stochastic programming  
Mathias Barkhagen: An optimization based method for arbitrage-free estimation of the implied risk neutral density surface  
Janos Mayer: Portfolio optimization with objective functions from cumulative prospect theory  

Game theory: New models and solution concepts I [p. 228]  
Leqin Wu: A new solution concept for cooperative games  
Daniel Granot: Subgame perfect consistent stability  

Game theory: Software piracy and mastermind [p. 229]  
Yael Perlman: Software piracy prevention and price determination  
Carola Winzen: Playing mastermind with many colors  

Global optimization: Advances in global optimization III [p. 229]  
Chu Nguyen: The interior exterior approach for linear programming problem  
Duy Van Nguyen: Solving standard problem [STQP]  

Implementations and software: Modeling languages and software III [p. 229]  
Christian Valente: Optimisation under uncertainty: Software tools for modelling and solver support  
Vincent Beraudier: Modeling best practices: How to write good optimization models efficiently thanks to IBM ILOG CPLEX Optimization Studio’s Integrated Development Environment (IDE) and its debugging support.  

Integer and mixed-integer programming: Topology, clustering and separation [p. 230]  
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Inácio Andruski-Guimarães: Comparison of techniques based on linear programming to detect separation  

Integer and mixed-integer programming: Branch-and-price IV [p. 230]  
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François Vanderbeck: Primal heuristics for branch-and-price  
Michael Bastubbe: A branch-and-price algorithm for rearranging a matrix into doubly bordered block-diagonal form  

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Nam Dung Hoang: Steiner tree packing revisited  
Matthias Miltenberger: Advances in linear programming  

Life sciences and healthcare: Mathematical modeling of disease [p. 231]  
Rujira Ouncharoen: Stability of HIV aphaeresis model  

Logistics, traffic, and transportation: Logistics and transportation [Organizer: Arash Asadpour] [p. 231]  
Nitish Korula: Prize-collecting Steiner network problems on planar graphs  
Mohammadhossein Bateni: PTAS for planar multiway cut with bandwidth constraints  

Logistics, traffic, and transportation: Real-world applications [p. 231]  
Rodrigo Branchini: Fleet deployment optimization model for tramp and liner shipping  

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Raymond Hemmecke: N-fold integer programming in cubic time
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Gabriele Eichfelder: A procedure for solving vector optimization problems with a variable ordering structure [p. 232]

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Jinyan Fan: Accelerating the modified Levenberg-Marquardt method [p. 232]

Nonlinear programming: Polynomial optimization and semidefinite programming
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Nonlinear programming: Nonlinear multilevel and domain decomposition methods in optimization
Zdenek Dostal: Optimal massively parallel algorithms for large problems arising in mechanics [p. 232]

Nonlinear programming: Optimization with variable ordering structures
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Nonlinear programming: Optimization with variable ordering structures
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### Telecommunications and networks: Robust communication networks
- **Grit Claßen**: A branch-and-price approach for the robust wireless network planning
- **Peter Hoffmann**: Robust and chance constraint models of failure scenarios in the design of telecommunication networks
- **Daniel Karch**: Fiber replacement scheduling

**Organizer**: Arie Koster  
**Location**: H 3503

### Variational analysis: Set-valued convex and quasiconvex duality
- **Carola Schrage**: Dini derivatives for vector- and set-valued functions
- **Andreas Hamel**: Lagrange duality in set optimization
- **Samuel Drapeau**: Complete duality for convex and quasiconvex set-valued functions

**Organizer**: Andreas Hamel  
**Location**: H 2035

### Variational analysis: Semi-continuous programming
- **Ademir Ribeiro**: Fenchel-Moreau conjugation for lower semi-continuous functions
- **Fernanda Raupp**: A duality scheme for semi-continuous programming
- **Wilfredo Sosa**: Separation theorems for closed sets

**Organizer**: Wilfredo Sosa  
**Location**: H 2051

### Friday 10:30–12:00

#### Approximation and online algorithms: Approximation of vehicle routing problems
- **Martijn van Brink**: Express delivery of packages
- **Ignacio Vargas**: An efficient decision making process for vehicle operations in underground mining based on a mixed-integer programming model

**Location**: H 3010

#### Combinatorial optimization: Combinatorial optimization for hard problems
- **Lin Chen**: Approximation algorithms for scheduling parallel machines with capacity constraints
- **Guangting Chen**: Approximation algorithms for parallel open shop scheduling
- **Xudong Hu**: New models for network connection problems with interval data

**Organizer**: Erwin Pesch  
**Location**: H 3004

#### Combinatorial optimization: Combinatorial optimization in logistics
- **Jens Schulz**: Explanation algorithms in cumulative scheduling
- **Jenny Nossack**: Benders decomposition for a 1-full-truckload pick-up-and-delivery vehicle routing problem

**Organizer**: Gaulter Stauffer  
**Location**: H 3005

#### Combinatorial optimization: Algorithms in claw-free graphs
- **Matthias Mnich**: Domination when the stars are out – Efficient decomposition of claw-free graphs
- **Yuri Faenza**: Separating stable sets in claw-free graphs through extended formulations

**Organizer**: Gaulter Stauffer  
**Location**: H 3008

#### Combinatorial optimization: Cliques, stable sets, and perfect graphs
- **Maribel Montenegro**: On the N-index of the stable set polytope related to antiwebs
- **Graciela Nasini**: Lovász-Schrijver \( N \) relaxations on the fractional stable set polytope in a superclass of near-perfect graphs
- **Claudia Sine**: Minimum weighted clique cover on strip-composed perfect graphs

**Organizer**: Guochuan Zhang  
**Location**: H 3012

#### Combinatorial optimization: Extended formulations
- **Paolo Serafini**: Compact formulations for large-scale LP problems
- **Rall Borndörfer**: Configuration models for solving integrated combinatorial optimization problems

**Location**: H 3013

#### Complementarity and variational inequalities: Algorithms for complementarity and related problems II
- **Mauro Passacantando**: Gap functions and penalization for solving equilibrium problems with nonlinear constraints
- **Goran Lesaja**: Infeasible full-Newton step interior-point method for linear complementarity problems

**Location**: MA 313

#### Conic programming: Algebraic geometry and conic programming, part I
- **Tim Netzer**: Describing the feasible sets of semidefinite programming
- **Sabine Burgdorf**: Lasserre relaxation for trace-optimization of NC polynomials

**Organizers**: Lek-Heng Lim and Cordian Riener  
**Location**: H 2036

#### Conic programming: Recent developments of theory and applications in conic optimization part II
- **Matsukawa Yasuaki**: A primal barrier function phase I algorithm for nonsymmetric conic optimization problems
- **Victor Magron**: Certification of inequalities involving transcendental functions using semi-definite programming.

**Organizers**: Hayato Waki and Masakazu Muramatsu  
**Location**: H 2038

#### Derivative-free and simulation-based optimization: MINLP and constrained optimization without derivatives
- **Francisco Sobral**: Constrained derivative-free optimization on thin domains
- **Juliane Müller**: A surrogate model algorithm for computationally expensive mixed-integer black-box global optimization problems

**Organizers**: Stefan Wild and Luis Nunes Vicente  
**Location**: H 3003A
Finance and economics: Portfolio selection problems  
Constanta Radulescu: Portfolio selection models with complementarity constraints  
Marius Radulescu: The efficient frontiers of mean-variance portfolio selection problems  

Finance and economics: Optimal control  
Arindum Mukhopadhyay: A socio-economic production quantity [SEPQ] model for imperfect items with pollution control and varying setup costs  
Yuchi Takano: Control policy optimization for dynamic asset allocation by using kernel principal component analysis  
Vasile Dikusar: An optimal control problem in estimation of parameters for economic models  

Game theory: New models and solution concepts II  
Ming Hu: Existence, uniqueness, and computation of robust Nash equilibrium in a class of multi-leader-follower games  
Silvia Schwarze: Equilibria in generalized Nash games with applications to games on polyhedra  
Yin Chen: Computing perfect equilibria of finite n-person games in normal form with an interior-point path-following method  

Global optimization: Recent advances in nonconvex quadratic programming with random data  
Nicolas Gillis: Fast and robust recursive algorithm for separable nonnegative matrix factorization  
Jiming Peng: Quadratic optimization with separable objective and a single quadratic and box constraint  
Paul Krokhmal: Asymptotic properties of random multidimensional assignment problems  

Global optimization: Advances in global optimization IV  
Syuuji Yamada: Global optimization methods utilizing partial separating hyperplanes for a canonical dc programming problem  
John Forrest: A bit of CLP (accelerated)?  
Amaya Nogales Gómez: Matheuristics for Ψ-learning  

Implementations and software: Open source software for modeling and optimization  
Gus Gassmann: Optimization services: Connecting algebraic modelling languages to several solvers using a web-aware framework  
Max Nattermann: A quadratic approximation of confidence region candidates for reversals in bacterium Myxococcus xanthus  

Integer and mixed-integer programming: Integer programming in data mining  
Yufeng Liu: Optimization issues on some margin-based classifiers  
James Brooks: Counting misclassifications: Robust support vector machines via integer programming  
Amaya Nogales Gómez: Matheuristics for Ψ-learning  

Integer and mixed-integer programming: Matheuristics  
José Valério de Carvalho: SearchCol algorithms for the level bin packing problem  
Patrick Schittekat: A matheuristic for competence building with the use of nurse re-rostering  
Marco Boschetti: A Lagrangian heuristic for the sprint planning in agile methods  

Integer and mixed-integer programming: Integer programming approaches to job scheduling  
Valentina Capaldi: Fixed job scheduling with resource constraints  
Riley Clement: A big-bucket time-indexed formulation for nonpreemptive single machine scheduling problems  
Hamish Waterer: Maintenance Scheduling in Critical Infrastructure Networks  

Life sciences and healthcare: Model discrimination and experimental design  
Max Nattermann: A quadratic approximation of confidence regions  
Tanja Binder: Numerical optimization methods for significance analysis of parameters and subsets of metabolic networks  
Alexandra Herzog: Discrimination of competitive model candidates for reversals in bacterium Myxococcus xanthus  

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Jürgen Pannek: Collision avoidance via distributed feedback design  
Cornelius Schwarz: The laser sharing problem with fixed tours  
Wolfgang Weitz: Conflict-free job assignment and tour planning of welding robots  

Logistics, traffic, and transportation: Disruption management  
Stephen Maher: Integrated airline recovery problem on a minimal disruption neighbourhood  
Kazuhiro Kobayashi: Alternative objective functions in ship scheduling for managing supply chain disruption risk  
Lucian Ionescu: Stochastic optimization models for airline resource schedules under disruptions  

Mixed-integer nonlinear programming: Applications of MINLP I  
Claudia Stang: Feasibility testing for transportation orders in real-life gas networks  
Francois Margot: The traveling salesman problem with neighborhoods: MINLP solution  
Jakob Schelbert: How to route a pipe – Discrete approaches for physically correct routing  

Mixed-integer nonlinear programming: Applications of MINLP II  
Claudia Stang: Feasibility testing for transportation orders in real-life gas networks  
Francois Margot: The traveling salesman problem with neighborhoods: MINLP solution  
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Convexity and nonlinear programming: Disjoint unions of convex sets  
Nicolas Gillis: Fast and robust recursive algorithm for separable nonnegative matrix factorization  
Jiming Peng: Quadratic optimization with separable objective and a single quadratic and box constraint  
Paul Krokhmal: Asymptotic properties of random multidimensional assignment problems  

Game theory: Algorithmic game theory [Organizer: Azarakhsh Malekian]  
Brendan Lucier: Strategyproof mechanisms for competitive influence in social networks  
Nicole Immorlica: Social networks and segregation  
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ABSTRACTS

The session codes

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- **Abstract for Mon.1.H 3004**
  - Combinatorial optimization in chip design I
  - Organizer/Chair Stephan Held, University of Bonn - Invited Session
  - Igor Markov, University of Michigan | Myung-Chul Kim
  - A primal-dual Lagrange optimization for VLSI global placement
  - We propose a projected subgradient primal-dual Lagrange optimization for global placement that can be instantiated with a variety of interconnect models. It decomposes the original non-convex problem into “more convex” subproblems. It generalizes the recent SimPL, SimPLR and Ripple algorithms and extends them. Empirical results on the ISPD 2005 and 2006 benchmark suites confirm the superiority of this technique compared to prior art.

- **Abstract for Mon.1.H 3004**
  - Combinatorial optimization
  - Organizer/Chair Lionel Pournin, EFREI - Invited Session
  - Markus Skurnik, Research Institute for Discrete Mathematics, Bonn University
  - Quadratic and constrained placement in chip design: Global flows and local realizations
  - The classical large scale placement problem is a key step in chip design. Given a finite set of modules connected by nets, the task is to find overlap-free positions to the modules in such a way that the overall net length is minimized. This talk presents a quadratic, partitioning-based placement algorithm which is able to handle non-convex and overlapping position constraints to subsets of modules, the *move bounds*. The core routine of our algorithm is the flow-based partitioning which combines a global MinCostFlow model for computing directions with extremely fast and highly parallelizable local realization steps. Despite its global view, the size of the MinCostFlow instance is only linear in the number of partitioning regions and does not depend on the number of cells. We prove that our partitioning scheme finds a fractional solution for any given placement or decides in polynomial time that none exists.

- **Abstract for Mon.1.A 041**
  - Approximation & online algorithms
  - Organizer/Chair Lionel Pournin, EFREI - Invited Session
  - Hyung-Chan An, EPFL | Robert Kleinberg, David Shmoys
  - Improving Christofides’ algorithm for the s-t path TSP
  - We present a deterministic $\frac{3}{2}$-approximation algorithm for the s-t path TSP for an arbitrary metric. Given a symmetric metric cost on n vertices including two prespecified endpoints, the problem is to find a shortest Hamiltonian path between the two endpoints; Hoogeveen showed that the natural variant of Christofides’ algorithm is a 5/3-approximation algorithm for this problem, and this asymptotically tight bound in fact had been the best approximation ratio known until now. We modify this algorithm so that it makes a minimum cost spanning tree but may still overlap, and the task is to arrange them overlap-free into rows such that the cells’ movement is minimized. We prove that our algorithm is the first to be able to handle non-convex and overlapping position constraints to subsets of modules, the *move bounds*. The core routine of our algorithm is the flow-based partitioning which combines a global MinCostFlow model for computing directions with extremely fast and highly parallelizable local realization steps. Despite its global view, the size of the MinCostFlow instance is only linear in the number of partitioning regions and does not depend on the number of cells. We prove that our partitioning scheme finds a fractional solution for any given placement or decides in polynomial time that none exists.

- **Abstract for Mon.1.H 3004**
  - Combinatorial optimization
  - Organizer/Chair Lionel Pournin, EFREI - Invited Session
  - Ulrich Breuer, University of Bonn
  - Fractional versus integral flows: A new approach to VLSI legalization
  - In VLSI placement legalization, a large set of rectangular cells and the same height is given. The cells are spread across a rectangular area but may still overlap, and the task is to arrange them overlap-free into rows such that the cells’ movement is minimized. We relax the problem by allowing to move fractions of cells, this leads to a minimum-cost flow formulation. Several legalization algorithms are based on that idea. However, in the end we have to get rid of the relaxation since cells cannot be split. Most approaches just round the flow solution and then iterate the whole process.
  - Our algorithm is based on the Successive-Shortest Path Algorithm which iteratively augments flow along paths, but we ensure that only augmentations are considered that can be realized exactly by cell movements. Hence, the method avoids realization problems which are inherent to previous flow-based legalization algorithms.
  - We compare our approach to legalization tools from industry and academia by experiments on recent real-world designs and public benchmarks. The results show that we are faster and produce significantly smaller movements than any other tool.

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dimensional cube. This result makes it possible to completely enumerate the triangulations of this vertex set in a reasonable time: it is found that there are 92487256 such triangulations, partitioned into 247451 symmetry classes.

Felix Schmied, Technische Universität München

**Gromov-Hausdorff distance of finite metric spaces**

The Gromov-Hausdorff distance of two compact metric spaces is a measure for how far the two spaces are from being isometric. It is a pseudometric on the space of compact metric spaces and has been extensively studied in the field of metric geometry. In recent years, a lot of attention has been devoted to computational aspects of the Gromov-Hausdorff distance. One of the most active topics is the problem of shape recognition, where the goal is to decide whether two shapes given as polygonal meshes are equivalent under certain invariances.

In this talk, we will investigate the computational complexity of several decision versions of the problem. By relating it to other well-known combinatorial optimization problems like the clique and the graph isomorphism problem, we prove that determining the largest subspace of two finite metric spaces with a fixed upper bound on the Gromov-Hausdorff distance is not in \( \mathcal{APX} \). Furthermore, novel algorithms for the problem will be derived from these results.

**Motivated by the current market ecosystem of online display advertising, where buyers buy goods through intermediaries, we study a natural setting where intermediaries are allowed to price discriminate buyers based on their willingness to pay. We show that introducing perfect price discrimination via an intermediary into the Fisher model with piecewise-linear, concave (PLC) utilities renders its equilibrium polynomial time computable. Moreover, and surprisingly, its set of equilibria is captured by a convex program that generalizes the classical Eisenberg-Gale program, and always admits a rational solution. We also give a combinatorial, polynomial time algorithm for computing an equilibrium. We note that the problem of computing an equilibrium for the traditional Fisher market with PLC utilities is unlikely to be in \( \mathcal{P} \), since it is PPAD-complete.**

**Eisenberg-Gale markets: Algorithms and game theoretic properties**

We define a new class of markets, the Eisenberg-Gale markets. This class contains Fisher's linear market, markets from the resource allocation framework of Kelly [1997], as well as numerous interesting new markets. We obtain combinatorial, strongly polynomial algorithms for several markets in this class. Our algorithms have a simple description as ascending price auctions. Our algorithms lead to insights into game-theoretic properties of these markets, such as efficiency, fairness, and competition monotonicity. They also help determine if these markets always have rational equilibria. A classification of Eisenberg-Gale markets w.r.t. these properties reveals a surprisingly rich set of possibilities.

Gagan Goel, Google Research (with Vijay Vazirani)

**A perfect price discrimination market model, and a rational convex program for it**

Combinatorial optimization

**Organizer/Chair Vijay Vazirani, Georgia Tech - Invited Session**

Vijay Vazirani, Georgia Tech

**Rational convex programs**

A nonlinear convex program that always has a rational optimal solution will be called a rational convex program (RCP). The notion is analogous to that of an integral linear program (ILP), i.e., an LP that always has integral optimal solutions. The field of combinatorial optimization is built around problems whose LP-relaxations are ILPs.

Our contention is that in many ways, the situation with RCPs is similar to that of ILPs. In both cases, the existence of much higher quality solution is indicative of combinatorial structure that can not only lead to efficient algorithms but also deep insights that yield unexpected gains. This was certainly the case with ILPs, which led to a very rich theory that underlies not only combinatorics but also the theory of algorithms.

Kamal Jain, eBay Research (with Vijay Vazirani)

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A rapid branching method for the vehicle rotation planning problem

The Vehicle Rotation Planning Problem is to schedule rail vehicles in order to cover the trips of a given timetable by a cost optimal set of vehicle rotations. The Problem integrates several facets of railway optimization: train composition, fleet management, maintenance planning, and regularity aspects. We model this problem as a multi-commodity min-cost-flow hypergraph problem and solve it by integer programming based on heuristics.

The core of our algorithm is the Rapid Branching method which also was successfully used to solve track allocation problems and integrated vehicle and duty scheduling problems. The Rapid Branching method can be seen as a very fast heuristical traversal of a branch-and-bound search tree. We also present computational results on very large instances of the vehicle rotation planning problem given by our industrial partner DB Fernverkehr AG, which is the largest intercity railway operator in Germany.

**Combinatorial optimization**

On the hardness of scheduling with precedence constraints to minimize makespan

We will talk about the recently established reductions from a bipartite (and k-partite) ordering problem to two classical scheduling problem: scheduling with precedence constraints on identical machines to minimize makespan \(\|P_{\text{prec}}(C_{\max})\|\) and scheduling with precedence constraints on related machines to minimize makespan \(\|P_{\text{prec}}(C_{\max})\|\). We will also talk about the hardness of the k-partite ordering problem remains open even if we assume the unique games conjecture.

**Conic programming**

How to solve when you have to buy your energy

We consider a situation where jobs arrive over time at a data center, consisting of identical speed-scalable processors. For each job, the scheduler knows how much income is lost as a function of how long the job is delayed. The scheduler also knows the fixed cost of a unit of energy. The online scheduler determines which jobs to run on which processors, and at what speed to run the processors. The scheduler’s objective is to maximize profit, which is the income obtained from jobs minus the energy costs. We give a \((1+\varepsilon)\)-speed \(O(1)\)-competitive algorithm, and show that resource augmentation is necessary to achieve \(O(1)\)-competitiveness.

**Geometry and duality in convex programming**

Facial reduction algorithm

Facial reduction algorithm [FRA] generates a smaller conic optimization problem by exploiting the degeneracy in a given conic optimization problem. However, the computation is comparable to solving
the original problem. In addition, the resulting problem may lose the sparsity. In this talk, we show that one can apply FRA effectively by using structure in the original problem. For this, we present some examples, such as SDP relaxation for polynomial optimization and graph partitioning. In particular, we prove that in SDP relaxation for polynomial optimization, some methods for reducing the size of the SDP relaxation problems are partial application of FRA. This is joint work with Professor Masakazu Muramatsu (UEC).

Vera Roshchina, University of Ballarat (with Javier Peña)

Partition and complementarity in multifold conic systems

We consider a homogeneous multifold convex conic system and its dual and show that there is canonical partition of the multifold structure determined by certain complementarity sets associated to the most interior solutions of the system. Our results are inspired by and extend the Goldman-Tucker Theorem for linear programming.

Roman Sahin, University of Maryland (UMBC)

Efficient first-order methods for convex programming

First-order methods for convex programming use only information about gradients (or subgradients). They are especially useful for large-scale problems since each iteration is cheap, memory requirements are low, and the convergence rates do not depend on the dimension of the problem. After the pioneering work by Polyak and later on by Yudin-Nemirovskii, and especially after Nesterov’s work on optimal first-order method which emulates the conjugate gradient method, there has been a lot of recent interest in such methods. These algorithms can be extended to optimization problems with constraints, minimax problems, and have connections with the proximal-point methods. However, certain aspects of the algorithms are somewhat mysterious and not well understood. In our talk, we will explore the theoretical underpinnings of these methods and find new applications for them.

Relational semantics and optimization

Eugenia Ternovska, University of Alberta (with Lewis Paul)

Constraint programming

We take an optimization perspective to constraint programming. We introduce the concept of variable elimination and solve a constraint satisfaction problem with a backtracking search algorithm. We then discuss the concept of lossless cuts and how to implement them in a branch-and-bound tree.

Mon.1.H 2038

Applications of semidefinite optimization

Organizers/Chair Miguel Anjos, École Polytechnique de Montréal - Limited Session

Henry Wolkowicz, University of Waterloo

Taking advantage of degeneracy in cone optimization with applications to sensor network localization and molecular conformation

The elegant theoretical results for strong duality and strict complementarity for linear programming, LP, can fail for cone programming over nonpolyhedral cones. Surprisingly, this happens for many instances of semidefinite optimization, SDP, more problems than arise from relaxations of hard combinatorial problems. Rather than being a disadvantage, we show that this degeneracy can be exploited. In particular, several huge instances of SDP completion problems can be solved quickly and at extremely high accuracy. We illustrate this on the sensor network localization and molecular conformation problems.

Mon.1.H 3003A

Constraint-based scheduling

Organizer/Chair Piet Van Hoesel, IBM Czech Republic - Limited Session

André Cun, Carnegie Mellon University (with William van Hoeve)

MDD propagation for disjunctive scheduling

Disjunctive scheduling refers to a wide range of problems in which activities must be scheduled on a resource capable of processing only one operation at a time. Constraint-based techniques, such as edge finding and not-first/not-last rules, have been a key element in successfully tackling large and complex disjunctive scheduling problems in recent years. In this work we investigate new constraint propagation methods based on limited-width Multivalued Decision Diagrams (MDDs), which represent a relaxation of the feasible sequences of activities that must be scheduled on the resource. We present theoretical properties of the MDD encoding and describe filtering and refinement operations that strengthen the relaxation it provides. Furthermore, we provide an efficient way to integrate the MDD-based reasoning with state-of-the-art propagation techniques for scheduling. Experimental results indicate that the MDD propagation can outperform existing domain filters especially when minimizing sequence-dependent setup times, in certain cases by several orders of magnitude.

Mon.1.H 3027

Applications of stochastic programming to finance and insurance

Organizers/Chair Giorgio Consigli, University of Bergamo - Limited Session

Andrea Consigli, University of Palermo (with Angelo Caroli, Alessandro Staini)

Convex lower bounding to generate multi-asset, arbitrage-free, scenario trees

Simulation models of economic and financial factors are nowadays widely used to support decisions or to assess risk exposures. An extensive literature on scenarios generation is available whose main aim is to build trees with the least number of nodes, while ensuring a given level of accuracy in describing the joint probability distribution of the process. There is, however, another important issue that is usually overlooked or, worse, ignored: the no-arbitrage restriction.

A possible solution, relatively to the moment matching approach, is to add the no-arbitrage restriction to the set of equations describing the moments of the multivariate distributions, with the shortcutting, however, of worsening the numerical stability and precision of the solution.

The aim of our analysis is to provide a new solution method for the moment matching model to overcome the limitation raised above. We re-formulate the problem of finding all the solutions of a set of non-linear equations as a global optimization problem. We then focus on new convex lower bounding techniques to provide a more stable and reliable approach to stochastic tree generation.

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Philipp Hungerländer, Alpen-Adria-Universität Klagenfurt (with Miguel Anjos, Franz Rendl)

Semidefinite optimization approaches to some facility layout problems

Facility layout is concerned with the optimal location of departments inside a plant according to a given objective function reflecting transportation and construction costs of a material-handling system. The Multi-Row Facility Layout Problem is concerned with optimizing the placement of departments along one or several rows. The Directed Circular Facility Layout Problem searches for the optimal arrangement of departments on a circle and contains several layout problems extensively discussed in the literature, namely the Equidistant Undirected Cyclic Layout Problem, the Balanced Undirected Cyclic Layout Problem, and the Directed Cyclic Arrangement Problem, as special cases. We show that all these layout problems can be modeled as Quadratic Programming Problems and hence solved to global optimality using a general semidefinite programming approach. We report optimal solutions for a variety of single-row instances from the literature with up to 42 departments that remained unsolved so far. Furthermore, we provide high-quality global bounds for double-row instances with up to 14 departments and optimal arrangements for directed circular instances with up to 80 departments.

Manuel Veiga, Nova University of Lisbon (with Miguel Anjos)

Relationships between minimal unsatisfiable subformulas and semidefinite certificates of infeasibility

It is known that if the semidefinite programming (SDP) relaxation of a satisfiability (SAT) instance is infeasible, then the SAT instance is unsatisfiable. Moreover, when the SDP relaxation is infeasible, we can exhibit a proof in the form of an SDP certificate of infeasibility. We can extract information about the SAT instance from the SDP certificate of infeasibility. In particular, we show how the SDP certificate of infeasibility can provide information about minimal unsatisfiable sub-formulas.
using real data are presented to compare the performance of different formalizations of the problem.

Giorgio Consigli, University of Bergamo (with Massimo di Tria, Vittorio Montigia, Davide Mustielli, Angela Iustini)

Institutional asset-liability management for a large P&C insurance company

We present an asset-liability management problem for a large insurance company based on a real world development. A 10 year problem is formulated as a stochastic quadratic program with a multifactor objective function based on short, medium and long term targets. The investment universe includes fixed-income, real estate and equity investment plus alternative investments such as private equity, renewable energy, infrastructures and commodities with dedicated stochastic models. Liability and insurance reserves are inflation adjusted and the management aims at controlling the risk exposure while achieving short and medium term goals without jeopardising the long term business sustainability.

Konstantinos Bimpikis, Stanford University (with Asuman Ozdaglar, Ercan Yildiz)

Message passing algorithms for MAP-MRF inference

I will consider the problem of computing maximum a posteriori configuration in a Markov Random Field, or equivalently minimizing a function of discrete variables decomposed as a sum of low-order terms. This task frequently occurs in many fields such as computer vision and machine learning. A popular approach to tackling this NP-hard problem is to solve its LP relaxation. I will talk about message passing algorithms that try to solve the LP, in particular sequential tree-reweighted message passing (TRW-S) and its extensions. TRW-S shows good performance in practice and is often used for computer vision problems.

Vladimir Kolmogorov, IST Austria

Convex relaxation techniques with applications in computer vision

Numerous computer vision problems can be solved by variational methods and partial differential equations. Yet, many traditional approaches correspond to non-convex energies giving rise to suboptimal solutions and often strong dependency on appropriate initialization. In my presentation, I will show how problems like image segmentation, multiview stereo reconstruction and optic flow estimation can be formulated as variational problems. Subsequently, I will introduce convex relaxation techniques which allow to compute globally optimal or near-optimal solutions. The resulting algorithms provide robust solutions, independent of initialization and compare favorable to spatially discrete graph theoretic approaches in terms of computation time, memory requirements and accuracy.

Maxwell Collins, University of Wisconsin-Madison (with Leo Grady, Vikas Singh, Xia Jia)

Random walks based multi-image segmentation: Quasiconvexity results and GPU-based solutions

We recast the cosegmentation problem using random Walker segmentation as the core segmentation algorithm, rather than the traditional MRF approach adopted in the literature so far. Our formulation is similar to previous approaches in that it also permits cosegmentation constraints which impose consistency between the extracted objects from 2+ images using a nonparametric model. However, several previous nonparametric cosegmentation methods have the limitation that they require one auxiliary node for every pair of pixels that are similar (limiting such methods to describing only those objects that have high entropy appearance models). Our proposed model eliminates this dependence – the resulting improvements are significant. We further allow an optimization scheme exploiting quasiconvexity for model-based segmentation with no dependence on the scale of the segmented foreground. Finally, we show that the optimization can be expressed in terms of operations on sparse matrices which are easily mapped to GPU architecture. We provide a specialized CUDA library for cosegmentation exploiting this special structure, and report experimental results showing these advantages.
Michael Friedlander, University of British Columbia (with Ewout van den Berg)

Spot: A linear-operator toolbox for Matlab

Linear operators are at the core of many of the most basic algorithms for signal and image processing. Matlab’s high-level, matrix-based language allows us to express naturally many of the underlying matrix operations – e.g., computation of matrix-vector products and manipulation of matrices – and is thus a powerful platform on which to develop concrete implementations of these algorithms. Many of the most useful operators, however, do not lend themselves to the explicit matrix representations that Matlab provides. This talk describes the new Spot Toolbox, which aims to bring the expressiveness of Matlab’s built-in matrix notation to problems for which explicit matrices are not practical. I will demonstrate features of the toolbox with examples from compressed sensing and image reconstruction.

Kaya Scheinberg, Lehigh University

Studying effects of various step selection strategies in first order approaches to compressed sensing and other composite optimization problems

We will discuss theoretical and practical implications of various strategies for selecting the prox parameters in prox gradient methods and related alternating direction methods. We will show extension of existing convergence rates for both accelerated and classical first-order methods. Practical comparison based on a testing environment for L1 optimization will be presented.

Dirk Lorenz, TU Braunschweig (with Christian Kuschel)

Constructing test instances for basis pursuit denoising

The number of available algorithms for the so-called Basis Pursuit Denoising problem (or the related LASSO-problem) is large and keeps growing. Similarly, the number of experiments to evaluate and compare these algorithms on different instances is growing.

In this talk, we discuss a methods to produce instances with exact solutions which is based on a simple observation which is related to the so-called source condition from sparse regularization and the so-called dual certificate. We construct such dual-certificate by alternating projections on convex sets and also by linear programming method. The method have been implemented in a MATLAB package L1TestPack.

Dzmitry Ouzeyarnci, Izmirt University of Economics

Allocation of proposals to reviewers to facilitate effective ranking: A branch and price approach

One of the key problems for the funding agencies is to determine the proposals that are worth funding. A recent evaluation approach uses the ordinal ranking of the proposals. The approach allocates the proposals to the reviewers and each reviewer provides pairwise comparison of the assigned proposals. The approach uses a set covering IP model to assign the proposals so as to receive the maximum pairwise comparison information considering the capabilities and the preferences of the reviewers. In this study, we develop two new mathematical models for this approach. The size of the first model is polynomial in the number of the proposals. We propose a branch and price algorithm in the second model. We conduct a computational experiment to compare the performances of three models on a set of randomly generated instances.

Richard Lusby, Department of Management Engineering, Technical University of Denmark (with Jørgen Larsen, Troels Range)

A column generation approach for solving the patient admission scheduling problem

The Patient Admission Scheduling Problem (PASP) is the problem of assigning patients to hospital rooms in such a way that the preferences of the patients as well as the effectiveness of the medical treatment are maximized. We present a Dantzig-Wolfe decomposition of PASP into a set partitioning master problem and a set of room scheduling problems for the pricing problems; here each column of the master corresponds to a feasible room schedule over the planning horizon. We describe an implementation of the dynamic constraint aggregation methodology proposed by Elhallaoui et al. (2005) to overcome the degeneracy of the master problem and show how this improves the performance of the column generation significantly. The method is tested on benchmark instances described by Demeester et al. (2008) where we derive tighter lower bounds than those previously reported for several of the instances. The computation time for identifying these lower bounds is, in most cases, significantly less than those presented by Ceshia and Schaerf (2011). A discussion on several branching strategies to integerize the lower bound solution is also provided.

Chuangang Deng, City University of Hong Kong (with Yinya Ye)

A fixed-point iterative approach to integer programming and distributed computation

Integer programming is concerned with the minimization of a linear function over integer or mixed-integer points in a polytope, which is equivalent under binary search to determining whether there is an integer or mixed-integer point in a polytope. Integer programming is an NP-hard problem and has many applications in economics and management. By constructing an increasing mapping satisfying certain properties, we develop in this paper a fixed-point iterative method for integer programming. The self-dual embedding technique will be applied for a solution to a bounding linear program in the development. Given any polytope, within a finite number of iterations, the method either yields an integer or mixed-integer point in the polytope or proves no such point exists. As a very appealing feature for integer programming, the method can be easily implemented in a distributed way. Furthermore, the method can be applied to compute all integer or mixed-integer points in a polytope. Numerical results show that the method is promising.

Thomas Rehn, University of Rostock (with Katrin Herr, Achill Schürmann)

Exploiting symmetry in integer convex optimization using core points

In this talk we consider symmetric convex programming problems with integrality constraints, that is, problems which are invariant under a linear symmetry group. We define a core point of such a symmetry group as an integral point for which the convex hull of its orbit does not contain integral points other than the orbit points themselves. These core points allow us to decompose symmetric integer convex programming problems. In particular for symmetric integer linear programs we describe two algorithms which make use of this decomposition. We characterize core points for some frequently occurring symmetry groups, in particular for direct products of symmetric groups. We use these results for prototype implementations, which can compete with state-of-the-art commercial solvers on some highly symmetric problems and helped solving an open MIPLIB problem.

Timm Oertel, ETH Zurich (with Christian Wagner, Robert Weismantel)

Convex integer minimization in fixed dimension

We show that minimizing a convex function over the integer points of a bounded convex set is polynomial in fixed dimension. For that, we present a geometric cone-shrinking algorithm. That is, we search for improving integer points within cones, reducing their volume step by step.

Antoine Oza, McMaster University (with Frédéric Meunier, Taman Stephen, Feng Xie)

Combinatorial, computational, and geometric approaches to the colourful simplicial depth

In statistics, there are several measures of the depth of a point $p$ relative to a fixed set $S$ of sample points in dimension $d$. One of the most intuitive is the simplicial depth of $p$ introduced by Liu (1999), which is the number of simplices generated by points in $S$ that contain $p$. Obtaining a lower bound for the simplicial depth is a challenging problem. Carathéodory’s Theorem can be restated as: The simplicial depth is at least 1 if $p$ belongs to the convex hull of $S$. Bárány (1982) showed that the simplicial depth is at least a fraction of all possible simplices generated from $S$. Gromov (2010) improved the fraction via a topological approach. Bárány’s result uses a colourful version of the Carathéodory’s theorem leading to the associated colourful simplicial depth. We present recent generalizations of the Colourful Carathéodory’s theorem due to
Arocha et al. and Homlisen et al. and our strengthening of these. We provide a new lower bound for the colourfull simplicial depth improving the earlier bounds of Bárány & Matoušek and of Stephen & Thomas. Computational approaches for small dimension and the colourfull linear programming feasibility problem introduced by Bárány & Onn are discussed.

Justo Puerto, Universidad de Sevilla

Ordered weighted average optimization of combinatorial problems

This talk addresses a class of combinatorial optimization models that include among others, bottleneck, k-centrum, general balanced, lexicographic, ordered median and universal optimization. These problems have been analyzed under different names for different authors in the last years [Calvete and Mateos (1998), De la Croce et al. (1999), Lee (1992), Nickel and Puerto (2005), Puerto and Tamir (2005), Punnen and Anjema (1996, 2004), Turner and Hamacher (2011), Turner et al. (2011)]. We study the common framework that underlines these models, present different formulations as integer programs and study their relationships and reinforcements. This approach leads to a branch and cut algorithm applicable to the general problem which is effective up to median size instances. For some specific cases we also analyze specific properties leading to polynomial time combinatorial algorithms.

Matthew Köppe, University of California, Davis (with Nicole Berline, Michèle Vergne)

A discretization-free FPTAS for polynomial optimization over the mixed-integer points in a class of polytopes of varying dimension

We present a new fully polynomial-time approximation scheme for the problem of optimizing non-convex polynomial functions over the mixed-integer points of a polytope of fixed dimension. This improves upon earlier work that was based on discretization [De Loera, Hemmecke, Köppe, Weismantel, FPTAS for optimizing polynomials … Math. Prog. Ser. A 118 (2008), 273–290]. The algorithm also extends to a class of problems in varying dimension.

The algorithm is based on the study of intermediate sums, interpolating between integrals and discrete sums, initiated by A. Barvinok (2006) and continued by Baldoni, Berline, De Loera, Köppe, Vergne [Computation of the highest coefficients … Found. Comput. Math. 2012] and Baldoni, Berline, Köppe, Vergne [Intermediate sums on polyhedra … Mathematika 2012]. For a given polytope \( P \) with facets parallel to rational hyperplanes and a rational subspace \( A \), we integrate a given polynomial function \( h \) over all lattice slices of the polytope \( P \) parallel to the subspace \( A \) up the integral.

This is the culmination of an effort to extend the efficient theory of discrete generating functions to the mixed-integer case.

Marco Molinaro, Carnegie Mellon University (with Sanjeeb Dash, Oktay Günlük)

Strength of cross cuts

Split cuts are among the most important cuts in practice, and modern heuristics can essentially harness their full power. Aiming at improving over split cuts, we study their most natural generalization, cross cuts. We present a theoretical comparison of the strength of the cross closure and the second split closure. We also analyze the strength of cuts. We present a theoretical comparison of the strength of the cross-closure and the second split-closure. We also analyze the strength of cuts. We present a theoretical comparison of the strength of the cross-closure and the second split-closure. We also analyze the strength of cuts.
scenarios of the outlook of the random variables while satisfying the first order stochastic dominance constraints (sdc) for a set of profiles in order to reduce the risk of the cost impact of the solution in non-wanted scenarios. And second, a scheme to obtain the solution of the stochas-tic p-median problem is developed by considering the splitting variable representation of the static Deterministic Equivalent Model (DEM) of the stochastic p-median problem. This scheme dualizes the non-anticipativity constraints and treats with a special procedure the sdc for each profile (since those constraints have variables from different scenarios). A computational experience is reported.

Vinicius Xavier, Federal University of Rio de Janeiro (with Felipe Franca, Priscila Lima, Adisson Xavier) Solving the Werber-Webber location problem by the hyperbolic smoothing approach

The Werber-Webber problem considers the optimum location of a given number of facilities. The problem corresponds to the minimization of the sum of the euclidean distances of each city to the n nearest facility weighted by relative importance of each one. The mathematical modeling of this problem leads to a min-sum-min formulation which in addition to its intrinsic bi-level nature, has the significant characteristics of being strongly non-differentiable and non-convex problem, with a large number of local minima. The hyperbolic smoothing strategy solves a sequence of low dimension differentiable unconstrained optimization sub-problems, which gradually approaches the original problem. The reliability and efficiency of the method are illustrated via a set of computational experiments by using traditional instances presented in the literature.

Halit Sural, METU Ankara (with Hoysun Guden) The dynamic p-median problem with relocation

The dynamic location problem considers changes of demand amounts over the horizon and minimizes the location and service costs. In this paper, facilities can be opened in addition to the operating facilities and some of the operating ones can be relocated or abolished. We develop exact and heuristic methods for solving the dynamic p-median problem. The former is a branch-and-price algorithm using the reduced size form of an integer programming formulation based on discretization of the number of different distances between facilities and demand points. The latter effort explores the dynamic structure of the problem to find upper bounds on the problem objective function. Our computational results are presented to assess the performance of our methods on test instances derived from the p-median literature.

Mon.1.H 0111 Supply chain optimization

Organizer/Chair Edwin Romeijn, University of Michigan - Invited Session

Joseph Geunes, University of Florida (with Yiqiang Su) Multi-period price promotions in a single-supplier, multi-retailer supply chain under asymmetric demand information

This paper considers a two-level supply chain in which a supplier serves a retail chain. We consider a two-stage Stackelberg game in which the supplier sets price discounts for each period of a finite planning horizon under uncertainty in retail-store demand. To stimulate sales, the supplier offers periodic off-invoice price discounts to the retail chain. Based on the price discounts offered, and after store demand uncertainty is resolved, the retail chain determines order quantities in each period. The retailer may ship inventory between stores, a practice known as diverting. We demonstrate that, despite the resulting bullwhip effect and associated costs, a carefully designed price promotion scheme can improve the supplier’s profit when compared to the case of everyday low pricing (EDLP). We model this problem as a stochastic bilevel optimization problem with a bilinear objective at each level and with linear constraints. We provide an exact solution method based on a Reformulation-Linearization Technique (RLT). In addition, we compare our solution approach with a widely used heuristic and another exact solution method from the literature in order to benchmark its quality.

Dolores Romero Morales, University of Oxford (with H. Edwin Romeijn, Wilco van der Heuvel) A multi-objective economic lot-sizing problem with environmental considerations

In this talk we study a Multi-Objective Economic Lot-Sizing Problem. This Multi-Objective Economic Lot-Sizing Problem is a generalization of the classical Economic Lot-Sizing Problem, where we are concerned with both the lot-sizing costs, including production and inventory holding costs, as well as the production and inventory emission of pollution. With respect to the planning horizon, the planning horizon will be split into blocks of the same length (except for possibly the last one), and the total emission in each block will be minimized. This includes the case in which we are interesting in measuring the pollution in each of the planning periods, or across all periods, or more generally, across subsets of periods. We assume fixed-charge production cost and emission functions, and linear inventory holding cost and emission functions. When more than one objective function is optimized, the Pareto efficient frontier is sought. In this talk, we show that the Pareto optimal problem is NP-complete. We then identify classes of problem instances for which Pareto optimal solutions can be obtained in polynomial time. We end with some results on the Pareto efficient frontier of the problem.

Zuhair Shihabi, University of Michigan (with H. Edwin Romeijn) Approximation algorithms for risk-averse selective newsvendor problems

We consider a single-item single-period problem of a supplier who faces uncertain demands in a collection of markets and wishes to choose a subset of markets \( x \) whose demand to satisfy as well as a corresponding overall order quantity \( Q \). The supplier faces costs associated with satisfying demands, overage and underage costs, and lost revenues in the markets whose demand is not selected. Moreover, the supplier optimizes a risk measure associated with those random costs. Finally, we assume that the joint distribution of all market demands and revenues is nonnegative with finite mean. We develop an approximation framework that, under certain conditions on the cost structure and risk measure, provides a solution whose objective function value is, with high probability, within a constant factor of the optimal value. This framework depends on two key techniques: \(|I|\) rounding the solution to a continuous distribution of the problem values and \(|I|\) sampling the true revenue and demand distribution. We provide explicit examples of some cost structures and risk measures for which the algorithm we develop is efficiently implementable.

Mon.1.MA 005 Global mixed-integer nonlinear optimization I

Organizer/Chair Ignacio Grossmann, Carnegie Mellon University - Invited Session

Ignacio Grossmann, Carnegie Mellon University (with Juan Ruiz) Using convex nonlinear relaxations in the global optimization of nonconvex generalized disjunctive programming problems

In this paper we address the global optimization of GDP problems that in addition to bilinear and concave terms, involve other terms such as linear fractional terms for which nonlinear convex relaxations have shown to provide rigorous convex envelopes that are magnitude much tighter than linear relaxations. The use of nonlinear convex relaxations leads to a nonlinear convex GDP which relaxation can be strengthened by using recently results from the recent work of Ruiz and Grossmann. We first define the general nonconvex GDP problem that we aim at solving and review the use of the hull relaxation, the traditional method to find relaxations. Second, we show how we can strengthen the relaxation of the traditional approach by presenting a systematic procedure to generate a hierarchy of relaxations based on the application of basic steps to nonlinear convex sets in disjunctive programming. We outline a set of rules that avoids the exponential transformation to the Disjunctive Normal Form leading to a more efficient implementation of the method. Finally we analyse the performance of the method by solving to global optimality engineering design test problems.

Milivoj Bogataj, Faculty of Chemistry and Chemical Engineering, University of Maribor (with Zdravko Kranjčar) A multilevel approach to global optimization of MINLP problems

In this work, we present an approach for global optimization of non-convex mixed-integer nonlinear programs (MINLPs) containing bilinear and linear fractional terms. These terms are replaced by piecewise convex under- / overestimators defined over domains of one or both complicating variables. The domains are partitioned over at least two levels with a coarsening grid density in domains that make the gap between the upper and lower bound falls below the predefined convergence criterion. The derived multilevel convex MINLP is then solved using a modified outer approximation/equality relaxation (OA/ER) algorithm. The key idea of the approach is progressive tightening of convex relaxation, whilst keeping low combinatorial complexity of the convexified MINLP throughout the solution procedure. After each major OA/ER iteration, tighter under-/overestimators are activated, however, only over the domain partitions containing currently optimal solution. Hence, only the most promising alternatives are being explored from the start on. The multilevel approach was tested on illustrative examples to show its advantage over a single level approach.

Tapti Westerlund, Åbo Akademi University (with Andrzej (Adi) Lundell) A reformulation framework for global optimization

In some previous papers we have published results connected to an optimization framework for solving non-convex mixed integer non-linear programming problems, including signomial functions. In the framework the global optimal solution of such non-convex problems
can be obtained by solving a converging sequence of convex relaxed MINLP problems. The relaxed convex problems are obtained by replacing the non-convex constraint functions with convex underestimators. The signomial functions are first convexified by single-variable power and exponential transformations. The non-convexities are then moved to the transformations. However, when replacing the transformations with piecewise linear approximations the problem will be both convexified and relaxed.

The scope of this paper is to show how any twice-differentiable function can be handled in an extended version of the global optimization framework. For C2-functions, it is shown how a spline version of the so-called αBB-underestimator can be applied in a slightly similar way as the approach utilized for signomial functions. It is, further, shown how this underestimator can easily be integrated in the actual reformulation framework.

A multi-objective linear programming approach to data envelopment analysis

Data envelopment analysis (DEA) is a very popular parameter free method for performance measurement of decision making units. Based on linear programming (LP), DEA is closely related to multi-objective linear programming (MOLP) in the sense that efficient decision making units represent efficient solutions of some MOLP. We exploit this relationship and apply the primal and dual variants of Benson’s outer approximation algorithm for MOLP as presented in Ehrgott, Löhne and Shao (2012) in order to solve DEA problems. We show that when applied to DEA many of the LPs that need to be solved in these algorithms are ill-defined. Based on our recent high order path following strategy, we obtain a useful algorithmic framework. This context provides a case where Shamanskii-like high order variants are useless while genuine high order extrapolations yield a solution.

Nonlinear optimization

We examine the computational behavior of a number of variations on the alternating direction method of multipliers (ADMM) for convex optimization, focusing largely on lasso problems, whose structure is well-suited to the method. In particular, we computationally compare the classical ADMM to minimizing the augmented Lagrangian essentially exactly by alternating minimization before each multiplier update, and to approximate versions of this strategy using the recent augmented Lagrangian relative error criterion of Eckstein and Silva.

A family of second order methods for L1 convex optimization

We describe and analyze a family of second order methods for minimizing an objective that is composed of a smooth convex function and an L1 regularization term. The algorithms in this family are categorized as two phase methods, differing with respect to the active manifold identification phase and the second order subspace step. We will show how to endow these algorithms with convergence guarantees and as well,
Dynamic batch methods for L1 regularized problems and constrained optimization

A methodology for using dynamic sample sizes in batch-type optimization methods is proposed. Motivated by machine learning applications, dynamic batching can successfully be applied to smooth convex constrained problems as well as non-smooth L1-regularized problems. By dynamically changing the batch size, the algorithm is able to keep overall costs low. The use of a batch approach allows the algorithm to exploit parallelism.

The second order generalized derivative and generalized equalizations

We consider a generalized equation of the form $0 \in f(x) + G(x)$ where $f : R^n \to R^m$ and $G : R^n \to R^{m \times n}$ is a set-valued map metrically regular. First of all, we present some iterative methods introduced for solving this equation and then we state our main result. In fact, we propose a method using the second order generalized derivative and we show existence and convergence of a sequence defined by this method.

Nonsmooth optimization

Iterative methods for variational analysis

Celia Jean-Alexis, Université des Antilles et de la Guyane (with Michel Geoffroy, Alain Piétrus)
The second order generalized derivative and generalized equalizations

We consider a generalized equation of the form $0 \in f(x) + G(x)$ where $f : R^n \to R^m$ and $G : R^n \to R^{m \times n}$ is a set-valued map metrically regular. First of all, we present some iterative methods introduced for solving this equation and then we state our main result. In fact, we propose a method using the second order generalized derivative and we show existence and convergence of a sequence defined by this method.

Robert Baire, University of Bayreuth
Set-valued Newton’s method for computing convex invariant sets

A new realization of Newton’s method for “smooth” set-valued fixed-point problems is presented. For a dynamical system $x_{k+1} = g(x_k)$ a convex invariant set $X \subset R^m$ has to be determined with $g(X) = X$.

This fixed-point problem is transformed to a zero-finding problem in the Banach space of directed sets for which Newton’s method can be formulated. The cone of convex, compact subsets of $R^m$ can be embedded into this Banach space such that usual set arithmetics are extended and a visualization of differences of embedded convex compact sets as usual is possible.

Important assumptions are the existence of a set of convex subsets such that their image under $g$ remains convex and the existence of a differentiable extension of $g$ to directed sets. The visualization of an embedded fixed set for the transformed problem is a convex invariant set for the original problem.

First examples illustrate that the convergence assumptions can be verified and local quadratic convergence even to unstable convex invariant sets is observed in contrary to fixed set iterations. Further extensions of this approach are indicated.

Elza Farkhi, Tel Aviv University (with Robert Baire, Vera Roshchina)
The directed subdifferential and applications

The directed subdifferential of quasidifferentiable functions is introduced as the difference of two convex subdifferentials embedded in the Banach space of directed sets. Preserving the most important properties of the quasidifferential, such as exact calculus rules, the directed subdifferential lacks major drawbacks of the quasidifferential: non-uniqueness and growing in size of the two convex sets representing the quasidifferential after applying calculus rules. Its visualization, the Rubinov subdifferential, is a non-empty, generally non-convex set in $R^n$.

Calculus rules for the directed subdifferentials are derived. Important properties as well as necessary and sufficient optimality conditions for the directed subdifferential are obtained. The directed subdifferential is compared with other well-known subdifferentials.

Optimization in energy systems

Optimization models to manage risk and uncertainty in power systems operations

Alexandra Street, Pontifical Catholic University of Rio de Janeiro (PUC-Rio) (with Arroyo Jose, Alexandre Moreira)
Energy and reserve scheduling under a joint GT $\alpha$ – K security criterion: An adjustable robust optimization approach

This presentation shows a new approach for energy and reserve scheduling in electricity markets under a joint $\alpha$ – K security criterion. It extends previous robust optimization based works that only considered generation faults to consider a joint GT criterion. A Benders decomposition is applied in combination with a set of valid constraints based on a single-bus reduction of the problem. Such constraints provide a tighter formulation for the master problem resulting in significant improvements in the method computational burden.

Jinye Zhao, ISO New England
Adaptive robust optimization for the security constrained unit commitment problem

Unit commitment, one of the most critical tasks in electric power system operations, faces new challenges as the supply and demand uncertainty increases dramatically due to the integration of variable generation resources. To meet these challenges, we propose a two-stage adaptive robust unit commitment model and a practical solution method. We present a numerical study on the real-world large scale power system operated by the ISO New England. Computational results

Alexandre Street, Pontifical Catholic University of Rio de Janeiro (PUC-Rio) (with Arroyo Jose, Alexandre Moreira)
demonstrate the economic and operational advantages of our model over the traditional reserve adjustment approach.

Anthony Papavasiliou, University of California at Berkeley (with Shumuet Oren)

Applying high performance computing to multi area stochastic unit commitment for high wind penetration

We use a two-stage stochastic programming formulation in order to schedule locational generation reserves that hedge power system operations against the uncertainty of renewable power supply. We present a parallel implementation of a Lagrangian relaxation algorithm that is solving the stochastic unit commitment problem. The model we present addresses the uncertainty of wind power supply, the possibility of generator and transmission line outages and transmission constraints on the flow of power over the network. We present a scenario selection algorithm for representing uncertainty in terms of a moderate number of appropriately weighted scenarios and use a high performance computing cluster in order to validate the quality of our scenario selection algorithm. We compare the performance of our approach to N − 1 reliable unit commitment. We examine the dependence of the Lagrangian dual variables and coordination methods can be applied to exploit the structure of the underlying scenario tree. It has been shown that progressive hedging can yield good solutions for this problem, and we give a short review of our findings from applying it. However, this method is not guaranteed to converge for mixed-integer problems. Therefore the focus of the talk is on a branch & price framework which guarantees convergence. Numerical results are given to illustrate the behaviour of the method.

PDE-constrained opt. & multi-level/multi-grid meth.

Mon.1.MA C15

Applications of PDE-constrained optimization

Organizer/Chair Michael Ulbrich, Technische Universität München - Invited Session

Rene Pinnau, TU Kaiserslautern

Exploiting model hierarchies in space mapping optimization

The solution of optimization problems in industry often requires information on the adjoint variables for very complex model equations. Typically, there is a whole hierarchy of models available which allows to balance the computational costs and the exactness of the model. We exploit these hierarchies in combination with space mapping techniques to speed up the convergence of optimization algorithms. The use of surrogate models yields finally a suboptimal design or control, which is typically near to the optimal design. In this talk we present three applications where this approach proved to be very successful. We will cover questions from semiconductor design, the control of particles in fluids and shape optimization for filters.

Michael Ulbrich, Technische Universität München (with Christian Böhm)

An adaptive semismooth Newton-CG method for constrained parameter identification in seismic tomography

Seismic tomography infers the material properties of the Earth based on seismic data. This can be stated as an optimization problem that minimizes the misfit between observed and simulated seismograms. We present a semismooth Newton-CG method for full-waveform seismic inversion with box constraints on the material parameters. It uses a Moreau-Yosida regularization and a trust-region globalization. The matrix-free implementation relies on adjoint-based gradient and Hessian-vector computations and a PCG method. The state equation is a coupled system of the elastic and acoustic wave equations. Our MPI-parallelized solver uses a high order continuous Galerkin method and an explicit Newmark time stepping scheme. We address ill-posedness by a regularization and, in addition, by inverting sequentially for increasing frequencies. Thereby, the parameter grid is adaptively refined using goal-oriented a posteriori error estimates.

Numerical results are shown for the application of our method to a dataset of marine geophysical exploration in the North Sea.

Mon.1.H 3503

Extensions of robust optimization models

Chair Frank Pfeuffer, Zuse-Institut Berlin

Michael Todd, Cornell University (with Martina Gancarova)

A robust robust (sic) optimization result

We study the loss in objective value obtained when an inaccurate objective is optimized instead of the true one, and show that “on average”, the loss incurred is very small, for arbitrary compact feasible regions.

Frank Pfeuffer, Zuse-Institut Berlin (with Ulf-Dien Haus)

An extension of the controlled robustness model of Bertsimas and Sim

Realistic data in optimization models is often subject to uncertainty. Robust optimization models take such data uncertainty into account. Bertsimas and Sim proposed a robust model which deals with data uncertainty while allowing to control the amount of robustness in the problem by bounding the number of simultaneously uncertain coefficients. They showed that under this model robust min-cost-flow problems are solved by binary search using an oracle for min-cost-flow problems. We extend this model by allowing more general means of imposing control on the amount of robustness via polyhedral control sets, which contain the model of Bertsimas and Sim as a special case. Under our model, robust min-cost-flow problems are solved by a subgradient approach using an oracle for min-cost-flow problems. Applying our approach to the restrictive control set of Bertsimas and Sim reduces the number of oracle calls needed by their approach by half.
Sparse optimization & compressed sensing

Mon. 1 H 1028
New models and algorithms in sparse optimization
Organizer/Chair: Benjamin Recht, University of Wisconsin-Madison - Invited Session
Nicolas Boumal, UC Louvain (with Pierre-Antoine Absil, Amit Singer)
Riemannian algorithms and estimation bounds for synchronization of rotations
We estimate unknown rotation matrices \( R_i \) in \( SO(n) \) from a set of measurements of relative rotations \( R_i R_j^T \). Each measurement is either slightly noisy, or an outlier bearing no information. We study the case where most measurements are outliers. We propose a Maximum Likelihood Estimator (MLE) approach, explicitly acknowledging outliers in the noise model.

The MLE maximizes the log-likelihood function over the parameter space. That space is a product of rotation groups, possibly quotiented to account for invariance under a common rotation of the estimators.

To compute the MLE, we use Riemannian trust-region methods to maximize the log-likelihood function over the parameter space. That space is a matrix manifold, hence tools and analyses from Absil et al., Optimization Algorithms on Matrix Manifolds, Princeton Univ. Press, 2008)
apply gracefully.

We derive Riemannian Cramer-Rao bounds for synchronization, valid for a broad class of problem dimensions and noise distributions. These bounds admit a simple expression in terms of an information-weighted Laplacian of the measurement graph. Numerical tests suggest the MLE is asymptotically efficient in many cases.

Mark Davenport, Georgia Institute of Technology (with Michael Wakin)
A simple framework for analog compressive sensing
Compressive sensing (CS) has recently emerged as a framework for efficiently capturing signals that are sparse or compressible in an appropriate basis. Our approach, known as Anthony T. Allen is motivated by the problem of Nyquist-rate sampling, there remains a gap between the discrete, finite-dimensional CS framework and the problem of acquiring a continuous-time signal.

In this talk, I will describe a new approach to bridging this gap by exploiting the Discrete Prolate Spheroidal Sequences (DPSS's), a collection of functions that trace back to the seminal work by Slepian, Landau, and Pollack on the effects of time-limiting and bandlimiting operations. DPSS's form a highly efficient basis for sampled bandlimited functions; by modulating and merging DPSS bases, we obtain a dictionary that offers high-quality sparse approximations for most sampled multiband signals. This multiband modulated DPSS dictionary can be readily incorporated into the CS framework. I will provide theoretical guarantees and practical insights into the use of this dictionary for recovery of sampled multiband signals from compressive measurements.

Benjamin Recht, University of Wisconsin-Madison (with Budhik Bhashar, Panikshih Shah, Gousoung Tang)
Atomic norm denoising with applications to spectrum estimation and system identification
One of the most common goals of data analysis is to reject noise by leveraging the latent structure present in the true signal. This talk will propose a general approach to such denoising problems by regularizing data fidelity with a penalty called the atomic norm. Atomic norm denoising is posed as a convex optimization problem and has generic, mean-squared-error guarantees. For sparse signals, atomic norm denoising is equivalent to soft-thresholding, but our techniques can be applied to a broad class of problem dimensions and noise distributions. This talk will present a simple expression in terms of an information-weighted Laplacian of the measurement graph. Numerical tests suggest the MLE is asymptotically efficient in many cases.

David Brown, Duke University
Optimal sequential exploration: Bandits, clairvoyants, and wildcats
This paper is motivated by the problem of developing an optimal strategy for exploring a large oil and gas field in the North Sea. Where should we drill first? Where do we drill next? The problem resembles a classical multiarmed bandit problem, but probabilistic dependence plays a key role: outcomes at drill sites reveal information about neighboring targets. Good exploration strategies will take advantage of this information as it is revealed. We develop heuristic policies for sequential exploration problems and complement these heuristics with upper bounds on the performance of an optimal policy. We begin by grouping the targets into clusters of manageable size. The heuristics are derived from a model that treats these clusters as independent. The upper bounds are given by assuming each cluster has perfect information about the results from all other clusters. The analysis relies heavily on results for bandit superprocesses, a generalization of the classical multiarmed bandit problem. We evaluate the heuristics and bounds using Monte Carlo simulation and, in our problem, we find that the heuristics are nearly optimal.

Ciamac Cooi, Carnegie Mellon, University of Texas at Austin
Optimization at all levels: Probabilistic Envelope Constraints
In optimization under uncertainty, we often seek to provide solutions that guarantee performance at least \( p \)% of the time. But what happens the other \( (1−p)% \) of the time? Current methodology fails to provide any constraints on these bad events: \( (1−p)% \) of the time, all bets are off. In this talk we provide a computationally tractable framework to design optimization solutions that have performance guarantees at all levels of uncertainty realizable. We call these probabilistic envelope constraints, and, as we show, they have a surprising connection to an extension of robust optimization.

Stochastic optimization

Mon. 1.MA 144
Optimization of physical systems under uncertainty
Organizer/Chair: Mihai Anitescu, Argonne National Laboratory - Invited Session
Victor Zavala, Argonne National Laboratory (with Mihai Anitescu, John Birge)
Stochastic optimization: Impacts on electricity markets and operations
In this talk, we discuss impacts of stochastic optimization on market design for electricity consumption and supply. In particular, we demonstrate that stochastic optimization leads to more consistent prices that maximize social welfare, reduce variance of spot prices, and diversify generation. In addition, we demonstrate how stochastic optimization leads to large amounts of power can be saved in large base-load plants in the presence of water constraints.

Jim Luedtke, University of Wisconsin-Madison (with Tingfeng Song)
Branch-and-cut approaches for chance-constrained formulations of reliable network design problems
We study the design of reliably connected networks. Given a graph with arcs that may fail at random, the goal is to select a minimum cost set of arcs such that a path between nodes \( s \) and \( t \) exists with high probability. We model this problem as a chance-constrained stochastic integer program, and present two solution approaches. The first approach is based on a formulation that uses binary variables to determine if an \( s-t \) path exists in each arc failure scenario. We present a branch-and-cut decomposition algorithm to solve this formulation, based on inequalities derived from individual scenario graph cuts. The second approach uses an alternative formulation based on probabilistic \( s-t \) cuts, which is an extension of \( s-t \) graphs to graphs with random arc failures. Probabilistic \( s-t \) inequalities define the feasible region and can be separated efficiently at integer solutions, allowing this formulation to be solved by a branch-and-cut algorithm. Computational results indicate that the approaches can solve large instances. We also show how our results can be applied to more general connectivity requirements.

Bernardo Pagonceli, University of Adolfo Ilurin (with Adriana Piazz)
The optimal harvesting problem under risk aversion
I will present a model for the exploitation of a one species forest plantation when timber price is governed by a stochastic process. The problem is stated as a risk averse stochastic dynamic programming, with the conditional value-at-risk (CVaR) as a risk measure. Timber price is uncertain and two important cases are considered: geometric Brownian motion and a mean-reverting (Ornstein-Uhlenbeck) process.
In both cases the problem is solved for every initial condition and the best policy is obtained endogenously, that is, without imposing any ad hoc restrictions such as maximum sustained yield or convergence to a predefined final state. I will compare the results with the risk neutral framework and discuss the differences between the two cases. Finally I will show how to generalize the results to any coherent risk measure that is affine on the current price.

**Mon.1.H 3002**

**Optical access networks**

Organizer/Chair Andreas Bley, TU Berlin · Invited Session

Cédric Heruet, Orange Labs / CNAM (with Matthieu Chardy, Marie-Christine Costa, Alain Fayé, Stanislas Franchi)

**Robust optimization of optical fiber access networks deployments**

Due to the recent increase in bandwidth requirements, telecommunication operators have to support it with the deployment of optical fiber networks through Fiber-To-The-Home Gigabit Passive Optical Network technology (FTTH GPON). One great challenge, in a deregulated context, is to design this network while not knowing who and where the future subscribers will be. We focus on the problem of the robust optical fiber network deployment under demand uncertainty. A two-stage robust optimization model is proposed for this problem, as well as two robust solution methods extending classical results from Ben-Tal et al. and Babonneau et al. in order to be compliant with our uncertainty set.

Maria João Lopes, University Institute of Lisbon (ISCTE-IUL) and CIO (with Amara de Sousa, Luís Gouveia)

**Modelling the minimum cost PON access network design problem**

A PON is an optical access network connecting a Central Office to a set of terminals using optical splitters, installed on intermediate nodes, and optical fibres connecting all elements. In the network design problem, terminals are clustered in a minimum number of PONs and each PON has a maximum capacity in number of terminals. For each PON, we have to decide where to install splitters and how to connect all elements through optical fibres. In intermediate nodes, optical splitters of different PONs can co-exist. There are costs associated with intermediate nodes, splitter types and fibre connections. We define the minimum cost design problem in the context of densely populated urban areas, proposing different ILP formulations and valid inequalities. We address this problem in the general context where the number of splitting stages (and the splitting ratio on each stage) is an outcome of the optimization problem. Therefore, previous works become particular cases of this general network design problem. We present computational results discussing the trade-off between the linear relaxation bounds and the runtime to achieve integer optimal solutions of the different models.

Olaf Maurer, TU Berlin (with Andreas Bley, Ivana Ljubic)

**Lagrangian approaches to a two-level FTTH network design problem**

We consider the design of a passive optical telecommunication access network, where clients have to be connected to an intermediate level of distribution points (DPs) and further on to some central offices (COs). Each client demands a given number of connections to its CO. Passive optical splitters installed at the DPs allow several connections to share a single common connection between the DP and the CO. The objective is composed of fixed-price charges for the use of facilities and hardware and linear costs which depend on the edge utilisation. We present two Lagrangian decomposition approaches that were improved with additional cuts and heuristics. The subproblems are solved using MILP techniques. We report computational results and compare the efficiency of the Lagrangian approach to the direct approach via an integrated MILP model.

**Mon.1.H 2035**

**Nonsmooth phenomena in optimal control**

Organizer/Chair Roland Herzog, TU Chemnitz · Invited Session

Christian Meyer, TU Dortmund

**Boundary control of the obstacle problem**

The talk deals with optimal control problems governed by the obstacle problem, where the control is given by Neumann data. Several stationarity concepts for the problem under consideration and additionally second-order sufficient conditions are presented.

Matthias Gerdts, Universität der Bundeswehr

**Globalized semi-smooth Newton methods in optimal control problems with DAEs**

This paper addresses the numerical solution of optimal control problems subject to differential-algebraic equations and mixed control-state constraints by semi-smooth Newton methods. A particular focus is on globalization techniques for semi-smooth Newton methods and on regularization and smoothing techniques for the Fischer–Burmeister function. An open problem for the convergence analysis remains the construction of a smoothing operator for the Fischer–Burmeister function. Numerical experiments on various problems without smoothing operator however suggest that the methods work well in practice and a
superlinear convergence rate and mesh independence can be observed numerically.

Frank Schmidt, TU Chemnitz (with Roland Herzog)

Properties of the optimal value function and application to worst-case robust optimal control problems

Sufficient conditions ensuring weak lower semi-continuity of the optimal value function are presented. To this end, refined inner semi-continuity properties of set-valued maps are introduced which meet the needs of the weak topology in Banach spaces. The results are applied to prove the existence of solutions in various worst-case robust optimal control problems governed by semilinear elliptic partial differential equations.

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Mixed-criticality scheduling of sporadic task systems on a single machine

We consider scheduling an implicit-deadline task system on a single machine in a mixed-criticality (MC) setting. MC systems arise when multiple functionalities are scheduled upon a shared computing platform. This can force tasks of different importance (i.e., criticality) to share a processor. Each task generates a (possibly infinite) string of jobs, released with an interarrival time bounded from below by a task-dependent period. Each job has a relative deadline equal to the length of its period.

In an MC setting, each task has multiple levels of worst-case execution times and its own criticality level. By executing the tasks, we learn what level the system is in, which may change over time. When the system is in level $\ell$, all jobs of tasks of level $\ell' > \ell$ should be scheduled for their level-$\ell$ execution time, to meet their deadline.

We give an algorithm for scheduling an MC task system, called EDF-VD (Earliest Deadline First with Virtual Deadlines). We give sufficient conditions to check feasibility for $K$ levels. We show that if a $2$-level task system is schedulable on a unit-speed processor, it is correctly schedulable by EDF-VD on a processor of speed $\sqrt{2}$.

Jian-Jia Chen, KIT (with Sasanjir Chakraborty)

Resource augmentation in real-time systems

Timing satisfaction is an important property for maintaining the stability or correctness of many real-time embedded systems, especially for avionic or automotive applications. For decades, schedulability of real-time systems has been extensively studied, from periodic tasks, to sporadic tasks, and even to tasks with irregular arrival curves. A task set is guaranteed to be schedulable if it passes the correct schedulability tests. However, the main issue for such an approach is to answer what is guaranteed when a task set does not pass the schedulability test. For such cases, the resource augmentation factor provides a nice feature for ensuring the schedulability by augmenting the resources, e.g., by speeding-up, adding more processors, etc. This talk will focus on the recent research on resource augmentation with respect to speeding-up and allocating more processors in real-time systems for sporadic real-time tasks, from uniprocessor systems to multiprocessor systems. The analysis for this resource augmentation upper bound and lower bound will be presented.
computational results demonstrating the high and often superior quality of our buffering solutions.

Stephan Held, University of Bonn

Delay bounded Steiner trees and time-cost tradeoffs for faster chips

We will present combinatorial optimization algorithms that focus on maximizing the clock frequency of modern microprocessors. One central problem is the construction of Steiner trees with delay constraints. They are used for optimizing electrical interconnections and symmetric Boolean functions. We provide a bicriteria algorithm for tree topologies with node delays in addition to length dependent delays. This is done by generalizing light approximate shortest path trees.

For finding globally optimal solutions, many resource critical problems such as threshold voltage of transistors and layer assignment of interconnect wires can be modeled as time-cost tradeoff problems. We will present a new method based on rounding the dual of Minimum-Cost Flows.

Finally, we will demonstrate how the presented algorithms are employed for increasing the clock frequency by 18% of an upcoming microprocessor.

Combinatorial optimization

Mon.2.H 3005

Structural graph theory and methods
Organizer/Chair: Paul Wollan, University of Rome - Invited Session

Sang-Il Oum, KAIST

Vertex-minors and pivot-minors of graphs

We will survey vertex- and pivot-minor relations of graphs which are defined in terms of local complementation and pivot operations, respectively. Many theorems on graph minors can be extended to graph vertex- or pivot-minors. We will discuss various known aspects and then talk about partial results towards some conjectures generalizing some of the deepest theorems in structural graph theory including the graph minor theorem of Robertson and Seymour.

Gwenaël Joret, Université Libre de Bruxelles (with Samuel Fiorini, David Wood)

Excluded forest minors and the Erdős-Pósa Property

A classical result of Robertson and Seymour states that the set of graphs containing a fixed planar graph \( H \) as a minor has the so-called Erdős-Pósa property; namely, there exists a function \( I \) depending only on \( H \) such that, for every graph \( G \) and every integer \( k \in \mathbb{N} \), either \( G \) has \( k \) vertex-disjoint subgraphs each containing \( H \) as a minor, or there exists a subset \( X \) of vertices of \( G \) with \( |X| \leq I(k) \) such that \( G - X \) has no \( H \)-minor. While the best function \( I \) currently known is super-exponential in \( k \), a \( O(\log k) \) bound is known in the special case where \( H \) is a forest. This is a consequence of a theorem of Bienstock, Robertson, Seymour, and Thomason on the pathwidth of graphs with an excluded forest-minor.

Gwenaël Joret, Université Libre de Bruxelles (with Samuel Fiorini, David Wood)

Mon.2.H 3008

Discrete structures and algorithms I
Organizer/Chair: Satoru Fujishige, Kyoto University - Invited Session

Shuji Kijima, Graduate School of Information Science and Electrical Engineering, Kyushu University

Efficient randomized rounding in permutahedron

Permutahedron \( P_n \) is a polyhedron in the \( n \)-dimensional space defined by the convex hull of all permutations vectors \( \pi \) (1, \( \pi \), \( \ldots \), \( \pi(n) \)) \( \in \mathbb{R}^n \). In this talk, we are concerned with randomized rounding in permutahedron; given a point \( p \in P_n \), output a permutation vector \( X(\pi) \) with a probability satisfying that \( \sum_{\pi \in \mathcal{S}_n} Pr(X = \pi(\pi))x(\pi) = p \). It is well known that \( P_n \) is a base polyhedron of a submodular function, more precisely \( P_n = \{ x | \sum_{i=1}^{n} x_i \leq \sum_{j=1}^{n} (n+1-j) \text{ for any } J \subset [n], \text{ and } \sum_{i=1}^{n} x_i = n(n+1)/2 \} \). In this talk, we present an algorithm for randomized rounding in permutahedron, with \( O(n \log n) \) time using \( O(n) \) space. We also explain an extension to a base polyhedron of an arbitrary cardinality based submodular function.

Júlia Pap, Eötvös Loránd University (with András Frank, Tamás Király, David Pritchard)

Characterizing and recognizing generalized polymatroids

Generalized polymatroids are a family of polyhedra with several nice properties and applications. A main tool used widely in the literature is that generalized polymatroids can be described by a linear system whose dual can be uncrossed: there is an optimal dual solution with laminar support. We make this notion of “total dual laminarity” explicit and show that the polyhedra described by such systems are always generalized polymatroids. We also show that for a full-dimensional generalized polymatroid every describing system is totally dual laminar. Using these we give a polynomial-time algorithm to check whether a given linear program defines a generalized polymatroid, and whether it is integral if so. Additionally, whereas it is known that the intersection of two integral generalized polymatroids is integral, we show that no larger class of polyhedra satisfies this property.

Jens Miezberg, University of Ulm (with Saturo Fujishige)

Mon.2.H 3012

Scheduling I
Chair: George Steiner, McMaster University

Thomas Rieger, Technische Universität Braunschweig (with Ronny Hansmann, Uwe Zimmermann)

Two variants of flexible job shop scheduling with blockages

Motivated by an application in rail car maintenance, we discuss minimization problems for two variants of flexible job shop scheduling with work centers (FJC). In contrast to standard FJC in these variants a work center (rail track) consists of a linearly ordered set of machines with restricted accessibility. In particular, a busy machine blocks both the access to and the exit from succeeding machines of a work center. The two considered variants only differ in the implication of the latter restricting requirement. If a succeeding machine is blocked when it completes a job then this job is either allowed to wait on its machine (until the exit is free again) or not.

In particular, we present the computational complexity and solution methods (heuristic and exact) and introduce a mixed integer linear programming model for both variants. Our exact methods are based on a dedicated branch-and-bound-implementation using bounds generated from certain longest paths.

Finally, we present some computational results for several data sets, discuss the solution quality of both FJC-variants and compare our results to results obtained using the commercial solvers CPLEX and Gurobi.

Leen Stougie, VU University & CWI Amsterdam (with Frans Schalekamp, Rene Sitters, Suzanne van der Ster, Anke van Zuylen)

Scheduling with job-splitting and fixed setup

We consider a scheduling problem with a fixed setup time and job-splitting. Jobs can be preempted and machines can work on the same job simultaneously. We encountered this problem in studying disaster relief operations. We consider minimisation of total completion time. The version with preemption and fixed setup time is still solved by the Shortest Processing Time first rule (SPT), in which the option of preemption is not used. The situation with job-splitting is much less clear. If its very large, then splitting becomes too expensive and the problem is solved by SPT again. If its very small (say 0), then each job is split over all machines and the jobs are scheduled in SPT order. To find out

\[ \sum_{x \in \mathcal{S}_n} Pr(X(\pi) = \pi(\pi))x(\pi) = p. \]
where to start splitting jobs and over how many machines appears to be a non-trivial problem. We will present a polynomial time algorithm for the case in which there are 2 machines exploiting the structure of optimal solutions. Some of the crucial properties of optimal solutions already fail to hold on 3 machines. This leaves the complexity of the problem for more than 2 machines open.

We will study two scenarios to represent the uncertainty. First, a finite set of realizations is discussed. Second, the uncertainty is modelled by allowing limited recovery actions after all data is revealed. In this talk I will present a special case of RR where the recovery actions are limited by changing at most $k$ elements of the previous fixed solution and apply this method to various combinatorial optimization problems. For the shortest path problem, we will see that small changes in the problem setting, e.g., choosing simple $s,t$-paths at the beginning instead of any $s,t$-paths, strongly influence the complexity status and combinatorial structures of the optimal solutions. I will conclude the talk with an overview of current results on cutting planes for the recoverable robust knapsack polytope and an application to the train classification problem.

Arie Koster, RWTH Aachen University (with Christina Büsing, Manuel Kutschka)

The recoverable robust knapsack problem

In this talk, we consider the knapsack problem with uncertain item weights. In contrast to the classical robust setting, a limited recovery action is allowed, i.e., up to $k$ items may be removed when the actual weights are known. This problem is motivated by the assignment of traffic nodes to antennas in wireless network planning and the bandwidth packing problem from telecommunication. We study two scenarios to represent the uncertainty. First, a finite set of realizations is discussed. Second, the uncertainty is modelled by the approach of Bertsimas and Sim (2003, 2004) limiting the number of deviations from nominal values by a parameter $\Gamma$. For both cases, we present the results of a polyhedral study, generalizing the well-known cover inequalities. Computational experiments conclude the presentation.

Marjan van den Akker, Utrecht University (with Paul Bouman, Han Hoogeveen, Denise Toniolo)

Column generation for the demand robust shortest path problem

We study the demand robust shortest path problem with a constant speedup factor of $1 + \alpha$ when the number of machines is arbitrary. Further, we show that any polynomial-time algorithm needs a speedup factor of at least $2$, unless $P \neq NP$. Also, if the number of machines is constant, we approximate the speedup factor to within a factor of $1 + \epsilon$. Key to these results are two new relaxations of the demand bound function which yields a sufficient and necessary condition for a task system on a single machine to be feasible.

Andreas Wiese, Universität di Roma `La Sapienza` (with Elisabeth Günther, Olaf Maurer, Nicole Megow)

Nearly optimal universal solutions for knapsack and sequencing on an unreliable machine

Dual-value sequencing with an unknown covering or packing constraint appears as a core subproblem, e.g., when scheduling on an unreliable machine or when determining a universal knapsack solution. A sequence is called $\alpha$-robust when, for any possible constraint, the maximal or minimal prefix of the sequence that satisfies the constraint is at most a factor $\alpha$ from an optimal packing or covering. It is known that the covering problem always admits a $4$-robust solution, and there are instances for which this factor is tight. For the packing variant no such constant robustness factor is possible.

In this work we aim for more meaningful, instance-dependent robustness guarantees. We present an algorithm that constructs for each instance a solution with a robustness factor arbitrarily close to optimal. This implies nearly optimal solutions for universal knapsack and sequencing on an unreliable machine. The crucial ingredient is an approximate feasibility test for dual-value sequencing with a given target function. This result may be of independent interest. We show that deciding exact feasibility is strongly NP-hard, and thus, our test is best possible, unless $P=NP$.

Nicole Megow, Technische Universität Berlin (with Julian Mestre)

Organizer/Chair Zhi-Quan (Tom) Luo, University of Minnesota. Invited Session

Game theoretic analysis and optimization for resource allocation in communication systems

Sławomir Stanczak, Fraunhofer HHI and TU Berlin

Progress and challenges in decentralized resource allocation optimization

This talk presents an overview of algorithmic solutions to optimization problems that naturally appear in the radio resource management for wireless networks. A wireless network is modeled as a weighted graph, in which pairs of nodes form communication links, while the weighted edges capture the interference effects between different links. The focus is on utility maximization approaches. We will show how...
primal-dual methods can provide quadratic convergence, while still allowing for efficient implementation in decentralized wireless networks. Given the limited and costly nature of wireless resources, decentralized algorithms are required to minimize the control message overhead for each iteration step. Therefore we present a distributed handshake scheme based on the use of so-called adjoint network to efficiently estimate iteration updates from some locally measurable quantities. Due to estimation errors and other distorting factors, the proposed algorithm has to be analyzed in a more general context of stochastic approximation.

Zhi-Quan (Tom) Luo, University of Minnesota (with Mingyi Hong, Razaviyayn Meisam, Sun Runyu)
Linear precoder optimization and base station selection for heterogeneous networks

Consider the problem of weighted sum rate maximization in a MIMO interference communication network. We propose to jointly optimize the users’ linear precoders as well as their base station (BS) associations. This approach enables the users to avoid congested BSs and can improve system performance as well as user fairness. In this paper we first show that this joint optimization problem is NP-hard and thus is difficult to solve to global optimality. We also identify a special case (single antenna case) where the joint maximization of the minimum rate problem is solvable via an appropriate weighted bipartite matching for base station assignment and then a simple linear program for power allocation.

To obtain a locally optimal solution, we formulate the problem as a noncooperative game in which the users and the BSs act as players who autonomously optimize their own utility functions. We then develop an algorithm that allows the players to distributedly reach the Nash Equilibrium (NE) of the game. Moreover, we introduce a set of utility functions for the players and show that every NE of the resulting game is a stationary solution of the weighted sum rate maximization problem.

Gesualdo Scutari, State University of New York at Buffalo (with Francisco Facchinei, Jong-Shi Pang)
Monotone communication games

In recent years, there has been a growing interest in the use of noncooperative games to model and solve many resource allocation problems in communications and networking, wherein the interaction among several agents is by no means negligible and centralized approaches are not suitable. In this talk we present a mathematical treatment of (generalized) Nash equilibrium (NE) problems based on the variational inequality approach. Our emphasis is on the design of distributed algorithms for computing best-response iterations along with their convergence properties. The proposed framework has many desirable novel features: i) it can be applied to (monotone) games having no specific structure; ii) the algorithms proposed for computing a NE converge under mild conditions that do not imply the uniqueness of the equilibrium; and iii) in the presence of multiple NE, one can control the quality of the computed solution by guaranteeing convergence to the “best” NE, according to some prescribed criterion, while keeping the distributed implementation of the algorithm. These are new features enlarge considerably the applicability and flexibility of game-theoretic models in wireless distributed networks.

Mon.2 MA 313 Optimization and equilibrium problems I
Organizers/Chairs Christian Kanzow, University of Würzburg; Michael Ulbrich, Technische Universität München - Invited Session
Oliver Stein, Karlsruhe Institute of Technology (with Nadja Harms, Christian Kanzow)
On differentiability properties of player convex generalized Nash equilibrium problems

Any smooth generalized Nash equilibrium problem allows a reformulation as a single constrained minimization problem with possibly non-smooth objective function. Under the assumption of player convexity, we study smoothness properties of this objective function and, by using several results from parametric optimization, we show that, except for special cases, all locally minimal points of the reformulation are differentiability points. This justifies a numerical approach which basically ignores the possible nondifferentiability.

Alexandra Schwartz, University of Würzburg (with Jörg Franke, Christian Kanzow, Wolfgang Leisening)
Biased lottery versus all-pay auction contests: A revenue dominance theorem

We allow a contest organizer to bias a contest in a discriminatory way, that is, he can favor specific contestants through the choice of the contest success function in order to maximize the total equilibrium effort. For large enough enhancement through biasing is analyzed and compared for the two predominant contest regimes: all-pay auctions and lottery contests. In order to determine the optimally biased all-pay auction or lottery contest, the organizer has to solve a mathematical program with equilibrium constraints. We derive the optimally biased lottery contest analytically. But although this optimal lottery has a few interesting properties, it turns out that the optimally biased lottery contest will always be dominated by an appropriately biased all-pay auction.

Mon.2.H 2034 Algorithms for matrix optimization problems
Chair Tu Xia, Lakehead University
Qingna Li, AMSS, Chinese Academy of Sciences (with Houduo Qi)
Sequential semismooth Newton method for nearest low-rank correlation matrix problems

Rank constrained matrix optimization problems have been receiving great interest in the past few years due to the applications in various fields. One of such problems is the nearest low-rank correlation matrix problem, arising from finance. In this talk, we propose the sequential semismooth Newton method to solve it. We analyze the connections between the proposed method and some other methods. Potential improvement of the method is also discussed.

Chengdong Wang, Southwest Jiaotong University (with Defeng Sun, Kim-Chuan Toh)
On how to solve large scale matrix log-determinant optimization problems

We propose a Newton-CG primal proximal point algorithm (PPA) and a Newton-CG primal augmented Lagrangian method (ALM) for solving large scale nonlinear semidefinite programming problems whose objective functions are a sum of a log-determinant term with a linear function and a sum of a log-determinant term with a convex quadratic function, respectively. Our algorithms employ the essential ideas of the PPA, the ALM, the Newton method, and the preconditioned conjugate gradient (CG) solver. We demonstrate that our algorithms perform favorably compared to existing state-of-the-art algorithms and are much preferred when a high quality solution is required for problems with many equality constraints.

Tu Xia, Lakehead University
Gradient methods for a general least squares problem

We consider a constrained least squares problem over cones. We show how to adapt Nesterov’s fast gradient methods to the problem efficiently. Numerical examples will be provided.

Mon.2.H 2038 Nonlinear semidefinite programs and copositive programs
Organizers/Chair Florian Jarre, Universität Düsseldorf - Invited Session
Michał Kocvara, University of Birmingham (with Jan Fiala, Michael Stingl)
Introducing PENLAB, a Matlab code for nonlinear conic optimization

We will introduce a new code PENLAB, an open Matlab implementation and extension of our older PENNON. PENLAB can solve problems of nonconvex nonlinear optimization with standard (vector) variables and constraints, as well as matrix variables and constraints. We will demonstrate its functionality using several nonlinear semidefinite examples.

Mirjam Dür, University of Trier (with Willemieke van Vliet)
Remarks on copositive plus matrices and the copositive plus completion problem

A matrix $A$ is called copositive plus if it is copositive and if for $x \geq 0$, $x^T Ax = 0$ implies $Ax = 0$. These matrices play a role in linear complementarity problems (LCPs), since it is well known that Lemke’s algorithm can solve LCPs when the matrix involved is copositive plus.

In this talk, we study two issues: first, we discuss properties of the cone of copositive plus matrices. In particular, we formulate an analogous result to the well-known fact that any copositive matrix of order $up$
to four can be represented as a sum of a positive semidefinite and an entrywise nonnegative matrix.

The second problem we are interested in is the copositive plus completion problem: Given a partial matrix, i.e., a matrix where some entries are unspecified, can this partial matrix be completed to a copositive plus matrix by assigning values to the unspecified entries? We answer this question both for the setting where diagonal entries were unspecified, and for the case of unspecified non-diagonal entries.

Peter Dickinson, Johan Bernoulli Institute, University of Groningen (with Kurt Anstreicher, Samuel Burer, Luk Gielen)

**Considering the complexity of complete positivity using the Ellipsoid method**

Copositive programming has become a useful tool in dealing with some optimization problems. It has however been shown by Murty and Kabadi (Some NP-complete problems in quadratic and nonlinear programming, Mathematical Programming, 39, no.2:117–129, 1987) that the strong membership problem for the copositive cone, that is deciding whether or not a given matrix is in the copositive cone, is a co-NP-complete problem. The dual cone to the copositive cone is called the completely positive cone, and, because of this result on the copositive cone, it has widely been assumed that the strong membership problem for this cone would be an NP-complete problem. The proof to this has however been lacking. In order to show that this is indeed true we would need to show that the problem is both an NP-hard problem and a problem in NP. In this talk we use the Ellipsoid Method to show that this is indeed an NP-hard problem and that the weak membership problem for the completely positive cone is in NP (where we use a natural extension of the definition of NP for weak membership problems). It is left as an open question as to whether the strong membership problem itself is in NP.

Michel Rueher, University of Nice Sophia Antipolis

**Using IIS for error localization**

Modern model-checkers are often very efficient for generating counterexamples, i.e., to compute input data violating a given property or a post-condition. However, the associated execution traces are often lengthy and difficult to understand. Hence, the localization of the portions of code that contain errors is therefore often very expensive, even for experienced programmers. Recently, Griesmayr et al proposed to encode a trace of a program and the post-condition as a failing Boolean formula F. They use MAX-SAT to compute the maximum number of clauses that can be satisfied in F and output the complement as a potential cause of the errors. We propose here to improve their approach and to use IIS (irreducible infeasibility set) for the linear constraint subsystems. The advantage is that linear constraints provide a much more rich and concise model for numeric programs than Boolean formula.

Charlotte Truchet, LINA, Université de Nantes (with Frédéric Benhamou, Marie Pellissier)

**Octagonal domains for constraint programming**

Continuous Constraint Programming relies on interval representations of the variables of domains. Filtering and solution set approximations are based on Cartesian products of intervals, called boxes. We propose to improve the Cartesian representation precision by introducing an n-ary octagonal representation of the domains in order to improve the propagation accuracy. The principles of constraint solving remain the same: reduce the domains by applying constraint propagators (filtering), by computing fixpoints of these operators (propagation) and by splitting the domains to search the solution space. Nevertheless, each of these steps is redesigned so as to take the new domains into account. Our contributions are the following: first, we show how to transform the partial constraint problem into an equivalent semidefinite programming problem on octagonal domains. Second, we define a specific local consistency, oct-consistency, and propose a propagation algorithm, built on top of any continuous filtering method. Third, we propose a split algorithm and a notion of precision adapted to the octagonal case. Practical experiments show that the octagonal domains perform well on the Coconut benchmark.

Thomas Coleman, University of Waterloo (with Xi Chen)

**On the use of automatic differentiation to efficiently determine first and second derivatives in financial applications**

Many applications in finance require the efficient computation of the first and second derivatives (i.e., Creed and sometimes 2nd derivatives of pricing functions of financial instruments. This is particularly true in the context of portfolio optimization and hedging methodologies. Efficient and accurate derivative computations are required. If the target instruments are simple, e.g., vanilla instruments, then this task is simple: indeed, analytic formulae exist and can be readily used. However, explicit formulae for more complex models are unavailable and the accurate and efficient calculation of derivatives is not a trivial matter. Examples include models that require a Monte Carlo procedure, securities priced by the Libor swap model, the Libor swap market model, and the copula model. A straightforward application of automatic differentiation (AD) is exorbitantly expensive; however, a structured application of AD can be very efficient (and highly accurate). In this talk we illustrate how these popular pricing models exhibit structure that can be exploited, to achieve significant efficiency gains, in the application of AD to compute 1st and 2nd derivatives of these models.

Raghu Fornaciari, Faculty of Sciences - University of Lisbon (with Ber, Ristem)

**Robust value-at-risk with linear policies**

We compute the robust value-at-risk in the context of a multistage international portfolio optimization problem. Decisions at each time period are modeled as linearly dependent on past returns. As both the currency and the local asset returns are accounted for, the original model is non-linear and non-convex. With the aid of robust optimization techniques, however, we develop a tractable semidefinite programming formulation of our model, where the uncertain returns are contained in an ellipsoidal uncertainty set. The worst case value-at-risk is minimized over all possible probability distributions with the same first two order moments. We additionally show the close relationship between the minimization of the worst case value-at-risk and robust optimization, and the conditions under which the two problems are equivalent. Numerical results with simulated and real market data demonstrate the potential gains from considering a dynamic multiperiod setting relative to a single stage approach.

Christoph Reisinger, University of Oxford

**The effect of the payoff on the penalty approximation of American options**

This talk combines various methods of analysis to draw a comprehensive picture of penalty approximations to the value, hedge ratio, and optimal exercise strategies of American options. While convergence of the penalized PDE solution for sufficiently smooth obstacles is well-established in the literature, sharp rates of convergence and particularly the effect of gradient discontinuities (i.e. the ‘semi-present kinks’ in option payoffs) on this rate have not been fully analysed so far. We use matched asymptotic expansions to characterise the boundary layers between exercise and hold regions, and to compute first order corrections for representative payoffs on a single asset following a diffusion or jump-diffusion model. Furthermore, we demonstrate how the viscosity theory framework can be applied to this setting to derive upper and lower bounds on the value. In small extension, we derive weak convergence rates also for option sensitivities for convex payoffs under jump-diffusion models. Finally, we outline applications of the results, including accuracy improvements by extrapolation.

Giacomo Cone, Lund University (with Danos Acemoglu, Munther Dahleh, Emilio Frazzoli, Ketan Savla)

**Stability analysis of transportation networks with multiscale driver decisions**

Stability of Wardrop equilibria is analyzed for dynamical transportation networks in which the drivers’ route choices are influenced by information at multiple temporal and spatial scales. The considered model
involves a continuum of drivers commuting between a common origin/destination pair in an acyclic transportation network. The drivers’ route choices are affected by their, relatively infrequent, perturbed best responses to global information about the current network congestion levels, as well as their instantaneous local observation of the immediate surroundings as they transit through the network. A novel model is proposed for the drivers' route choice behavior, exhibiting local consistency with their preference toward globally less congested paths as well as myopic decisions in favor of locally less congested paths. The main result shows that, if the frequency of updates of path preferences is sufficiently small as compared to the frequency of the traffic flow dynamics, then the state of the transportation network ultimately approaches a neighborhood of the Wardrop equilibrium. The presented results may be read as a further evidence in support of Wardrop's postulate of equilibrium.

Oleg Prokopyev, University of Pittsburgh (with Osman Ozaltin, Andrew Schaefer)
Optimal design of the annual influenza vaccine with autonomous multi-agent networks

We consider a doubly (over time and space) distributed averaging algorithm in a large multi-agent network. At every iteration, each single agent first computes a weighted average of its own time-averaged estimate and those of its neighbors and then generates a new estimate in order to drive the time-averaged estimate towards a pre-assigned set. The main contribution of the paper is to prove that under certain assumptions, if all agents reach consensus on time-averaged estimates, and if the estimates approach the pre-assigned set. Conditions for this to happen are related to the connectivity over time of the communication topology and to the approachability principle. Motivations arise in the context of repeated coalitional games with transferable utilities (TU). Here, the algorithm represents a distributed allocation process converging to the core of the game in the limit.

Peter Caines, McGill U. (with Zhengbing Ma, Roland Malhame)
Nash equilibria in radial communication networks via mean field game theory

Mean Field Game theory is developed and applied in this paper to call admission control in a point process model of communication networks. In general the MFG methodology establishes the existence of approximate Nash equilibria for large populations of agents which employ only local feedback and precomputed solutions to the Mean Field equations. In this paper dynamic communication networks are modeled by highly symmetric radial loss networks driven by Poisson call request point processes subject to decentralized admission control. A key concept introduced in the analysis in this paper is that of the so-called network decentralized state (NDS) which is a state induced asymptotically (in population size) in a given network under any (randomized) local admission control law when it is common to all agents. Under appropriate assumptions, an analysis of networks in an NDS establishes the existence of Nash equilibria which are achieved for all sufficiently large populations. Computational illustrations of the methodology are included.

Good linear approximations for MINLP Problems with tolerance guarantee

For functions depending on one or two variables, we systematically construct optimal breakpoint systems subject to the condition that the linear approximation never deviates more than a given $\varepsilon$-tolerance from the original function over a given domain. The optimization problem of computing the minimal number of breakpoints satisfying the $\varepsilon$-tolerance leads to semi-infinite problems. We introduce several discretization schemes and algorithms, computing linear approximator, underestimator and overestimator systems with $\varepsilon$-tolerance.

Oleg Prokopyev, University of Pittsburgh (with Osman Gachin, Andrew Schaefer)
Optimal design of the annual influenza vaccine with autonomous manufacturer

Seasonal influenza (flu) is a major public health concern, and the first line of defense is the flu shot. Frequent updates to the flu shot strains are required, as the circulating strains mutate rapidly. The World Health Organization recommends which flu strains to include in the annual vaccine based on international surveillance. These recommendations have to be made under uncertainty well in advance before the epidemic because the production has many time-sensitive steps. Furthermore, there is a decision hierarchy between the government agencies, who design the flu shot, and the manufacturers, who make it available.

This hierarchy results from the fact that the Committee optimizes the societal vaccination benefit by taking into account production decisions of the manufacturers, who maximize their own profits. The manufacturers’ profit maximization problem is affected by the strain selection decisions of the Committee. We quantify the trade-offs involved through a bilevel stochastic mixed-integer program. Calibrated over publicly available data, our model determines the optimal flu shot composition and production in a stochastic and dynamic environment.

Dina Basso, Università di Palermo (with Giuseppe Notastefano, Raffaele Pessoni)
Time-averaged consensus and distributed approachability in large multi-agent networks

We consider the flu shot, and the manufacturers, who make it available. More, there is a decision hierarchy between the government agencies, which indicate the optimal server to dispatch to each customer type in each state. Optimal policies are fully state dependent and may be tedious to use in practice. Restricted policies that are partially state dependent and conform to a priority list policy for each type of customer may be easier to use in practice. This research demonstrates how the

Mon.2. H 1058
Optimization tools for R
Organizer/Chair Erling Andersen, MOSEK A/S - Invited Session
Henrik Friberg, MOSEK
The R-to-MOSEK optimization interface

Currently, R and a wide variety of contributed packages on CRAN as well as other package repositories offer tools to solve many different optimization problems (see the overview at http://cran.R-project.org/ view=Optimization). However, the user interfaces to available optimizers and the output, i.e., the format of the returned solution, often differ considerably. It is not only the users interested in R as an optimization tool, but also the developers who need to handle different optimization problem classes transparently and who are facing this lack of standardization. Therefore, an integrative multi-purpose optimization framework for R seems to be desirable.

In this talk we present the R Optimization Infrastructure package ROI, an extensible framework for modeling and solving linear as well as nonlinear (possibly mixed-integer) optimization problems. Without the need to learn a domain specific language ROI enables users to employ both, open source and commercial solvers directly within R via so-called plugin packages.

Steven Dirkse, GAMS Development Corporation (with Michael Ferris, Renger van Nieuwkoop)
GDXXRW: Exchanging data between GAMS and R

We discuss GDXXRW (GDX–R Read/Write), a tool for moving data between GAMS and R. This data exchange is beneficial for those in both user communities. For example, it gives R users the capability to use the superior modeling and optimization capabilities of GAMS, and it allows for visualization and analysis of GAMS data (both pre- and post-solution) directly within R to take advantage of R’s wide range of functionality. The freely available tool is based on GDX (GAMS Data eXchange), a well-established and public API for sharing data.

Mon.2. H 2013
 MILP formulations I
Chair Silvio de Araujo, UNESP/Brazil
Laura McClay, Virginia Commonwealth University
A mixed-integer programming model for enforcing priority list policies in Markov decision processes

Optimal dispatching policies for server-to-customer systems can be identified using Markov decision process models and algorithms, which indicate the optimal server to dispatch to each customer type in each state. Optimal policies are fully state dependent and may be tedious to use in practice. Restricted policies that are partially state dependent and conform to a priority list policy for each type of customer may be easier to use in practice. This research demonstrates how the
optimal priority list policy can be identified by formulating constrained Markov decision processes as mixed integer programming models.

Silvia de Araujo, UNESP/Brasil (with Diego Forero)

Lagrangian heuristics for a reformulated lot sizing problem in parallel machines

The capacitated lot sizing problem with multiple items, setup time and unrelated parallel machines is considered. The aim of this work is to design a Lagrange heuristic that provides good solutions for this problem and strong lower bounds to assess their quality. Based on a strong reformulation of the problem, Lagrange relaxation is applied on the demand constraints and the subgradient optimization procedure is used. A primal heuristic, based on production transfers, is developed to generate feasible solutions (upper bounds). Computational experiments are presented on data sets available from the literature.

Diego Moran, Georgia Tech (with Santanu Subhas Dey, Juan Pablo Vielma)

The Quadratic Assignment Problem (QAP) is the problem of allo-
ding variables. A primal heuristic, based on production transfers, is developed to generate feasible solutions (upper bounds). Computational experiments are presented on data sets available from the literature.

Serigne Gueye, Université d’Avignon, Laboratoire d’Informatique d’Avignon (LIA) (with Philippe Michelon)

Using distance variables for the quadratic assignment problem

The Quadratic Assignment Problem (QAP) is the problem of allocating facilities to locations such as to minimize the sum of a linear and quadratic cost depending on the distances between facilities and flows. The Minimum Linear Arrangement (MiniLa) is a special case of (QAP) where . It has been proposed for MiniLa a linear model using distance variables. The lower bound is poor, equal to 0, but can be improved with facets [see (1,2)]. We have independently observed that the distance variables can be used for (QAP), and that some facets are also applicable each time defines a metric, as the grid graphs in QAPLIB instances. Adding valid inequalities linking and we have tested this model. The result shows a competitive average relative gap of 10.7% with a minimum of 3.4%.


Organizer/Chair Ricardo Fukasawa, University of Waterloo - Invited Session

Improving the accuracy of linear programming solvers with iterative refinement

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

Franz Wiesemann, University of Paderborn (with Iwa Suhl)

Computational experiments with general-purpose cutting planes

General-purpose cutting planes are known to play a crucial role in solving mixed-integer linear programs. We report on computational experiments with families of split cuts which can be generated efficiently such as Gomory mixed-integer cuts, reduce-and-split cuts, lift-and-project cuts and pivot-and-reduce cuts. We also consider several variants of these basic algorithms, e.g., lift-and-project cuts generated from split disjunctions obtained with the reduce-and-split algorithm or reduce-and-split cuts generated using tableau rows produced by the lift-and-project method. Moreover, we present computational results obtained with different variants of multi-row cut separators.

Daniel Espinoza, Universidad de Chile (with Angelo Anand)

Cutting and separation for semi-continuous variables

Semi-continuous variables appear naturally when modeling general functions with mixed integer linear programs (MILP), and are widely used in many applications. In this talk we present several classes of inequalities to be facet-defining; and also, we describe an approximate lifting function, and conditions under which the approximate lifting is exact. Although the separation problem is NP-complete, we present some separation heuristics, as well as extensive testing on instances coming from unit commitment problems. Our results show that, in our test instances, we close in average between 50 and 90 percent of the root LP gap.

Daniel Bienstock, Columbia University (with Alexander Michalka)

Strong formulations for convex functions over nonconvex sets

In this paper we derive strong linear inequalities for systems representing a convex quadratic over the complement of a convex set, and present, in several cases, characterizations of the convex hull by poly- nomially separable linear inequalities. An example of this situation is that of positive definite quadratic over the complement of a polyhedron.

Diego Moran, Georgia Tech (with Santanu Sahbas Dey, Juan Pablo Vielma)

Strong dual for conic mixed-integer programs

Mixed-conic integer programming is a generalization of mixed-integer linear programming. We present an extension of the duality the- ory for mixed-integer linear programming to the case of mixed-integer conic programming. Under a simple condition on the primal problem, we are able to prove strong duality.
approachability of hybridization number and directed feedback vertex set

We show that the problem of computing the hybridization number of two rooted binary phylogenetic trees on the same set of taxa X has a constant factor polynomial-time approximation if and only if the problem of computing a minimum-size feedback vertex set in a directed graph (DFVS) has a constant factor polynomial-time approximation. The latter problem, which asks for a minimum number of vertices to be removed from a directed graph to transform it into a directed acyclic graph, is one of the problems in Karp’s seminal 1972 list of 21 NP-complete problems. Despite considerable attention from the combinatorial optimization community, it remains to this day unknown whether a constant factor polynomial-time approximation exists for DFVS. Our result thus places the (in)approximability of hybridization number in a much broader complexity context. On the positive side, we use results from the DFVS literature to give an \(O(\log \log r)\) approximation for the hybridization number where \(r\) is the correct value.

Céline Scornavacca, ISMÉ, Université Montpellier II (with Steven Kelk)

Constructing minimal phylogenetic networks from softwired clusters is fixed parameter tractable

Here we show that, given a set of clusters \(C\) on a set of taxa \(X\), where \(|X| = n\), it is possible to determine in time \(\text{f}(k)\cdot \text{poly}(n)\) whether there exists a level-\(k\) network (i.e., a network where each biconnected component has reticulation number at most \(k\) that represents all the clusters in \(C\) in the softwired sense, and if so to construct such a network. This extends a polynomial time result from Kelk et al. on the elusiveness of clusters, IEEE/ACM Transactions on Computational Biology and Bioinformatics, and is achieved by generalizing the concept of “level-\(k\) generator” to general networks, we then extend this fixed parameter tractability result to the problem where \(k\) refers not to the level but to the reticulation number of the whole network.

Robert Voll, TU Dortmund University (with Uwe Clausen)

Branch-and-price algorithms in transportation

We present a consolidation problem from wagonload traffic, which is a production form in railway freight traffic. A huge number of OD-requests -each of them consists of only a small number of wagons-has to be routed through the railway network. Wagons from different OD-pairs (relations) are consolidated in reclassification yards in order to use trains jointly for parts of their routes. The route of each relation is determined by so called Blocking Plans which shall be optimized. The objective is to minimize the sum of train and reclassification costs. We consider a multimmodity flow problem with elements of a fixed charging problem. By generalization pattern developed earlier is extended to a Branch-and-Price-algorithm. Our branching rule destroys the simple subproblem structure of the aforementioned column generation approach, but we overcome this problem by dynamical programming. We can take advantage from our branching rule by deriving effective cuts. Numerical results are presented and compared to solutions provided by commercial solvers. We also analyze the impact of our cuts empirically. First experiments are very promising.

Michel Sijsca, University of Sao Paulo (with Andre Mendes)

Branch-and-price for a rich vehicle routing and scheduling problem

This study considers a vehicle routing problem with time windows, accessibility restrictions on customers and a fleet that is heterogeneous with regard to capacity and average speed. A vehicle can perform multiple routes per day, it can start and end up at a single depot, and it is assigned to a single driver, whose total work hours are limited. A column generation algorithm embedded in a branch-and-bound framework is proposed. The column generation pricing subproblem required a specific elementary shortest path problem with resource constraints algorithm to deal with the possibility for each vehicle to perform multiple routes per day and to deal with the need to work during the workday beginning instant of time within the planning horizon. To make the algorithm efficient, a constructive heuristic and a metaheuristic based on tabu search were also developed.

Vivek Farias, MIT (with Nikhil Bhat, Ciamac Moallemi)

Non-parametric approximate dynamic programming via the kernel method

We present a “kernelized” variant of a recent family of approximate dynamic programming algorithms we have dubbed “smoothed approximate linear programs”. Our new algorithm is non-parametric in that it does not require a basis function architecture and develops a value function approximation with accuracy that improves with the size of the training data set. We describe the efficient implementation of this method, and present sample complexity bounds and approximation guarantees that effectively extend state of the art guarantees for ADP to the non-parametric setting. In summary, we believe this is the first practical non-parametric ADP algorithm with performance guarantees.

Sahand Negahban, MIT (with Alok Agrawal, Martin Wainwright)

Noisy matrix decomposition via convex relaxation: Optimal rates in high dimensions

We analyze a class of estimators based on convex relaxation for solving high-dimensional matrix decomposition problems. The observations are noisy realizations of a linear transformation \(X\) of the sum of an approximately low rank matrix \(\Theta^*\) with a second matrix \(\Gamma^*\) endowed with a complementary form of low-dimensional structure; this set-up includes many statistical models of interest, including factor analysis, multi-task regression, and robust covariance estimation. We derive a general theorem that bounds the Frobenius norm error for an estimate of the pair \((\Theta^*,\Gamma^*)\) obtained by solving a convex optimization problem that combines the nuclear norm with a general decomposable regularizer. We specialize our general result to two cases that have been studied in past work: low rank plus an entrywise sparse matrix, and low rank plus a columnwise sparse matrix. For both models, our theory yields non-asymptotic Frobenius error bounds for both deterministic and stochastic noise matrices. Moreover, for the case of stochastic noise matrices and the identity observation operator, we establish matching lower bounds on the minimax error.

Organizer/Chair: Ignacio Grossmann, Carnegie Mellon University. Invited Session

Mixed-integer nonlinear programming

Global mixed-integer nonlinear optimization II

Organizer/Chair: Ignacio Grossmann, Carnegie Mellon University. Invited Session

Brage Kofstad, Norwegian University of Science and Technology (with Andrew Conn, Bjarte Foss)

Mixed integer optimization of the late-life performance of shale-gas wells

Efficient shale-gas recovery requires a large number of wells in order to maintain a sustainable total gas supply. The wells and the pro-
duction pads are often widely spread over a large geographical area, and interconnected by comprehensive surface gathering lines. We present a discrete time mixed integer nonlinear program (MINLP) for optimal scheduling of shale-gas multi-well pads. The MINLP model is formulated by using a dynamic reservoir proxy model and a nonlinear well model for each well, and show how such models may be efficiently scheduled to prevent liquid loading and boost late-life rates for these types of wells. Furthermore, by using a simplified well model and performing a linear reformulation, we do a preliminary comparison of solving the scheduling problem as an MILP compared to the MINLP.

Gonzalo Guillén-Gosálbez, Universitat Rovira i Virgili (with Pedro Copado, Ignacio Grossmann)

Solving mixed-integer linear-fractional programming problems via an exact MILP reformulation

We present a method to solve mixed-integer linear-fractional programming (MILFP) problems in which the objective function is expressed as a ratio of two linear functions and the equality and inequality constraints are all linear. Our approach extends the transformation of Charne and Cooper (1962), originally devised for linear-fractional programs with continuous variables, to handle the mixed-integer case. In essence, we reformulate the MILFP into an equivalent mixed-integer linear program (MILP) that makes use of auxiliary continuous variables. The solution of this MILP, which can be obtained by standard branch-and-cut methods, provides the global optimum of the original MILFP. Numerical results show that our strategy outperforms the most widely used general-purpose mixed-integer nonlinear programming solution methods (i.e., outer approximation – available in DICOPT –, nonlinear branch and bound – SBB –, and extended cutting plane, alphaBB) as well as the branch-and-reduce global optimization algorithm implemented in BARON.

Luís Paquete, University of Coimbra (with Carlos Fonseca, Kathrin Klamroth, Michael Stiglmayr)

Multicriteria disaggregation as a new paradigm for global optimization of mixed-integer polynomial programs

Multicriteria Disaggregation involves discretization of the domain of one of the variables appearing in a bilinear term, the basic building block to tackle higher order polynomials. Alternative numeric representation systems can be employed (e.g., decimal, binary) with the user specifying the accuracy level for the approximation. With this, the original MINLP can be approximated by an upper bounding MILP, which in many cases is easier to solve to global optimality. In this work, we propose a lower bounding relaxation MILP, where a truncation error is defined for the parameterized variables. Since the higher the chosen accuracy, the tighter the formulation, we can easily construct a global optimization algorithm starting with 1 significant digit (first iteration) and ending when the optimality gap is lower than a given tolerance. Starting with Disjunctive Programming models, we show that the new relaxation, although looser, leads to a better performance than the one from piecewise McCormick relaxations (using univariate and uniform domain partitioning). The primary cause is the linear vs. exponential increase in problem size for an order of magnitude reduction in optimality gap.

Pedro Castro, Laboratório Nacional de Energia e Geologia (LNEG) (with Ignacio Grossmann, João Teles)

Efficient set representations

We present a solution method for the multicriteria linear bottleneck assignment problem (MLBAP), which is the multicriteria analogon of the well studied linear bottleneck assignment problem. Our algorithm is an extension of the single criteria threshold algorithm. We define a residual graph by specifying a (multicriteria) threshold vector, such that all of its edges have cost dominated by the threshold. Any complete matching in this residual graph is a candidate for an efficient solution with at least the threshold values. The computation of matchings in the residual graph is realized by an efficient strategy that uses the most widening edges in the algorithm. While we restrict ourselves to bicriteria cases, we show possible extensions to multiple criteria.

Michael Stiglmayr, University of Wuppertal

The multicriteria linear bottleneck assignment problem

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Michael Stiglmayr, University of Wuppertal (with Carlos Fonseca, Kathrin Klamroth, Michael Stiglmayr)

Concise representation of nondominated sets in discrete multicriteria optimization

The problem of finding a representative subset of the nondominated point set of a discrete multicriteria optimization problem with respect to uniformity and coverage is introduced. Provided that the decision maker is able to indicate the number of points to visualize, a subset of well-spread points (uniformity) that are close enough to the remaining points (coverage) is of interest.

Finding a representative p-point subset with respect to uniformity and coverage can be formulated as a combination of p-dispersion and p-center facility location problems, respectively, with a special location structure. In this work, polynomial-time dynamic programming algorithms to find representative subsets with respect to each of these measures in the two-dimensional case are presented. Moreover, the multicriteria version of this problem is shown to be solvable also in polynomial time using dynamic programming. The extension of these and related problems to larger dimensions will be discussed.

Florian Stepp, University of Kaiserslautern (with Stefan Ruzika)

A polynomial time approach for the multiple objective minimum spanning tree problem

The minimum spanning tree problem is a well-studied problem in combinatorial optimization. Whereas the single objective version can be solved in polynomial time by greedy algorithms, the multiple objective version is known to be intractable and NP-hard. Even worse, the number of both supported and unsupported nondominated points may be exponentially large in the number of edges of the underlying graph. In this talk, it is shown that it is however possible to bound the number of extremal supported nondominated points polynomially. The result is based on the theory of the arrangements of hyperplanes. It immediately implies that the first phase of the two-phases method, i.e., computing the nondominated frontier, can be accomplished by solving a polynomial number of weighted sum problems. A solution approach is presented which demonstrates how this can be achieved algorithmically.

James Hungerford, University of Florida (with William Hager)

Edge directions in polyhedral optimization

We consider the problem of maximizing a continuously differentiable function \( f(x) \) over a polyhedron \( P \subset \mathbb{R}^n \). We present new first and second order optimality conditions for this problem which stated in terms of the derivatives of \( f \) along directions parallel to the edges of \( P \). We show that for a special class of quadratic programs, local optimality can be checked in polynomial time. Finally, we present a new continuous formulation for a well known discrete optimization problem: the vertex separator problem on a graph \( G \). Easily checked optimality conditions for this problem are derived via the theory of edge directions. These optimality conditions are shown to be related to the existence of edges at specific locations in the graph.

Efficient set representations

Organizer/Chair Luís Paquete, University of Coimbra - Invited Session

Michael Stiglmayr, University of Wuppertal

The multicriteria linear bottleneck assignment problem

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Daniel Robinson, Johns Hopkins University (with Frank Curtis, Zheng Han)

A primal-dual active-set method for convex QP

We present a rapidly adapting active-set method for solving large-scale strictly convex quadratic optimization problems. In contrast to traditional active-set methods, ours allows for rapid changes in the active set estimate. This leads to rapid identification of the optimal active set, regardless of the initial estimate. Our method is general enough that it can be utilized as a framework for any method for solving convex quadratic optimization problems. Global convergence guarantees are provided for two variants of the framework. Numerical results are also provided, illustrating that our framework is competitive with state-of-the-art solvers on most problems, and is superior on ill-conditioned problems. We attribute these latter benefits to the relationship between the framework and a semi-smooth Newton method.

Sven Leyffer, Argonne National Laboratory

Large-scale nonlinear optimization solvers

We describe the development of a suit of tools and solvers for large-scale nonlinearly constrained optimization problems. We emphasize methods that can operate in a matrix-free mode and avoid matrix factorizations. Our framework implements a range of two-phase active-set methods, that are required, for example, for fast residues in mixed-integer solvers. In the first phase, we estimate the active set, and in the second phase we perform a Newton step on the active constraints. We show that our framework can be designed in a matrix-free mode, and analyze its convergence properties. We show that allowing a small number of active-set changes in the Newton step improves convergence.

Elizabeth Wong, University of California, San Diego (with Philip Gill, Daniel Robinson)

Regularized quadratic programming methods for large-scale SOP

We present a regularized method for large-scale quadratic programming [QP]. The method requires the solution of a sequence of bound-constrained subproblems defined in terms of both the primal and dual variables. The subproblems may be solved using a conventional active-set method, which would involve the solution of a regularized KKT system at each step, or a method based on gradient projection. In the convex case, the solution of the bound-constrained subproblem is also a solution of the QP subproblem for a stabilized sequential quadratic programming [SQP] method. Numerical results are presented.

Zhouchong Zhang, University of Minnesota (with Bo Jiang, Zhening Li)

Cones of nonnegative quartic polynomial functions and their applications

Polynomial and tensor optimization models have proved to be useful in a wide range of applications in engineering and scientific computation. Applications aside, the structure of higher order polynomial/tensor functions however remains largely unknown. For example, the computational testability to tell if a quartic function is convex or not had remained an open problem until 2010 when Ahmadi et al. proved that it is in fact strongly NP hard. In this talk we discuss six particular convex cones generated from the nonnegative quartic polynomial functions. Our goal is to illustrate the rich structure of nonnegative quartic polynomial functions. In particular, these convex cones are in decreasing order, much like the Russian Matroshka dolls, with varying computational complexities. We discuss the modeling power and applications of these convex cones in the context of these cones introduce an interesting result known as Hilbert’s identity, and discuss its role in our study.

Lek-Heng Lim, University of Chicago (with Christopher Hillar)

3-tensors as the boundary of tractability

Why do problems in numerical computing become intractable as they transition from linear to nonlinear or convex to nonconvex? We shall argue that 3-tensor problems form the boundary separating the tractability of linear algebra and convex optimization from the intractability of polynomial algebra and nonconvex optimization – 3-tensor analogues of many efficiently computable matrix problems are NP-hard. Our list includes: determining the feasibility of a system of bilinear equations, deciding whether a 3-tensor possesses a given eigenvalue, singular value, or spectral norm; approximating an eigenvalue, eigenvector, singular vector, or spectral norm; determining the rank or a best rank-1 approximation to a 3-tensor. Additionally, some of these problems have no polynomial time approximation schemes, some are undecidable over Q, and at least one enumerative version is #P-complete. Restricting these problems to symmetric 3-tensors does not alleviate their NP-hardness.

Ginghe Yang, Nankai University, China

Some properties of tensors’ eigenvalues and related optimization problem

In this talk, I will focus on the properties of tensors’ eigenvalues and related optimization problem. The tensor is an array of high dimensional data, which can be viewed as the extension of the vector and matrix. In the past some years, especially recent years, due to the needs of real problems, the study on the tensors attracts a great attention. Several different definitions of eigenvalues of tensors were presented, and various properties with respect to tensors’ eigenvalues were put forward, some interesting conclusions were generalized from the matrix to tensor, such as the Perron-Frobenius theorem for nonnegative matrix. In addition, for some problems one has to find the largest or smallest eigenvalues of tensors, which can be written as some special constrained optimization problem(s). I will introduce the recent development in properties of tensors’ eigenvalues as well as the algorithms for solving the related optimization problem(s).
Optimization in energy systems

Organizer/Chair Jon Lee, University of Michigan - Invited Session

Timo Lohmann, Colorado School of Mines (with Steffen Rebennack)

Stochastic hydro-thermal scheduling with CVaR risk constraints in deregulated markets

In the regulated electricity market, a power producer's goal is to satisfy his customers' electricity demand while minimizing his expected cost of operating his power system. In the deregulated market, a power producer has no longer to meet the electricity demand of his customers, but is able to trade the electricity in the market. This complicates the problem as uncertainty of spot prices and risk appetite have to be considered in addition. The objective of optimization is the maximization of expected net profit of the power system in the mid-term horizon. In our case the power system is hydro-dominated and the resulting multi-stage stochastic programming problem contains jointly uncertainties in the hydro inflows and electricity spot prices. These kinds of models are usually solved with the SDDP algorithm. For this special case we need to use a hybrid SDP/SDDP algorithm and we enhance it with CVaR risk constraints.

Nicola Sebastiani, Carnegie Mellon University (with Margot Francois, Nadarajah Selvaprabu)

Approximate linear programming relaxations for commodity storage real option management

Real option management of commodity storage typically gives rise to an intractable Markov Decision Process (MDP). We derive novel approximate dynamic programs for this MDP from partitioned surro-gate relaxations of an approximate linear program. We estimate lower bounds and dual upper bounds on the value of storage for a seasonal commodity (natural gas) and a non-seasonal commodity (oil). Our lower bounds essentially match the best known lower bounds for the natural gas storage instances, and are near-optimal for the oil instances, which are new. Our upper bounds either match or improve those available in the literature for natural gas, but are weaker than an exchange-option based upper bound from the literature for the oil instances. We use a tractable version of the problem to highlight the source of the bias in our estimated upper bounds.

Yongpei Guan, University of Florida (with Ruiwei Jiang, Jean-Paul Watson, Ming Zhao)

A branch-and-cut algorithm for the Multi-stage Stochastic Unit Commitment Problem

Due to the uncertainty from both supply and demand sides, power grid operation is generally a stochastic nonlinear problem for regulated electricity market. In this talk, we propose a Multi-stage Stochastic Unit Commitment (MSUC) model to address this problem, where we approximate the nonlinear fuel cost functions by piecewise linear functions. Commitment (MSUC) model to address this problem, where we approximate the nonlinear fuel cost functions by piecewise linear functions. Our mixed-integer formulation of this MDP from partitioned surrogate relaxations of a linear program. We estimate lower bounds and dual upper bounds on the value of storage for a seasonal commodity (natural gas) and a non-seasonal commodity (oil). Our lower bounds essentially match the best known lower bounds for the natural gas storage instances, and are near-optimal for the oil instances, which are new. Our upper bounds either match or improve those available in the literature for natural gas, but are weaker than an exchange-option based upper bound from the literature for the oil instances. We use a tractable version of the problem to highlight the source of the bias in our estimated upper bounds.

Optimization in energy systems

Organizer/Chair Jon Lee, University of Michigan - Invited Session

Mon.2 MA 549

Network operation under failures and losses

Chair Maicon Evaldt, University of Vale do Rio do Sinos (UNISINOS)

Richard Chen, Sandia National Laboratories (with Amy Cohn, Neng Fan, Ali Pinar, Jean-Paul Watson)

Survivability-constrained generation unit commitment with post-contingency corrective recourse

We consider the problem of optimizing generation unit commitment under load uncertainty while ensuring N-k ε survivability crite-
rion. This survivability criterion is a generalization of the well-known N-k criterion, and it requires that at least (1 – ε)k fraction of the total demand is met even after failures of any k system components, for all k = 0, 1, · · ·, kmax. We present a mixed-integer formulation of this problem that takes into account both transmission and generation com-
ponent losses. We propose a cutting plane algorithm that can avoid combinatorial explosion in the number of contingencies that needs to be considered, by seeking vulnerabilities in intermediary solutions and constraining the search space accordingly. Our empirical studies on modified instances from the IEEE test systems showed the effectiveness of our proposed techniques.

Jose Canto dos Santos, Unisinos - Brazil (with Iverson Costa)

New genetic algorithms for contingencies selection in electric power systems

The importance of a reliable supply of electricity to the industrial society is unquestionable. In a control center of an electrical utility, an important computational task is the security analysis. In this task, con-
tingency is the output of operation of an equipment and contingencies selection is the determination of the most severe contingencies for the system. Even with the current technological advances, an analysis in real time of all possible failures in a large grid is impractical. In this work we present a method to perform efficiently the selection of multi-
ple contingencies. The model is posed as a combinatorial optimization problem, and solved by genetic algorithms that make efficient the screenings of the associated non-convex and non-linear search spaces. We developed a robust method, which considers aspects of power flow and voltage that was tested with an IEEE test system and with a large real network, considering double outages of branches. Excellent results with levels of accuracy close to 100%, when compared with an exact method, obtained with scans of reduced portions of search spaces are presented.

Maicon Evaldt, University of Vale do Rio do Sinos (UNISINOS) (with Luís Basilio, Rodrigo de Figueiredo, José Vicente dos Santos, Márcio Rafael Stracke)

Optimal allocation of equipment for monitoring and identification of commercial losses in distribution networks

In 2011, the Brazilian National Agency of Electrical Energy estimated that economic losses due to fraud in distribution networks are around US. 4.6 billion a year in Brazil. This paper focuses on this problem and presents a system for monitoring and identification of commercial losses. The proposed solution is based on low cost power meters installed at strategic points of the network, communicating by wire-
less with a control center. It is implemented based on the network model and data received from power meters. A linear programming method is employed to define the areas of installation that produce the best coverage results, considering distance, number of customers and power demand. Graphic and mathematic tools PSGLS, DMS, GEPath and Google Earth are employed to represent the grid under test. The methodology is applied in a real network of 4 km of exten-
sion. Economic viability and payback analysis for the proposed solution are also presented. The main contribution of this work, for electrical utilities, is a reliable indication of commercial losses in each monitored segment of the distribution network.

Mon.2 MA 415

Iterative solution of PDE constrained optimization and subproblems

Chair Lutz Lehmann, Humboldt-Universität zu Berlin

Pavel Zilchob, University of Edinburgh (with Jack Gould)

Multilevel quasipseparable matrices in PDE-constrained optimization

Discretization of PDE-constrained optimization problems leads to linear systems of saddle-point type. Numerical solution of such systems is often a challenging task due to their large size and poor spectral properties. In this work we propose and develop the novel approach to solving saddle-point systems, which is based on the exploitation of low-rank structure of discretized differential operators and their inverses. This structure is known in the scientific literature as “quasipseparable”. One can think of a usual quasipseparable matrix as of a discrete analog of Green’s function of a one-dimensional differential operator. The remarkable feature of such matrices is that almost all of the algorithms with them have linear complexity. We extend the range of applicability of quasipseparable matrices to problems in higher dimensions. In par-
ticular, we construct a class of preconditioners that can be computed and applied at a linear computational cost. Their use with appropriate Krylov subspace methods leads to algorithms for solving saddle-point systems mentioned above of asymptotically linear complexity.

Gongxiao Kimel, University of Marburg

Covariance matrix computation for parameter estimation in nonlinear models solved by iterative linear algebra methods

For solving parameter estimation (PE) and optimum experimental design (OED) problems we need covariance matrices of the parameter estimates. So far numerical methods for PE and OED in dynamic processes have been based on direct linear algebra methods which involve explicit matrix factorizations. They are originally developed for systems of ordinary differential equations (ODEs) and are not effective for forward model problems than iterative methods. On the other hand for large scale constrained problems with sparse matrices of special structure, e.g., originating from discretization of PDE, direct linear algebra methods are not competitive with iterative linear algebra meth-
ods when used for forward models. Hence, for PDE models, generalizations of iterative linear algebra methods to the computation of covariance ma-
rices are crucial for practical applications. One of the intriguing results is that solving nonlinear constrained least squares problems by Krylov type methods we get as a by-product the covariance matrix and con-
nections.
Robust nonlinear optimization
Chair: Daniel Fleischman, Cornell University

Martin Mevissen, IBM Research Ireland (with Emanuele Ragnoli, Jia Yu)

Distributionally robust optimization for polynomial optimization problems

In many real-world optimization problems, one faces the dual challenge of hard nonlinear functions in both objective and constraints and uncertainty in some of the problem parameters. Often, samples for each uncertain parameter are given, whereas its actual distribution is unknown. We propose a novel approach for constructing distributionally robust counterparts of polynomial optimization problems. The approach aims to use the given samples, not only to approximate the support of the unknown distribution or the first and second order moments, but also its density. We show that optimal robust optimization problems with distributional uncertainty sets defined via density estimates are particular instances of the generalized problem of moments with polynomial data and employ Lasserre’s hierarchy of SDP relaxations to approximate the distributionally robust solutions. As a result of using distributional uncertainty sets, we obtain a less conservative solution than classical robust optimization. We demonstrate the potential of our approach for a range of polynomial optimization problems including linear regression and water network problems.

Hans Pirnay, Process Systems Engineering, RWTH Aachen (with Wolfgang Marquardt)

An algorithm for robust optimization of nonlinear dynamic systems

Nonlinear model predictive control (NMPC) is an attractive control methodology for chemical processes. In NMPC, the control is computed by solving a dynamic optimization problem constrained by a differential-algebraic model of the underlying process. These systems are often subject to unknown disturbances, which, if not taken into account, can lead to deterioration of the control quality, and even instability of the system. This is related to the recently introduced co-sparsity model. We will discuss sparse recovery results and applications to data separation. We illustrate our results with numerical experiments that confirm the theoretical predictions.

Daniel Fleischman, Cornell University (with Mike Todd)

On the trade-off between robustness and value

Linear programming problems may be formulated based on data collected with measurement error, which may make the optimal solution to the problem with the nominal parameters infeasible for the “real parameters”. One way to approach this difficulty is by using robust optimization, where we form an uncertainty set $\Sigma$ around the nominal parameter vector, and a solution has to be feasible for any vector in $\Sigma$. One question that arises is how large the uncertainty set $\Sigma$ should be. The larger it is, the safer we are, but at the same time, our solution becomes worse. We study such questions when the uncertainty set for each constraint is a uniform scale factor times a fixed ellipsoid, and propose a simple, easy to compute approximate solution depending on the scale factor.
developed, defined and solved using multi-extremals and stochastic programming problems.

Ralf Lenz, Zuse Institute Berlin (ZIB) (with Frederik Blank, Guido Dr. Sand, Martin Dr. Weiner)

Optimization of water network operation under uncertainties

Water utilities operate their water networks in a very conservative manner. To be able to satisfy a volatile demand, the current operation procedure focuses on maintaining high water levels in the reservoirs. This results in higher operation costs due to inefficiencies regarding reservoir levels and pump energy consumption. While common approaches available in literature and as software packages use deterministic water demand predictions as a base, the focus of this talk considers uncertainties in the water demands prediction. We present a methodology, which targets on lowering the minimum water storage levels, thereby increasing the release capacity of the reservoirs. This is done by modeling uncertainties in water demand and applying stochastic programming techniques. Controlling the water storage levels allows the decrease of the artificial high bounds. Reducing water storage levels implies a reduction of pumping costs, as pumps do not have to work against these high heads. Finally we present the results by means of a small practical problem.

Adriana Piazza, Universidad Técnica Federico Santa María (with Bernardo PaganoPELLI)

The optimal harvesting problem under price uncertainty

We study the exploitation of a one species forest plantation when timber price is governed by a stochastic process. The work focuses on providing closed expressions for the optimal harvesting policy in terms of the parameters of the price process and the discount factor. We assume that harvest is restricted to mature trees older than a certain age and neglect natural mortality and growth after maturity. We use stochastic dynamic programming techniques to characterize the optimal policy for two important cases: (i) when prices follow a geometric Brownian motion, we completely characterize the optimal policy, (ii) if prices are governed by a mean reverting Ornstein-Uhlenbeck process we provide sufficient conditions, based on explicit expressions for reservation prices, assuring that harvesting everything available is optimal. For the Ornstein-Uhlenbeck process, we propose a policy based on a reservation price that performs well in numerical simulations. In both cases we solve the problem for every initial condition and the best policy is obtained without imposing any ad hoc restrictions such as maximum sustained yield or convergence to a predefined final state.

Mon.2.MA 144

Production, inventory and project management

Chair Takashi Hasuike, Osaka University

Wen-Lung Huang, National Chung Cheng University (with Shi-Fin Chen)

Optimal aggregate production planning with fuzzy data

This paper investigates the optimization problem of aggregate production planning (APP) with fuzzy data. From a comprehensive viewpoint of conserving the fuzziness of input information, this paper proposes a method that can completely describe the membership function of the performance measure. The idea is based on the well-known Zadeh’s extension principle which plays an important role in fuzzy theory. In the proposed solution procedure, a pair of mathematical programs parameterized by possibility level is formulated to calculate the bounds of the optimal performance measure. Then the membership function of the optimal performance measure is constructed by enumerating different values. An example is solved successfully for illustrating the validity of the proposed approach. Solutions obtained from the proposed method contain more information, and can offer more chance to achieve the feasible disaggregate plan. This is helpful to the decision-maker in practical applications.

Ali Randa, Middle East Technical University (with Mustafa Dolgu, Cem Yigiyin, Iliaz Ozen)

Static-dynamic uncertainty strategy for a single-item stochastic inventory control problem

We consider a single-stage inventory system facing non-stationary stochastic demand of the customers in a finite planning horizon. Motivated by practice, the replenishment times need to be determined and from the price vector at the beginning of the horizon while decision on the exact replenishment quantities can be deferred until the replenishment time. This operating scheme is referred as a static-dynamic uncertainty strategy in the literature. We consider dynamic fixed/variable cost of ordering, linear holding costs as well as dynamic penalty costs, and upper/lower limits on order quantities. We prove that the optimal ordering policy is a base stock policy. We develop heuristics for computing the optimal policy parameters for longer planning horizons because the optimal ordering periods and the associated base stock levels need exponentially exhaustive search based on dynamic programming.

We then evaluate the efficiency of our heuristics by numerical examples. We also investigate the NP hardness of the problem considering the computational time required with the size of the problem.

Takashi Hasuike, Osaka University

Risk control approach to critical path method in mathematical programming under uncertainty

This paper considers a risk control approach to find a critical path in the project scheduling network under several uncertainties for each activity duration time. We present a scenario tree and compute the critical path based on the worst case scenario. This scenario tree is used as a basis for a stochastic program. We adopt the approach of stochastic integer programming to deal with the uncertainties. We then evaluate the performance of the proposed model by numerical examples. We also investigate the NP hardness of the problem considering the computational time required with the size of the problem.

Lanah Evers, TNO (with Ana Barros, Kristiaan Glorie, Herman Monseur, Suzanne Ster)

The orienteering problem under uncertainty: Robust optimization and stochastic programming compared

The Orienteering Problem (OP) is a generalization of the well-known traveling salesman problem and has many interesting applications in logistics, tourism and defense. To reflect real-life situations, we focus on an uncertain variant of the OP. Two main approaches that deal with optimization under uncertainty are stochastic programming and robust optimization. We will explore the potentialities and bottlenecks of these two approaches applied to the uncertain OP. We will compare the known robust approach for the uncertain OP (the robust orienteering problem) to the new stochastic programming counterpart (the two-stage orienteering problem). The application of both approaches will be explored in terms of their suitability in practice.

Word Romeijnders, University of Groningen (with Willem Klein Haneveld, Maarten van der Vlerk)

On the performance of a class of convex approximations for integer recourse models

We consider the performance of the convex approximations introduced by Van der Vlerk (2004) for the class of integer recourse problems with totally unimodular (TU) recourse matrices. We show that the main theorem in Van der Vlerk (2004) needs stronger assumptions. As a result, a performance guarantee for the convex approximations is lacking in general. In order to obtain such a performance guarantee, we first analyze the approximations for simple integer recourse models. Using a new approach we improve the existing error bound for these models by a factor of 2. We use insights from this analysis to obtain an error bound for complete integer recourse problems with TU recourse matrices. This error bound ensures that the performance of the approximations is good as long as the dispersion of the random variables in the model is large enough.

Singe Karacayev, Ohio State University (with Dinakar Gade, Sujoyen Sen)

Decomposition algorithms with Gomory cuts for two-stage stochastic integer programs

We consider a class of two-stage stochastic integer programs (SIP) with binary variables in the first stage and general integer variables in the second stage. We develop decomposition algorithms akin to the L-shaped or Benders’ decomposition scheme by utilizing Gomory cuts method to obtain iteratively tighter approximations of the second stage integer programs. We show that the proposed methodology is flexible in that it allows several modes of implementation, all of which lead to finitely convergent algorithms. This development also allows both retrospective as well as Gomory cuts to be included within finitely convergent decomposition algorithms for SIP. Such disparate collections of cuts have proved to be indispensable for the success of branch-and-cut algorithms in deterministic IP, and we are hopeful that the introduction of Gomory cuts within a decomposition framework will be just as valuable for SIP. We will illustrate the use of these cuts both within a pure cutting plane, as well as a branch-and-cut based decomposition algorithm.

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of Burke and Overton, we address the simplest such case, presenting functions are not Clarke regular at such points in matrix space, and the Jordan form of the optimal matrix has four blockscorresponding: the optimal relay node placement problem in wireless sensor networks

The Optimal Delay Constrained Relay Node Placement problem is stated as: given the locations of the root nodes, a set of source nodes and a set of candidate relay nodes and delays provided on possible links (edges), find a minimal set of relay nodes amongst the candidate relay nodes such that there is a path, within the specified delay bound, between each source node and the root node via the selected relay nodes only. In our work, we propose an algorithm which uses the constrained shortest path using Disijkstra and Lagrangian heuristic. The proposed polynomial time algorithm [complexity $O(n + \log(\text{diam}/\text{m})$], where $n$ is the number of candidate relay nodes, $m$ is the number of edges, and $d_{\text{m}}$ is the pre-specified delay bound, provides close to optimal solution (in most of the cases the optimality gap is within 10%). We also compare our algorithm with other existing polynomial time algorithms and demonstrate the efficiency of our algorithm in terms of solution strength as well as the CPU Time.

Andrè Berger, Maastricht University (with James Gross, Tobias Harks, Simon Tenbusch)

Constrained resource assignments: Fast algorithms and applications in wireless networks

Resource assignment problems occur in a vast variety of applications, from scheduling problems over image recognition to communication networks, just to name a few. While in some of the applications an assignment of the resources may be needed only once, often the assignment has to be computed more often for different scenarios. In that case it is essential that the assignments can be computed very fast. Moreover, implementing different assignments in different scenarios may come with a certain cost for the reconfiguration of the system.

In this paper we consider the problem of determining optimal assignments sequentially over a given time horizon, where consecutive assignments are coupled by constraints which control the cost of reconfiguration. We develop fast approximation and online algorithms for this problem with provable approximation guarantees and competitive ratios.

Finally, we establish the applicability of our model and our algorithms in the context of OFDMA wireless networks, finding a significant performance improvement for the total bandwidth of the system using our algorithms.

Variational analysis

Organizer/Chair: Alejandro Jofré, Universidad de Chile - Invited Session

A characterization of the free disposal condition for nonconvex economies on infinite-dimensional commodity spaces

Our aim in this talk is to prove a geometric characterization of the free disposal condition for non convex economies on infinite-dimensional commodity spaces even if the cone and the production set involved in the condition have empty interior such as in $I^V$ with the positive cone $I^V_+$. We then use this characterization to prove existence of Pareto and weak Pareto optimum points. We also explore a notion of approximate-Pareto optimum point, called extremal system. We show that the free disposal property and Pareto alone assures extremality of the production set with respect to some set.

Jean-Marc Bonnisseau, Université Paris I Panthéon-Sorbonne (with Achis Chery)

On the rank of payoff matrices with long-term assets

We consider a stochastic financial exchange economy with a finite date-event tree representing time and uncertainty and a nominal financial structure with possibly long-term assets. We exhibit a sufficient condition under which the return matrix and the full return matrix have the same rank. This generalizes previous results of Angeloni-Cornet and Magill-Quinzii involving only short-term assets. We then derive existence results with assumptions only based on the fundamentals of the economy.

Alejandro Jofré, Universidad de Chile (with Terry Rockafellar, Roger Wets)

The robust stability of every equilibrium in economic models of exchange even under relaxed standard conditions

In an economic model of exchange of goods, the structure can be specified by utility functions. Under utility conditions identified here, every equilibrium will simultaneously be stable with respect to shifts in the associated holdings of the agents and with respect to the Walrasian tatonnement process of price adjustment. This fact, seemingly contrary to widespread belief, is revealed by paying close attention not only to prices but also to the proximal space of initial holdings. The conditions on the concave utility functions are standard for stability investigations, in that they invoke properties coming from second derivatives, but significantly relaxed in not forcing all goods to be held only in positive amounts. Recent advances in variational analysis provide the support needed for working in that context. The stability results also point the way toward further developments in which an equilibrium might evolve in response to exogenous inputs to the agents' holdings, or extractions.
Location and routing problems
Chair Artem Panin, Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences
Tim Nannen, IBM Research – Zurich

Polynomial-time approximation schemes for shortest path with alternatives

Consider the generic situation that we have to select \( k \) alternatives from a given ground set, where each element in the ground set has a random arrival time and cost. Once we have done our selection, we will greedily select the first arriving alternative, and the total cost is the time we had to wait for this alternative plus its random cost. Our motivation to study this problem comes from public transportation, where each element in the ground set might correspond to a bus or train, and the user has some behavior trying to greedily select the first option from a given set of alternatives at each stop. First, we give an \( O(n (\log n + d^3)) \) time algorithm for exponentially distributed arrival times, where \( n \) is the number of stops in the transportation network and \( d \) is the maximal number of buses or trains leaving any stop, making this approach practicable for large networks if \( d \) is relatively small, and second, for uniformly distributed arrival times, we give a PTAS under reasonable assumptions. These results are obtained by combining methods from low-rank quasi-concave optimization with fractional programming. We finally complement them by showing that general distributions are NP-hard.

Adrian Bock, TU Berlin (with Elyot Grant, Jochen Könemann, Laura Santt)

The school bus problem

The School Bus Problem is an NP-hard vehicle routing problem in which the goal is to route buses that transport children to a school such that for each child, the distance travelled on the bus relative to the shortest distance from the child’s home to the school does not exceed a given regret threshold. Subject to this constraint and bus capacity limit, the goal is to minimize the number of buses required. We also consider the variant where we have a fixed number of buses to use and the goal is to minimize the maximum regret. We present logarithmic factor approximation algorithms as well as constant factor approximations for the special case where all children and the school are located on a fixed tree.

Artem Panin, Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences

On approximability some location and pricing problems

We consider location and pricing problems based on different pricing strategies: mill, uniform and discriminatory pricing. We suggest the bilevel mixed integer formulations. We prove that these problems are NP-hard in the strong sense. We present the polynomial time polyapproximate algorithms for these problems.

Mon.3.H 3010

Combinatorial optimization

Approximation & online algorithms

Mon.3.H 3005

Exact and approximation algorithms on graphs

Organizer/Chair Frédéric Meunier, CERMICS, Ecole des Ponts - Invited Session

Denis Connor, Université Paris-Dauphine (with Mouradell Philippa)

Strengthening Lovász bound for coloring with a new graph transformation

Let \( \alpha(G) \) and \( \chi(G) \) denote the stability number and the clique-partition number of \( G \), respectively. Using a new graph transformation, one constructs a new operator \( \Theta \) which associates to any graph parameter \( R \) such that \( \alpha(G) \leq R(G) \leq \chi(G) \) for all graphs \( G \), a graph parameter \( \Phi_R \) such that \( \alpha(G) \leq \Phi_R(G) \leq \chi(G) \) for all graphs \( G \). We prove that \( \Theta(G) \leq \Phi_R(G) \) and that \( \Phi_R(G) \leq \chi(G) \) for all graphs \( G \), where \( \Theta \) is Lovász theta function and \( \Phi_R \) is the fractional clique-partition number. The new operator \( \Theta - \Phi_R \) is unbounded and numerical experiments show that \( \Theta - \Phi_R \) is a significant better lower bound for \( \chi \) than \( \Theta \).

Frédéric Meunier, CERMICS, Ecole des Ponts (with Daniel Chemla, Roberto Wakker Calvo)

A routing problem raised by self-service bike hiring systems

Operating bike-sharing systems raises many problems. One of the most natural is the repositioning of the bikes with the help of one or many trucks. We focus in this talk on the case when there is only one truck. We are given a graph whose vertices model stations. The current repartition of the bikes is known. We wish to move these bikes with the truck in order to reach a target repartition, and we want to realize this task at a minimal cost. The concrete motivation corresponds to the situation encountered at the end of the night, when very few bikes are moving.

A part of the talk will be devoted to special polynomial cases and to approximation algorithms. An efficient method able to solve in practice instances of reasonable size will also be presented: this method combines the exact computation of a natural lower bound and a local search exploiting theoretical properties of the problem. Open questions will also be discussed.

Henning Bruhn, Université Pierre et Marie Curie (with Akira Saito)

Clique or hole in claw-free graphs

Given a claw-free graph and two non-adjacent vertices \( x \) and \( y \) without common neighbours we prove that there exists a hole through \( x \) and \( y \) unless the graph contains the obvious obstruction, namely a clique separating \( x \) from \( y \). As applications we derive an algorithm to verify whether there is a hole through two given vertices as well as an algorithm for the 3-in-a-tree problem in claw-free graphs.
Combinatorial optimization

Mon.3 H 3008

Distances in graphs
Organizers/Chair Christian Wulff-Nilsen, University of Southern Denmark; Glencora Borradaile, Oregon State University - Invited Session

Ruchit Agrawal, University of Illinois at Urbana-Champaign

The space-stretch-time tradeoff in distance oracles

We present distance oracles for weighted undirected graphs that return distances of stretch 2 and less. For the realistic case of sparse graphs, our distance oracle exhibit the three-way tradeoff between space, stretch and query time — a phenomenon that does not occur in dense graphs. In particular, for any positive integer $k$ and for any $1 < n < \infty$, our distance oracle is of size $O(m + n^2 \log n)$ and returns stretch $(1 + 2/(1 + k))$-approximate distances in time $O((n \Delta^2)k)$, where $\Delta = 2m/n$ is the average degree of the graph. The query time can be further reduced to $O((n + \Delta^2)k)$ at the expense of a small additive stretch.

Consider, for example, the realistic case of graphs with $m = O(n)$ edges and fix the query time to be $O(n^{2/3})$. Our distance oracles, then, return stretch 2 distances using space $O(n^{5/3})$ and stretch 5/3 distances using space $O(n^{6/3})$.

Christian Wulff-Nilsen, University of Southern Denmark

Approximate distance oracles with improved preprocessing and query time

Given an undirected graph $G$ with $m$ edges, $n$ vertices, and non-negative edge weights, and given an integer $k \geq 2$, we show that a $(2k - 1)$-approximate distance oracle for $G$ of size $O(kn^{1+k/2})$ and with $O(\log k)$ query time can be constructed in $O(\min\{k\min(km^{1/4},\sqrt{km} + kn^{1/2}\log^2 k)\}$ time for some constant $c$. This simultaneously improves the $O(kn^{1+k/2})$ preprocessing and the $O(k)$ query time of Thorup and Zwick. For any $0 < \epsilon \leq 1$, we also give an oracle of size $O(kn^{1+k/2})$ that answers $(\lceil 2 + \epsilon k \rceil)$-approximate distance queries in $O(1/\epsilon)$ time. At the cost of a $k$-factor in size, this improves the $O(kn^{1+k/2})$ approximation achieved by the constant query time oracle of Mendel and Naor and approaches the best tradeoff between space and stretch, implied by a widely believed girth conjecture of Erdős. We can match the $O(n^{1+k/2})$ size bound of Mendel and Naor for any constant $\epsilon > 0$ and $k = O(\log n / \log \log n)$.

Liam Roditty, Bar-Ilan University (with Mihai Patrascu, Mikkel Thorup)

A survey on distance oracles

Computing distances is one of the most fundamental computational problems. In many applications we are not really interested in all distances, we want the ability to retrieve them quickly. Thorup and Zwick (2005) initiated the theoretical study of data structures capable of representing approximated distances efficiently, in terms of space requirement and query time. Given an $n$-vertex weighted undirected graph with $m$ edges, they show that for any integer $k \geq 1$ it is possible to preprocess the graph in $O(mn^{1/4})$ time and generate a compact data structure of size $O(n^{1+k/2})$. For each pair of vertices, it is then possible to retrieve a stretch $k$ approximate distance in $O(k)$ time. Recently, Patrascu and Roditty (2010) broke the long-standing theoretical status-quo in the field of distance oracles. They obtained, in particular, a distance oracle for unweighted graphs of size $O(n^{7/5})$ that can supply in $O(1)$ time an estimated distance in the range $[d, 2d + 1]$, where $d$ is the actual distance between the two vertices queried.

Liam Roditty, Bar-Ilan University (with Mihai Patrascu, Mikkel Thorup)

Combinatorial optimization

Mon.3 H 3012

Scheduling II
Chair Alexander Tesch, TU Berlin / Zuse Institute Berlin (ZIB)

Matthew Oster, Rutgers University (with Jonathan Eckstein)

A branch and cut algorithm for solving capacitated max $k$-cut with an application in scheduling

We model the scheduling of a multi-track conference as a capacitated version of the combinatorial optimization problem known as Maximum $k$-Cut (MKC). We solve this NP-hard problem to optimality with a branch-and-bound framework equipped with a semidefinite programming relaxation of MKC, enhanced with triangle and clique cuts, as well as new problem-specific cuts (e.g., what we call star-capacity cuts, total-capacity cuts, etc.). We also introduce a heuristic for generating feasible solutions at most tree nodes. Test results for small to moderate-sized conferences will be discussed for both serial and parallel implementations of our algorithm.

Alexander Tesch, TU-Berlin / Zuse Institute Berlin (ZIB)

Optimization of the ISMP 2012 schedule

Your favourite sessions overlap at the same time, the lecture halls are overcrowded or your talk just wasn’t added to a suitable date-slot? Assignment-problems like that may occur in conference planning like this year’s ISMP. To avoid such incidents hopefully we developed a MIP with multi-criteria objective to handle several conflicts like an even offering of different clusters, room-capacity-requirements and prevention of time-depandant-crossovers of popular talks. Therefore we integrated a priority model for the talks to evaluate high visitor rates. We also used an approach to relax the original assignment problem and introduce a heuristic to solve the master problem from the obtained relaxed solution.

Mon.3 H 3013

Constrained clustering
Organizer/Chair Peter Gritzmann, TU München - Invited Session

Steffen Borgwardt, Technische Universität München

On the diameter of partition polytopes and vertex-disjoint cycle cover

We study the combinatorial diameter of partition polytopes, a special class of transportation polytopes. They are associated to partitions of a set $X = \{x_1, \ldots, x_n\}$ into clusters $C_1, \ldots, C_k$ of prescribed sizes $\kappa_1 \geq \cdots \geq \kappa_k$. We derive upper bounds on the diameter in the form of $\kappa_1 + \kappa_2 \cdots + \kappa_k$ and $\lceil \frac{\kappa_1}{2} \rceil$. This is a direct generalization of the diameter-2 result for the Birkhoff polytope. The bounds are established by a constructive, graph-theoretical approach which reveals that special sets of vertices in graphs that decompose into cycles can be covered by a set of vertex-disjoint cycles. Finally, we give exact diameters for partition polytopes with $k = 2$ or $k = 3$ and prove that, for all $k \geq 4$ and all $\kappa_1, \kappa_2, \kappa_3, \kappa_4$, there is a cluster size $\kappa_1, \ldots, \kappa_4$ such that the diameter of the corresponding partition polytope is at least $\lceil \frac{\kappa_1}{2} \rceil$.

Anastasia Shakh tooltip, Technische Universität München (with Andreas Brieden, Peter Gritzmann)

Hardness and non-approximability of constrained clustering

This talk is devoted to constrained clustering, where one would like to divide a given set of objects into groups according to some objective function. The objects are usually represented as points in the Minkowski space, and the objective function is a function of the distances between them. We assume that the points have weights and the total weight of points in a cluster is prescribed to be in a given interval.

The constrained clustering problems are known to be NP-hard. But there is much knowledge about their approximation status. In this talk we present new inapproximability results. In particular, we show that if the dimension is a part of the input, the problems are APX-hard and do not admit a $1.09$-approximation. These results hold even if the points have equal weights and an overlapping of the clusters is allowed. Moreover, when fractional assignments of the points are not permitted, there is no polynomial-time $2\frac{1}{2}$-approximate algorithm, where $\frac{1}{2}$ is the size of an input $x$. The hardness persists even if the points lie on a line.

Andreas Brieden, Universität der Bundeswehr München (with Peter Gritzmann)

Constrained clustering with convex objective function

In this talk the computation of strongly and weakly balanced clusters that are optimal with respect to the sum of pairwise cluster distances is considered. As it turns out, the problem can be reduced to a well studied norm-maximization problem over much lower dimensional polytopes called gravity polytopes. The vertices of these polytopes are closely related to power diagrams which implies nice properties of any optimal clustering and also of approximate solutions. Furthermore this reduction allows for much better approximation results.

Mon.3 H 3031

Equilibria and combinatorial structures
Organizer/Chair Britta Peis, TU Berlin - Invited Session

Walter Kern, Universität Twente

Cooperative games and fractional programming

Straightforward analysis of core-related optimization problems leads to interesting fractional versions of standard (combinatorial) opti-
mization problems and challenging open conjectures. We focus on two particular cases: TSP and bin packing.

Tamás Király, Eötvös University, Budapest (with Attila Barnáth, Máté-Nagy Gergely, Pap Gyula, Pap Júlia) Mulitplier multicommodity flows We investigate the Multiplier Multicommodity Flow Problem, a version of the multicommodity flow problem where players have different subnetworks and commodities over a common node set. Pairs of players have a common edge and one of them agrees to route the flow of the other player (up to a given capacity) between two specified nodes. In return, the other player pays an amount proportional to the flow value. We show that the social optimum can be computed by linear programming. In contrast, an equilibrium solution, although it always exists, often satisfies some additional conditions, i.e., PPAD-hard to find. We analyze hardness in relation to the structure of the digraph formed by the contracts between players, and prove that an equilibrium can be found in polynomial time if every strongly connected component of digraph is a cycle.

Tom McCormick, UBC Sauder School of Business (with Britta Peis) A primal-dual algorithm for weighted abstract cut packing Hoffman and Schwartz developed the Lattice Polyhedron model and proved that it is totally dual integral (TDI), and so has integral optimal solutions. The model generalizes many important combinatorial optimization problems such as polymatroid intersection, cut covering polyhedra, min cost aborences, etc., but has lacked a combinatorial algorithm. The problem can be seen as the blocking dual of Hoffman’s Weighted Abstract Flow (WAF) model, or as an abstraction of ordinary Shortest Path and its cut packing dual, so we call it Weighted Abstract Cut Packing (WACP). We develop the first combinatorial algorithm for WACP, based on the Primal-Dual Algorithm framework. The framework is similar to that used by Martens and McCormick for WAF, in that both algorithms depend on a relaxation by a scalar parameter, and then need to solve an unweighted “restricted” subproblem. The WACP subroutine uses an oracle to solve a restricted abstract cut packing/shortest path subproblem using greedy cut packing, breadth-first search, and an update that achieves complementary slackness. This plus a standard scaling technique yields a polynomial combinatorial algorithm.

Complementarity & variational inequalities

Mon.3 MA 313 Optimization and equilibrium problems II Organizers/Chairs Christian Kanzow, University of Würzburg; Michael Ulbrich, Technische Universität München - Invited Session

Sebastian Albrecht, Technische Universität München (with Stefan Glacauer, Marion Leibold, Michael Ulbrich) Inverse optimal control of human locomotion The general hypothesis of our approach is that human motions are (approximately) optimal for an unknown cost function subject to the dynamics. Considering tasks where participants walk from a start to an end position and avoid collisions with crossing persons, the human dynamics are modeled macroscopically on a point-mass level. The locomotion problem results in an optimal control problem and in case of a crossing interferer an MPC-like approach seems suitable. The task of inverse optimal control is to find the cost function within a given parameterized family such that the solution of the corresponding optimal control problem approximates the recorded human data best. Our solution approach is based on a discretization of the continuous optimal control problem and on a reformulation of the bilevel problem by replacing the discretized optimal control problem by its KKT conditions. The resulting mathematical program with complementarity conditions is solved by using a relaxation scheme and applying an interior-point solver. Numerical results for different navigation problems including hard and soft constraints in the optimal control problem are discussed.

Francisco Facchinei, University of Rome La Sapienza (with Christian Kanzow, Simone Sagratella) Solving quasi-variational inequalities via their KKT conditions We propose to solve a general quasi-variational inequality by using its Karush-Kuhn-Tucker conditions. To this end we use a globally convergent algorithm based on a potential reduction approach. We establish global convergence results for many interesting instances of quasi-variational inequalities, vastly broadening the class of problems that can be solved with theoretical guarantees. Our numerical tests are very promising and show the practical viability of the approach.

Christian Kanzow, University of Würzburg (with Atto Bori) Nash equilibrium multiobjective elliptic control problems The formulation and the semismooth Newton solution of Nash equilibria multiobjective elliptic optimal control problems are presented. Existence and uniqueness of a Nash equilibrium is proved. The corresponding solution is characterized by an optimality system that is approximated by second-order finite differences and solved with a semismooth Newton scheme. It is demonstrated that the numerical solution is second-order accurate and that the semismooth Newton iteration is globally and locally quadratically convergent. Results of numerical experiments confirm the theoretical estimates and show the effectiveness of the proposed computational framework.

Mon.3.H 2034 Semidefinite programming applications Chair Tomohiko Moudafi, Kanazawa University

Sunnyong Kim, Ewha W University (with Masakazu Kojima, Makoto Yamashita) A successive SDP relaxation method for distance geometry problems We present a new method using cliques and successive application of sparse semidefinite programming relaxation SFSDP for determining the structure of the conformation of large molecules from the Protein Data Bank. A subproblem of a clique and its neighboring nodes is initially solved by SFSDP and refined by the gradient method. This subproblem is gradually expanded to the entire problem by fixing the nodes computed with higher accuracy as anchors and successively applying SFSDP. Numerical experiments show that the performance of the proposed algorithm is robust and efficient.

Robert Freund, MIT (with Han Men, Ngoc Cuong Nguyen, Jaime Peraire, Joel Saa-Seoane) Implementation-robust design: Modeling, theory, and application to photonic crystal design with bandgaps We present a new theory for incorporating considerations of implementation into optimization models quite generally. Computed so-
utions of many optimization problems cannot be implemented directly due to (i) the deliberate simplification of the model, and/or (ii) human factors and technological reasons. We propose a new alternative paradigm for treating issues of implementation that we call “implementation robustness.” This paradigm is applied to the setting of optimizing the fabricable design of photonic crystals with large band-gaps. Such designs enable a wide variety of potential interactions with and control of mechanical and electromagnetic waves. We present and use an algorithm based on convex conic optimization to design fabricable two-dimensional photonic crystals with large absolute band gaps. Our modeling methodology yields a series of finite-dimensional eigenvalue optimization problems that are large-scale and non-convex, with low regularity and non-differentiable objective. By restricting to appropriate eigen-subspaces, we reduce the problem to a sequence of small-scale SDPs for which modern SDP solvers are successfully applied.

Tomohiko Mizutani, Kanagawa University (with Makoto Yamashita)

SDP relaxations for the concave cost transportation problem

We present a hierarchy of semidefinite programming (SDP) relaxations for solving the concave cost transportation problem (CCTP) with p suppliers and d demanders. The key idea of the relaxation method is in the change of variables to CCTPs, and due to this, we can construct SDP relaxations whose matrix variables depend on \(\min (p, d)\) at each relaxation step. The sequence of optimal values of SDP relaxations converges to the global minimum of the CCTP as the relaxation order goes to infinity. We show the performance of the relaxation method through numerical experiments.

Houdou Qi, University of Southampton
Computing the nearest Euclidean distance matrix

The Nearest Euclidean distance matrix (NEDM) is a fundamental computational problem in applications such as multidimensional scaling and molecular conformation from nuclear magnetic resonance data in computational chemistry. Especially in the latter application, the problem is often a large scale with the number of atoms ranging from a few hundreds to a few thousands. In this paper, we introduce a semismooth Newton method that solves the dual problem of NEDM. We prove that the method is quadratically convergent. We then present an application of the Newton method to NEDM with \(\ell\)-weights via majorization and an accelerated proximal gradient scheme. We demonstrate the superior performance of the Newton method over existing methods including the latest quadratic semi-definite programming solver. This research also opens a new avenue towards efficient solution methods for the molecular embedding problem.

Bin Wu, National University of Singapore (with Daow Ching, Defeng Sun, Kim-Chuan Toh)
The Moreau-Yosida regularization of the Ky Fan \(\ell_k\)-norm related functions

Matrix optimization problems (MOPs) involving the Ky Fan \(\ell_k\)-norm arise frequently in diverse fields such as matrix norm approximation, graph theory, and so on. In order to apply the proximal algorithms to solve large scale MOPs involving the Ky Fan \(\ell_k\)-norm, we need to understand the first and second order properties of the Moreau-Yosida regularization of the Ky Fan \(\ell_k\)-norm function and the indicator function of its epigraph. As an initial step, we first study the counterparts of the vector \(\ell_k\)-norm related functions, including the metric projectors over the dual vector \(\ell_k\)-norm ball and the vector \(\ell_k\)-norm epigraph, and their directional derivatives and Fréchet differentiability. We then use these results to study the corresponding properties for the Moreau-Yosida regularization of the Ky Fan \(\ell_k\)-norm epigraph indicator function.

Renato Monteiro, Georgia Tech (with Benar Sooto)
An accelerated hybrid proximal extragradient method for convex optimization and its implications to second-order methods

We present an accelerated variant of the hybrid proximal extra-gradient (HPE) method for convex optimization, referred to as the A-HPE method. Non-complexity results are established for the A-HPE method, as well as a special version of it, where a large stepsize condition is imposed. Two specific implementations of the A-HPE method are described in the context of a structured convex optimization problem whose objective function consists of the sum of a smooth convex function and an extended real-valued non-smooth convex function. In the first implementation, a generalization of a variant of Nesterov’s method is obtained for the case where the smooth component of the objective function has Lipschitz continuous gradient. In the second one, an accelerated Newton proximal extra-gradient (A-NPE) method is obtained for the case where the smooth component of the objective function has Lipschitz continuous Hessian. It is shown that the A-NPE method has a \(O(1/k^\gamma)\) convergence rate, which improves upon the \(O(1/k^\gamma)\) convergence rate bound for another accelerated Newton-type method presented by Nesterov.

Walter Farkas, University of Zurich, Department of Banking and Finance (with Pablo Koch-Medina, Carmen-Andrea Mainer)
Acceptability and risk measures: effectiveness, robustness and optimality

We discuss risk measures generated by general acceptance sets allowing for capital injections to be invested in a pre-specified eligible

Roberto Castaño Lazo, Swedish Institute of Computer Science (SICS) (with Mats Carlsson, Frej Dreghammar, Christian Schulte)
Robust code generation using constraint programming

Code generation in a compiler transforms an intermediate program representation into assembly code for a particular architecture. It has tremendous impact on the resulting code: optimal assembly code can be several times more efficient than naive assembly code. However, optimization techniques are typically not used for code generation as they are considered as non-scalable. Instead, traditional optimizing compilers compromise code quality by addressing code generation with heuristic algorithms and phase decomposition.

Two central phases in code generation are instruction scheduling and register allocation which are strongly interdependent. In this presentation, we introduce combinatorial models that naturally capture both phases. These models are easier to analyze and reuse than traditional heuristic algorithms. Then, we present an integrated model that captures the dependencies between phases and hence enables the generation of possibly optimal code. Finally, we illustrate why constraint programming with features such as flexible search and global constraints is a good candidate for robustly solving code generation problems.

Organizer/Chair Narendra Jussien, École des Mines de Nantes - Invited Session

Mon3.H 3029

Constraint programming standard and industrial applications

Organizer/Chair Narendra Jussien, École des Mines de Nantes - Invited Session

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Organizer/Chair Narendra Jussien, École des Mines de Nantes - Invited Session

JSR331 – Standard for Java constraint programming API

JSR331 is a standard for Java Constraint Programming API that was initiated in August-2009 and had been approved by the Java Community Process [www.jcp.org] Executive Committee in February-2012. In this presentation we will describe the major concepts currently covered by the JSR331 and will provide examples of well-known constraint satisfaction and optimization problems implemented using the standard. We will demonstrate how a user may switch between different implementations of the JSR331 without any changes in the problem representation. We will share the JSR331 implementation experience and will discuss the future directions of the standardization process.

Abder Aggoun, KLS OPTIM (with Raphaël Martin, Ahmed Rihai)
Modelling and solving a class of combinatorial problems in supply chain using the Choco constraint programming system

KLS OPTIM is an SME specialist in Logistic Optimization offering a complete suite of solutions. The main problems addressed are packing, pallet loading, optimization in distribution by minimizing the number of pallets, optimization of vehicle loading plans, optimization of assembly, optimization of container assignment in logistics, decision making applications. Most of the problems are known in the literature as bin packing problems. KLS OPTIM developed a set of dedicated business solvers. OptimalPallet is translated by a 3D solver which consists of box packing algorithms of various sizes into available pallets in a way which optimizes the total number of pallets. OptimTruck proposes an optimal loading plan for each vehicle of the fleet company. OptimTrain deals with the operational planning of trains. The objective is to minimize the number of wagons while placing the maximum number of containers. The CP Engine Choco is a key component for modeling and solving packing problems. Rules2CP is a rule-based language compiler developed at INRIA. It makes possible to model packing rules into a concise formalism which is automatically translated into Choco programs.

Organizer/Chair Walter Farkas, University of Zurich, Department of Banking and Finance - Invited Session

Walter Farkas, University of Zurich, Department of Banking and Finance (with Pablo Koch-Medina, Carmen-Andrea Mainer)
Acceptability and risk measures: effectiveness, robustness and optimality

We discuss risk measures generated by general acceptance sets allowing for capital injections to be invested in a pre-specified eligible
asset. Risk measures play a key role when defining required capital for a financial institution. We address the three critical questions: when is required capital a well-defined number for any financial position? When is required capital a continuous function of the financial position? Can the eligible asset be chosen in such a way that for every financial position the corresponding required capital is lower than any other asset had been chosen? Our discussion is not limited to convex or coherent acceptance sets and this generality opens up the field for applications to acceptance sets based both on Value-at-Risk and on Tail Value-at-Risk.

Cosimo-Andreas Munari, ETR Zurich [with Walter Farkas, Pablo Koch-Medina]

Risk measures and capital requirements with multiple eligible assets
We discuss risk measures associated with general acceptance sets for financial positions. Such risk measures represent the cost expressed as the minimum additional capital amount that, when invested in a pre-specified set of eligible assets, makes an unacceptable position acceptable. In contrast to earlier papers where the attention was focused on a single eligible asset, here we allow for multiple eligible assets. We show that the multiple eligible asset case can be reduced to the single asset case, provided that the set of acceptable positions can be properly enlarged. This is the case when it is not possible to make every financial position acceptable by adding a zero-cost portfolio of eligible assets. The results here simplify and generalize results of Frittelli and Scandolo from 2006 and of Artzner, Delbaen and Koch-Medina from 2009. However, in contrast to the literature, we do not impose any coherence or convexity requirements on the acceptance sets.

William Poulton, University of Birmingham

Value-at-Risk
The implementation of appropriate statistical techniques (backtesting) for monitoring conditional VaR models is the mechanism used by financial institutions to determine the severity of the departures of the VaR model from market results and, subsequently the tool used by regulators to determine the penalties imposed for inadequate risk models. So far, however, there has been no attempt to determine the timing of this rejection and with it to obtain some guidance regarding the cause of failure in reporting an appropriate VaR. This paper corrects this by proposing \( U \)-statistic type processes that extend standard CUSUM statistics widely employed for change-point detection. In contrast to CUSUM statistics these new tests are indexed by certain weight functions that enhance the statistical power to detect the timing of the market risk model failure. These tests are robust to estimation risk and can be devised to be very sensitive to detection of market failure produced early in the out-of-sample evaluation period, in which standard methods usually fail due to the absence of data.

Game theory

Mon.3.MA 843
Design of optimal mechanisms
Organizer/Chair Rudolf Müller, Maastricht University - Invited Session

Maria Polukarov, University of Southampton [with Nicholas R. Jennings, Victor Naroditskiy]
Optimal payments in dominant-strategy mechanisms for single-parameter domains
We study dominant-strategy mechanisms in allocation domains where agents have one-dimensional types and quasi-linear utilities. Taking an allocation function as an input, we present an algorithmic technique for finding optimal payments in a class of mechanism design problems, including utilitarian and egalitarian allocation of homogeneous items with nondecreasing marginal costs. Our results link optimality of payment functions to a geometric condition involving triangulations of polytopes. When this condition is satisfied, we constructively show the existence of an optimal payment function that is piecewise linear in agent types.

Mingyu Suo, University of Liverpool [with Vincent Conitzer, Amy Greenwald, Nicholas Jennings, Victor Naroditskiy]
Computationally feasible automated mechanism design: General approach and a case study on budget-balanced and nearly efficient randomized mechanisms
In automated mechanism design, the idea is to computationally search through the space of feasible mechanisms, rather than to design them analytically by hand. Unfortunately, the most straightforward approach to automated mechanism design does not scale to large instances, because it requires searching over a very large space of possible functions. We describe an approach to automated mechanism design that is computationally feasible. Instead of optimizing over all feasible mechanisms, we carefully choose a parameterized subfamily of mechanisms. Then we optimize over mechanisms within this family, and analyze whether and to what extent the resulting mechanism is suboptimal outside the subfamily.

We demonstrate the usefulness of our approach with a case study on budget-balanced and nearly efficient mechanisms. Faltings [05] proposed the idea of excluding one agent uniformly at random from the decision and making him the residual claimant. We show that Faltings’ mechanism can be generalized to a parameterized subclass of mechanisms. In two example scenarios, by optimizing within the above subfamily we are able to find mechanisms that are budget-balanced and nearly efficient.

Konrad Miesenbrod, University of Zurich [with Yoon-Koo Cha, Jinwoo Kim]
Generalized reduced-form auctions: A network-flow approach
We develop a network-flow approach for characterizing interim-allocation rules that can be implemented by ex post allocations. The network method can be used to characterize feasible interim allocations in general multi-unit auctions where agents face hierarchical capacity constraints. We apply the method to solve for an optimal multi-object auction mechanism when bidders are constrained in their capacities and budgets.
Dieter Weninger, FAU-Erlangen (with Gerald Gamrath, Thorsten Koch, Alexander Martin, Matthias Miltenberger)

SCIP preprocessing for MILPs arising in supply chain management

Supply Chain Management (SCM) deals with the combination of procurement, production, storage, transport and delivery of commodities. Problems of this kind occur in different industry branches. Since the integrated planning of these processes contain a high potential for optimization, it is of great importance for the efficiency of a related company. The method of choice to find optimal solutions for SCM problems is mixed integer programming. However, there are big challenges to overcome due to the very detailed and therefore large models. One way to reduce the large models is to perform an extensive preprocessing. We show preprocessing algorithms which decisively help reducing and solving the problems. The implementations of the preprocessing algorithms are done within the non-commercial mixed integer programming solver SCIP.

Philip Christoph, SAS Institute Inc. (with Amar Narisetty, Yan Xu)

Research topics of the SAS MILP solver development team

This talk will give an overview of current research interests of the SAS MILP solver development team. The focus will be on the use and customization of simplex algorithms inside MILP solvers. Other topics will be branching, cutting planes and primal heuristics.

Gerald Gamrath, Zuse Institute Berlin

The SCIP Optimization Suite 3.0 - It’s all in the bag!

We present the latest release of the SCIP Optimization Suite, a tool for modeling and solving optimization problems. It consists of the modeling language ZIMPL, the LP solver SoPlex, and the constraint integer programming framework SCIP. Furthermore, SCIP is able to solve a much wider range of optimization problems including pseudo-boolean optimization, scheduling, and non-convex MINLP. Its plugin-based design allows to extend the framework to solve even more different kinds of problems and to customize the optimization process. We report on current developments and new features of the SCIP Optimization Suite 3.0 release, including enhanced MINLP support, a framework to parallelize SCIP and the new exact solving capabilities for MILPs.

Stefan Schneider, FAU Erlangen-Nürnberg (with Alexander Martin)

Optimizing Life cycle costs for buildings

Life cycle oriented optimization of infrastructures is concerned with the automatic planning of buildings, plants etc. from the first line of drawing up to the final polishing of the windows. Turning this into a mathematical model results in a very complex problem. There are a vast number of influencing factors, which have to be considered and which have a strong impact on the final solutions. In the case of our application scenario, namely public buildings, this leads to huge mixed-integer linear programs. To develop solution methods for the application we decompose the problem into subproblems, which stay hard to solve individually. The preprocessed scenario contains the full allocation problem and take a closer look at different aspects like the planning of escape routes which we formulate as a graph theoretical problem and analyze its complexity. Moreover we present a mathematical model and solution methods for the complete room allocation problem.

Ali Fattahi, KOC University (with Erfan Sadeqi Azer, Hossein Shams Shemirani, Metin Turkay)

A novel integer programming formulation for U-shaped line balancing problems type-1

U-shaped production lines are regarded as an efficient configuration in Just-in-Time manufacturing and attract the attention from academia and industry. Balancing the workload in these lines is an unsolved problem and significant research has been done within the past two decades. So far, only a few optimization models have been developed and researchers and practitioners use these models to solve different variants of the balancing problem in U-shaped production lines. We present a novel integer programming formulation for U-shaped line balancing problems (type-1), where the cycle time is given and the aim is to minimize number of utilized stations. This new formulation has been tested on all of the benchmarking problems in literature and a paired t-test is also applied to provide a comparative analysis with the existing models. The analysis of the results shows that this novel integer programming formulation leads to significant improvement over the other models.

Rui Oliveira, ISTAD (with Ana Catana)

Models for school networks planning

School network planning can be formulated as a multi-facility location problem, and these formulations are reviewed in this paper. In practice, however, decisions on where to build new schools or to close/convert existing education facilities have to take into account numerous conflicting factors of different nature [social, political, pedagogical, financial, etc.] and various stakeholders with contrasting value points and objectives. This leads to a fluid decision context for which such a normative approach has been recognized to have limitations to effective decision support. An alternative framework that nicely fits the ill-structured nature of the decision context, adopting a more descriptive/prescriptive approach, was developed for school network planning at municipal level in Portugal and is reported in this paper. This includes education demand forecasting based on demographic projection models, coupled with strategic options derived from urban and regional plans, leading to geographic-based education services demand-supply balancing analysis.

Mon.3 H 1508

MILP software I

Organizer/Chair Thorsten Koch, ZIB - Invited Session

Mon.3 H 1513

MILP formulations II

Chair Rui Oliveira, ISTAD

Stefan Schneider, FAU Erlangen-Nürnberg (with Alexander Martin)

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Linear optimization
Chair Angelo Sifalas, University of Macedonia

Sergei Chuabanov, University of Siegen
An improved polynomial relaxation-type algorithm for linear programming

To find a solution of a system of linear inequalities, the classical relaxation method projects the current point, at every iteration, onto a hyperplane defined by a violated constraint. The constructed sequence converges to a feasible solution. It is well known that the method is not polynomial. One of the reasons for this is that each iteration considers only one violated constraint among the original constraints of the system.Unlike the relaxation method, each iteration of our algorithm considers an appropriate nonnegative linear combination of the inequalities. The algorithm runs in $O(n^2 \min(n, m))$ time where $n$ is the number of variables and $m$ is the minimum binary size of a feasible solution. In particular, the algorithm either finds a nonnegative solution of a system of linear equations or proves that there are no $0,1$-solutions in $O(n^3)$ time. This theoretical estimate is less by the factor of $n^2$ than that of our previous algorithm.

Roland Wunderling, IBM

The kernel simplex method

The Simplex Method has stopped seeing major computational advances for years, yet it remains the most widely used algorithm for solving LPs, in particular the dual Simplex algorithm is used for MIP because of its warm-start capabilities. State-of-the-art MIP solvers use branch-and-cut algorithms, but the standard dual simplex algorithm only addresses the branching aspect of it. When cuts are added usually a fresh factorization of the basis matrix is needed which greatly reduces true warm-start support. Using a row basis or dualization can mitigate the issue, but this is only efficient for models with more rows than columns.

In this talk we introduce a new simplex algorithm, the kernel simplex method (KSM), which defines a kernel instead of a basis as the central data structure. KSM, provides full warm-start functionality for row and column additions or deletions. We describe the algorithm and differentiate its computational properties against the traditional simplex method. Further, we show how KSM unifies primal and dual algorithms into one symmetric algorithm, thus matching duality theory much better than the traditional methods.

Angelo Sifalas, University of Macedonia (with Nikolaos Samaras)

Exterior point simplex-type algorithms for linear and network optimization problems

The linear problem is one of the most useful and well-studied optimization problems, which is widely used in several areas of science. Lots of real world problems can be formulated as linear programs. The popularity of linear programming can be attributed to many factors such as the ability to model large problems, and the ability to solve large problems in a reasonable amount of time. Many algorithms have been invented for the solution of a linear program. The majority of these algorithms belong to two main categories: (i) Simplex-type or pivoting algorithms and (ii) interior-point methods (IPMs). All the algorithms presented in this paper belong to the first category, except one that belongs to both categories. The first exterior point simplex type algorithm (EPSA) was originally developed by Paparrizos for the assignment problem. EPSA constructs two paths to the optimal solution. One path consists of basic but not feasible solutions, while the second path is feasible. The key idea behind EPSA is that making steps in directions that are linear combinations of attractive descent direction can lead to faster convergence than that achieved by classic simplex type algorithms. and some results from our tests. Our model differs from others used in the brachytherapy field by more directly including dosimetric indices.

Rasmus Bokrantz, KTH Royal Institute of Technology / RaySearch Laboratories
Multi-criteria optimization for volumetric-modulated arc therapy by convex decompositions

Volumetric-modulated arc therapy (VMAT) is a technique for rotational radiation therapy that has gained widespread clinical use due to its ability of improving delivery efficiency without compromising treatment quality. Treatment planning for VMAT is a challenging multi-criteria decision problem due to a high-dimensional trade-off between tumor coverage and sparing of healthy structures in the vicinity of the target volume. Here, an approach to multi-criteria VMAT optimization is presented that relies on two convex decompositions of an initially nonconvex problem formulation. An infeasible relaxation with the elements of the energy fluence vector as variables is first used to define a global trade-off between conflicting objectives. The solution to the relaxed problem is subsequently converted into a deliverable VMAT plan. A feasible restriction with segment weights as variables is finally used to evaluate deliverable solutions in its neighborhood. The practical value of the presented method is discussed in view of comparative results with a commercially available single-objective method.

Laurene Gillmann, Münster - University of Applied Sciences (with Helmut Maurer)
Combination therapy considered as a multiple delayed optimal control problem

We consider optimal control problems with multiple time delays in state and control and present an enhanced form of Pontryagin’s minimum principle as well as a numerical discretization method. Let $x(t) \in \mathbb{R}^n$ denote the state and $u(t) \in \mathbb{R}^m$ denote the control of a system at time $t$. Time delays for $x$ and $u$ are given by a vector $(r_1, \ldots, r_q)$. The problem for two delays has been investigated earlier in [1]. The problem considered in this talk is much more general and presents a generalization in form of necessary conditions for the problem with multiple delays. We finally optimize a combination therapy by a model of the innate immune response with a delayed antibody production and a retarded drug action.

Joshua Magbagbeola, Joseph Aro Babalola University, Kogi-Araji (with Samuel Awonijii, Eunice Magbagbeola)
Operations research approach to enhancing enterprise through alliances: A case study of Mowe Town, Ogun State, Nigeria

Small firm sub-sector has the potential to reduce poverty and unemployment in Nigeria. However, in the face of global competition, market uncertainties and rapid technological changes, it is necessary to assist firms, particularly small enterprise to access information that can build their business competencies to create income and employment generation opportunities. Through in-depth recourse to existing theories and empirical literature on factors that explain firm growth, the study identifies business competencies, derived through inter-firm alliances, as determinants of enterprise performance. The study establishes that the size of the firm influences the choice of business association among manufacturing enterprises in Nigeria. It is further noted that the decision to join a business association is positively related to the ages of the entrepreneur and enterprise. The study recommends incentive mechanisms that encourage business associations among small enterprise.

Hidetoshi Miura, Nanzan University (with Toshio Nemoto)
Comparative study of reduced total travel times in check-pattern and hierarchical express systems

Express-service stop pattern on railway is an important factor to shorten travel time for long-distance users. However, it is difficult for trunk line to run enough expresses during rush hours by reason of track capacity for safety. Lack of track capacity gives trains few occasions to pass others. This study calculates reduced total travel time by existing theories and empirical literature on factors that explain firm growth, the study identifies business competencies, derived through inter-firm alliances, as determinants of enterprise performance. The study establishes that the size of the firm influences the choice of business association among manufacturing enterprises in Nigeria. It is further noted that the decision to join a business association is positively related to the ages of the entrepreneur and enterprise. The study recommends incentive mechanisms that encourage business associations among small enterprise.
scribe the optimal limited-service stop patterns and the optimal num-
ber of stops of three systems.

Pasha Pellegrini, IFSTTAR - Univ. Lille Nord de France (with Gregory Mariére, Joaquin Rodriguez)

Exact models for the real time railway traffic management problem: tackling perturbed traffic considering real junction details

A railway traffic management problem appear when trains are de-
layed: the originally planned routing and scheduling become infeasible. This problem must be solved in real time (i.e., in a short time) by finding a new schedule for re-planning the remaining trains on the network. Solution cost is assessed in terms of either punctuality or fluidification. In the literature, this problem, known as "real time railway traffic man-
agement problem", is typically tackled with heuristic algorithms. Opti-
mal approaches appear only when few network details are considered. We propose two mixed-integer linear programming models which con-
sider real railway junctions details. They differ in the computation of so-
lution cost. We test the two models on real instances representing three complex junctions: Pierrefitte-Gonesse (France), Lille Flandres station (France), and Utrecht Den Bosh line (Netherlands). In all cases, compu-
tation time is very short. Interestingly, different junctions are differently complex for the two models. We will devote further research to the ex-
planation of these differences, and to the identification of effective valid ineq-
ualities.

Kwong Meng Teo, National University of Singapore

Network problems

Thomas Kalinowski, Universität Rostock (with Natalia Boland, Ramin Wottrich, Lanbo Zhang)

Scheduling arc outages in networks to maximize total flow over time

We present a problem arising in the annual maintenance planning
process for the Hunter Valley Coal Chain which has the potential to be
applied in a variety of transportation network contexts. The problem consists of sending flow from a source s to a sink t in each time period
1, 2, ..., T. An additional difficulty comes from the fact that some arcs in
the network have associated jobs that have to be scheduled and during processing of a job the corresponding arc is not available. In the talk we
discuss some complexity results (NP-hardness of the single node case, efficiently solvable special cases), a MIP model and some computational
results on real world data sets.

Daniel Ferber, Petrobraz – Petróleo Brasileiro S/A

Incorporating temporal in-transit inventory into linear programming network flow models

We consider a network flow model to support planning the pipeline
supply chain of oil refined commodities. The traditional supply chain
models discussed in literature do not regard temporal aspects of in-
transit inventory. Hence, they may underestimate the utilization of
pipelines and risk proposing impracticable solutions. We take into ac-
count a multi-product, multi-period network with production, demand
and storage on facilities, through a pure linear programming model.
For a better approximation of pipeline utilization rates, we incorporate
temporal aspects of transit in-transit inventory on their path between fac-
ties. By allowing to integral variables, we extend the model to estimate on each time slot dynamic flow capacities which depend on the current in-
transit inventory configuration. Further, pipelines are allowed to reverse their flow. A result for a real world industry scenario is compared in order to attest benefits of our model.

Kwong Meng Teo, National University of Singapore (with Trung Hieu Tran)

Solving network flow problems with general non-separable convex costs using a two-phase gradient projection algorithm

Network flow problems are often encountered in practical applica-
tions such as multi-commodity flows, traffic assignment and telecom-
nunications problems. Simpler problems such as those with quadratic
costs are often solved using general solvers such as CPLEX, while more
realistic but difficult ones with generalized non-separable convex costs
would require specialized network optimization algorithms where speed of convergence and problem size becomes challenging issues in prac-
tice. We propose a two-phase gradient projection algorithm to bridge this gap. The proposed algorithm is designed to address the weakness of
traditional gradient projection approaches reported in the lit-
erature, including choice of step size, speed of convergence and ease of
implementation. Furthermore, the algorithm has been implemented as a toolbox riding on general solvers such as CPLEX for easy adop-
tion and to handle industrial size problems. We evaluate and compare
the performance of the proposed algorithm with other approaches un-
der common network flow scenarios such as (i) integral or continuous
flows and (ii) explicit or non-explicit objective.

Kwong Meng Teo, National University of Singapore (with Trung Hieu Tran)

On the efficient construction of disjunctive cutting planes for mixed-integer quadrication optimization problems

We present an algorithmic procedure for efficiently constructing
disjunctive cutting planes for non-basic solutions or proving their non-
existence. The method extends an algorithm proposed by Perregaard
and Balas, such that it is applicable for non-basic solutions, e.g., ob-
tained from the continuous relaxation of a mixed-integer quadricap-
gram.

We also present preliminary numerical results for test problems,
that arise within MIQP-based solution methods for mixed-integer
nonlinear optimization problems, such as MISQP proposed by Exler,
Lehmann and Schittkowski. The results indicate the potential of the pro-
posed cut generator, but they also stress the necessity of an advanced
cut management.

Dennis Michaels, ETH Zurich (with Martine Balleracq, Robert Weismantel)

The convex hull of vectors of functions

A challenging task in global optimization is to construct tight convex relaxations that provide reasonably globally valid bounds on a mixed-integer nonlinear program (MINLP). For a general MINLP, convex relaxations are usually obtained by replacing each non-linearity by convex under- and concave overestimators. The mathematical object studied to derive such estimators is given by the convex hull of the graph of the function over the relevant domain. To derive improved relaxations, we consider a finite set of given functions as a vector-valued function and study the convex hull of its graph. We establish a link between such a convex hull object and the convex hulls of the graphs of a certain family of real-valued functions. This link can be used to define improved relax-
ations. We especially focus on small sets of well-structured univariate functions. Numerical examples are presented demonstrating the im-
pact of this concept.

Ambros Gleixner, Zuse Institute Berlin (ZIB) (with Timo Berthold, Stefan Weltge)

Rapid optimality-based bound tightening

Optimality-based bound tightening (OBBT) is a well-known, simple,
yet computationally expensive procedure to reduce variable domains of
mixed-integer nonlinear programs (MINLPs) by solving a series of aux-
iliary linear programs (LPs). We present techniques to reduce the com-
pilation effort incurred by OBBT and exploit dual information from the
LP solutions during a subsequent branch-and-bound solution process.
We evaluate the performance impact of these techniques using an im-
plementation within the MINLP solver SCIP.

Fernando Flores-Tlacuahuac, Universidad Iberoamericana (with Morales Pilán, Zavala Vélez)

An utopia-tracking approach to multobjective predictive control

We propose a multiobjective strategy for model predictive control
(MPC) that we term utopia-tracking MPC. The controller minimizes, in
some norm, the distance of its cost vector to that of the unreachable
steady-state utopia point. Stability is ensured by using a terminal con-
straint to a selected point along the steady-state Pareto front. One of the
key advantages of this approach is that multiple objectives can be han-
dled systematically without having to compute the entire Pareto front or
selecting weights. In addition, general cost functions (i.e., economic,
regularization) can be used.

Wlodzimierz Ogryczak, Warsaw University of Technology

Fair multiojective optimization: Models and techniques

In systems which serve many users there is a need to respect some
fairness rules while looking for the overall efficiency, e.g., in network
design one needs to allocate bandwidth to flows efficiently and fairly,
in location analysis of public services the clients of a system are en-
tied to fair treatment according to community regulations. This leads to
criteria of fairness expressed by the equitable multiple objective op-
timization. The latter is formalized with the model of multiple objective
optimization of fair averages and the Lorenz order enhancing the Pareto
dominance concept. Due to the duality theory the order is also equiv-
alent to the second order stochastic dominance representing multiple
objective optimization of the mean shortages (mean below-target devi-
ations). Despite equivalent, two orders lead to different computational
models though both based on auxiliary linear inequalities and criteria.
Moreover, the basic computational models can be differently enhanced. We analyze advantages of various computational models when applied to linear programming and mixed integer programming problems of fair optimization.

Kai-Simon Gertzmann, TU Berlin (with Christina Büsing, Janek Matuschke, Sebastian Stiller)

**Compromise solutions**

The most common concept in multicriteria optimization is Pareto optimality. However, in general the number of Pareto optimal solutions is exponential. To choose a single, well-balanced Pareto optimal solution, Yu (1973) proposed compromise solutions. A compromise solution is a feasible solution closest to the ideal point. The ideal point is the component-wise optimum over all feasible solutions in objective space. Compromise solutions are always Pareto optimal. Using different weighted norms, the compromise solution can attain any point in the Pareto set. The concept of compromise solutions (and the slightly more general reference point methods) are widely used in state-of-the-art software tools. Still, there are very few theoretical results backing up these methods.

We establish a strong connection between approximating the Pareto set and approximating compromise solutions. In particular, we show that an approximate Pareto set always contains an approximate compromise solution. The converse is also true if we allow to substitute the ideal point by a sub-ideal reference point. Compromise solutions thus neatly fit with the concept of Pareto optimality.

**Mon.3.H 0107**

Methods for nonlinear optimization III
Chair Masoud Ahookhosh, University of Vienna

Yuan Shen, Nankai University (with Bingzhong He)

**New augmented lagrangian-based proximal point algorithms for convex optimization with equality constraint**

The augmented Lagrangian method (ALM) is a classic and efficient method for solving constrained optimization problem. It decomposes the original problem into a series of easy-to-solve subproblems to approach the solution of the original problem. However, its efficiency is still, to large extent, dependent on how efficient the subproblem can be solved. In general, the accurate solution of the subproblem can be expensive to compute, hence, it is more practical to relax the subproblem to make it easy to solve. When the objective has some favorable structure, the relaxed subproblem can be simple enough to have a closed form solution. Therefore, the resulting algorithm is efficient and practical for the low cost in each iteration. However, compared with the classic ALM, this algorithm can suffer from slow convergence rate. Based on the same relaxed subproblem, we propose several new methods with faster convergence rate. We also report their numerical results in comparison to some state-of-the-art algorithms to demonstrate their efficiency.

Mehdiddin Al-Baali, Sultan Qaboos University (with Mohammed Al-Lawatia)

**Hybrid damped-BFGS/Gauss-Newton methods for nonlinear least-squares**

The damped-technique in the modified BFGS method of Powell (1978) for constrained optimization will be extended to the hybrid BFGS/Gauss-Newton methods for unconstrained nonlinear least squares. It will be shown that this extension maintains the useful convergence properties of the hybrid methods and improves their performance substantially in certain cases. The analysis is based on a recent proposal for using the damped-technique when applied to the Broyden family of methods for unconstrained optimization, which enforces safety the positive definiteness property of Hessian approximations.

Masoud Ahookhosh, University of Vienna (with Nordinpour Hadi, Amin Keyvan)

**An improved nonmonotone technique for both line search and trust-region frameworks**

The nonmonotone iterative approaches are efficient techniques for solving optimization problems avoiding a monotone decrease in the sequence of function values. It has been believed that the nonmonotone strategies not only can enhance the likelihood of finding the global optimum but also can improve the numerical performance of approaches. Furthermore, the traditional nonmonotone technique contains some disadvantages encountering with some practical problems. To overcome these drawbacks, some different nonmonotone strategies have proposed with more encouraging results. This study concerns with exploiting the nonmonotone strategies in advance of the traditional nonmonotone technique and introduce a variant version which mostly avoids the drawbacks of original one. Then we incorporate it into both line search and trust-region frameworks to construct more reliable approaches. The global convergence to first-order and second-order stationary points are investigated under some classical assumptions. Preliminary numerical experiments indicate the efficiency and the robustness of the proposed approaches for solving unconstrained nonlinear optimization.

Yuan Shen, Nankai University (with Bingzhong He)

**Infeasibility detection in nonlinear optimization**

Contemporary numerical methods for nonlinear optimization possess strong global and fast local convergence guarantees for feasible problems under common assumptions. They also often provide guarantees for (eventually) detecting if a problem is infeasible, though in such cases there are typically no guarantees of fast local convergence. This is a critical deficiency as the optimal solution to the optimization system, one often finds that nonlinear optimization methods can fail or stall due to minor constraint incompatibilities. This may suggest that the problem is infeasible, but without an infeasibility certificate, no useful result is provided to the user. We present a sequential quadratic optimization (SQO) method that possesses strong global and fast local convergence guarantees for both feasible and infeasible problem instances. Theoretical results are presented along with numerical results indicating the practical advantages of our approach.

Figen Oztoprak, Northwestern University

**Two-phase active set methods with applications to inverse covariance estimation**

We present a semi-smooth Newton framework that gives rise to a family of second order methods for structured convex optimization. The generality of our approach allows us to analyze their convergence properties for a unified setting, and to contrast their algorithmic components. These methods are well suited for a variety of machine learning applications, and in this talk we give particular attention to an inverse covariance matrix estimation problem arising in speech recognition. We compare our method to state-of-the-art techniques, both in terms of computational efficiency and theoretical properties.

Frank E. Curtis, Lehigh University (with James Burke, Hao Wang)

**Mon.3.H 0110**

Nonlinear optimization III
Organizers/Chairs Frank E. Curtis, Lehigh University, Daniel Robinson, Johns Hopkins University - Invited Session

Mikhail Solodov, IMPA (with Damian Fernández)

**Convergence properties of augmented Lagrangian methods under the second-order sufficient optimality condition**

We establish local convergence and rate of convergence of the classical augmented Lagrangian algorithm under the sole assumption that the dual starting point is close to a multiplier satisfying the second-order sufficient optimality condition (SOSC). No constraint qualifications of any kind are needed. Previous literature on the subject required, in addition, the linear independence constraint qualification and either strict complementarity or a stronger version of SOSC. Using only SOSC, for penalty parameters large enough we prove primal-dual $Q$-linear convergence rate, which becomes superlinear if the parameters are allowed to go to infinity. Both exact and inexact solutions of subproblems are considered. In the exact case, we further show that the primal convergence rate is of the same $Q$-order as the primal-dual rate. Previous assertions for the primal sequence all had to do with the weaker $R$-rate of convergence and required the stronger assumptions cited above. Finally, we show that under our assumptions some of the popular rules of controlling the penalty parameters ensures they stay bounded.

Frank E. Curtis, Lehigh University (with James Burke, Hao Wang)

**Unconstrained optimization I**
Chair Rousmmel Marcia, University of California, Merced

Saman Babaie-Kafaki, Semnan University

**A modification on the Hager-Zhang conjugate gradient method**

Conjugate gradient (CG) methods comprise a class of unconstrained optimization algorithms characterized by low memory requirements and strong global convergence properties which made them popular for engineers and mathematicians engaged in solving large-scale unconstrained optimization problems. One of the efficient CG methods has been proposed by Hager and Zhang. Here, a singular value study is made in order to find lower and upper bounds for the condition number of the matrix which generates the search directions of the Hager-Zhang method. Then, based on the insight gained by the analysis, a modified version of the Hager-Zhang method is proposed using an adaptive switch form the Hager-Zhang method to the Hestenes-Stiefel method, when the determined condition number is large. It can be shown that if the line search fulfills the strong Wolfe conditions, then the
proposed method is globally convergent for uniformly convex objective functions. Numerical experiments on a set of unconstrained optimization test problems of the CUTEr collection demonstrate the efficiency of the suggested adaptive CG method in the sense of the performance profile introduced by Dolan and Moré.

Tove Odland, Royal Institute of Technology (with Anders Forsgren)

On the relationship between quasi-Newton methods and the conjugate

It is well known that a Quasi-Newton method using any well-defined update from the Broyden class of updates and the conjugate gradient method produce the same iterates on a quadratic objective function with positive-definite Hessian. In this case both methods produce conjugate directions with respect to the Hessian. This equivalence does not hold for any quasi-Newton method. We discuss more precisely what the updates in a Quasi-Newton method need satisfy to give rise to this behavior.

Ronanm Marcia, University of California, Merced (with Jennifer Erway)

Limited-memory BFGS with diagonal updates

We investigate a formula to solve limited-memory BFGS quasi-Newton Hessian systems with full-rank diagonal updates. Under some conditions, the system can be solved via a recursion that uses only vector inner products. This approach has broad applications in trust region and barrier methods.

Organizer/Chair: Gabriel Peyré, CNRS - Limited Session

Gabriel Peyré, CNRS (with Jalal Fadili, Hugo Raguet)

A review of proximal splitting methods with a new one

In the first part of this talk, I will review proximal splitting methods for the resolution of large scale non-smooth convex problems (see for instance [1, 2]). I will show how each algorithm is able to take advantage of the structure of typical imaging problems. In the second part of this talk I will present the Generalized Forward Backward (GFB) splitting method [3] that is tailored for the minimization of the sum of a smooth function and an arbitrary number of “simple” functions (for which the proximal operator can be computed in closed form). I will show on several imaging applications the advantage of our approach over state of the art proximal splitting schemes. Demos and codes for these proximal splitting schemes can be obtained by visiting www.numerical-tours.com.


Thomas Pock, Graz University of Technology (with Karl Kunisch)

On parameter learning in variational models

In this work we consider the problem of parameter learning for variational image denoising models. We formulate the learning problem as a bilevel optimization problem, where the lower level problem is given by the variational model and the higher level problem is given by a loss function that penalizes errors between the solution of the lower level problem and the ground truth data. We consider a class of image denoising models incorporating a sum of analysis based priors over a fixed set of linear operators. We devise semi-smooth Newton methods to solve the resulting non-smooth bilevel optimization problems and show that the optimized image denoising models can achieve state-of-the-art performance.

Volkkan Cevher, École Polytechnique Fédérale de Lausanne (with Anastasios Kyrillidis)

Nonconvex models with exact and approximate projections for constrained linear inverse problems

Many natural and man-made signals exhibit a few degrees of freedom relative to their dimension due to natural parameterizations or constraints. The inherent low-dimensional structure of such signals are mathematically modeled via combinatorial and geometric concepts, such as sparsity, unions-of-subspaces, or spectral sets, and are now revolutionizing the way we address linear inverse problems from incomplete data. In this talk, we describe a set of low-dimensional, non-convex models for constrained linear inverse problems that feature exact and epsilon-approximate projections in polynomial time. We pay particular attention to structured sparsity models based on matroids, multi-knapsack, and clustering as well as spectrally constrained models. We describe a hybrid optimization framework which explicitly leverages these non-convex models along with additional convex constraints to improve recovery performance. We then analyze the convergence and approximation guarantees of our framework based on restrictions on the linear operator in conjunction with several well-known acceleration techniques, such as step-size selection, memory, splitting, and block coordinate descent.

Mon.3 MA 547
Optimization in energy systems

Optimization models for renewables integration

Organizers/Chairs: Rodrigo Moreno, Imperial College London; Lucio Barros, PSR - Invited Session

Ezequ Sauma, Pontificia Universidad Catolica de Chile (with Javier Contreras, David Pozo)

Transmission planning and generation response for integrating renewables

Using a Mixed Integer Linear Programming (MILP) model, we analyze the transmission planning decisions while characterizing the competitive interaction among generation firms whose decisions in generation capacity investments and production are affected by both the transmission investments and the market operation. We illustrate the model by means of the implementation of a stylized version of the transmission planning in the main Chilean network.

Alvaro Vega, PUC-Rio (with Bianca Amaral, Bruno Fársanes, Lucas Freire, Deibers Lima, Alexandre Street)

Back up wind power firm contract sales on hydro generation with stochastic optimization: A Brazilian case study

In this case study, a wind power producer (WPP) backs up a contract sell in the forward market on a small run-of-river hydro (SH) Genco production. The model determines the amount of SH participation and the WPP willingness to contract. To achieve this goal, a joint wind-into-hydro statistical model is used to simulate renewable resources consistently with a set of simulated scenarios of short-term prices provided by an independent dispatch simulation tool. Such methodology is able to couple both sets of independently simulated scenarios such that a joint contracting opportunity can be evaluated and optimized.

Rodrigo Moreno, Imperial College London (with Danny Pudjianto, Goran Strbac)

Transmission network operation and planning with probabilistic security to facilitate the connection of renewable generation

Current transmission networks are mainly operated and designed based on deterministic decision-making methods. Such methods do not take consideration of real outage risks of network components and therefore of actual benefits and costs of corrective control (or operational measures). This leads to over requirement of transmission capacity in planning timescales and significant constraints to access remote wind power in operational timescales. In this context, this presentation analyses various characteristics of a fully integrated economic and reliability probabilistic framework for network operation and planning that takes account of efficient operational measures to deliver network capacity to users. For the demonstrations, a new two-stage probabilistic optimization model for the operational and planning problems is presented. The model is based on a Benders algorithm and is able to balance network utilisation/redundancy levels against the use of operational measures by minimising costs and risks in every operating condition. A novel contingencies-selection technique to identify the relevant outages and therefore lower the computational burden is also presented.

Mon.3 MA 550
Optimization in energy systems

Stochastic optimization for electricity production and trading

Organizers/Chair: Raimund Kovacevic, University of Vienna - Invited Session

Densing Martin, Paul Scherrer Institute (with János Mayer)

Multistage stochastic optimization of power dispatch and multiperiod duality of CVaR

We consider cost-optimization models of power production in the context of mean-risk multi-stage stochastic optimization problems. We introduce the concept of occupation times to reduce the size of the scenario tree in a finite setting in time and states. In terms of financial risk measurement, we apply multiperiod extensions of the risk measure Conditional-Value-at-Risk (CVaR), which is widely used in applications due to its coherence properties. We show a time-consistent generalization to multiple periods that applies CVaR-like measures recursively over the time periods and compare with other extensions. In terms of modeling, we discuss how financial futures may reduce risk and how
demand can be incorporated in the proposed framework. Numerical results are presented.

Georg Pflug, U Vienna (with Raimund Kovacevic)

Stochastic bilevel programs with applications to electricity contracts

We describe a typical contracting situation for flexible energy contracts as a bilevel stochastic program: The upper level sets the price and the lower level sets the execution pattern. Bilevel programs are hard nonconvex global problems and typically no polynomial algorithms exist. We present here some solution algorithms, including stochastic quasigradient methods, penalty methods and line search methods.

We give illustrative examples for electricity swing option pricing, but remark that the very same type of problems appears in insurance pricing (adverse selection and moral hazard) as well as in terrorism modeling.

Bita Arashii, University of Vienna

Multistage stochastic optimization problems under model ambiguity

A multistage stochastic optimization problem with uncertainty about the underlying model is considered. In this paper and for the first time we introduce and develop an approach that explicitly takes into account the ambiguity in probability model for the real world class of multistage stochastic optimization problems where the robustness of the decisions is highly expected. This is done by developing the concept of ambiguity of dynamic trees for multistage stochastic optimization problems incorporating the results from multistage distance. In the presence model ambiguity one approach is to study a set of possible models in which the true model sits. In this line, we define this set as an $\varepsilon$-radius (for the given $\varepsilon$) ball around a reference measure $P$ with respect to a multistage distance $d$ and therefore robustify the original problem by a worst case approach with respect to this ambiguity neighborhood. This way we analyze the sensitivity with respect to model changes. For implementation, we consider an optimization horizon with weekly discretization, the uncertainty is the random behavior of electricity spot prices.

Kevin Sturm, WIAS (with Michael Hintermüller, Dietmar Hömberg)

Shape optimization for an interface problem in linear elasticity for distortion compensation

In this talk I will introduce a sharp interface model describing a workable model for the heat treatment of steel different phases, e.g., martensite and pearlite can be produced in the workpiece. The goal of my work is to obtain a desired workpiece shape by controlling the final phase distribution. Therefore our control variables are sets and thus we have to consider a shape optimization problem. I will show how one can derive the shape derivative for this problem, which then can be used to solve the shape optimization problem approximately. Moreover, numerical results for different workpiece shapes in two dimensions will be presented.

Volkker Schulz, University of Trier

On the usage of the shape Hessian in aerodynamic shape optimization

The talk describes how approximations of the shape Hessian can be profitably used to accelerate shape optimization strategies significantly in the application field of aerodynamics. However, at least theoretically, the shape Hessian is of less advantage than usual Hessians - essentially because there does not yet exist a Taylor series expansion of the shape Hessian, and it tends to be nonsymmetric. In this talk, a new view on the shape Hessian is proposed in terms of an appropriate distance measure. Furthermore consequences for numerical implementations are explained.

Phantipa Thipwiwatpotjana, Faculty of Science, Chulalongkorn University (with Weldon Lodwick)

Pessimistic, optimistic, and min-max regret approaches for linear programs under uncertainty

Uncertain data appearing as parameters in linear programs can be categorized variously. However, most theoretical approaches and models limit themselves to the analysis involving merely one kind of uncertainty within a problem. This paper presents reasonable methods for handling linear programs with mixed uncertainties which also preserve all details about uncertain data. We show how to handle mixed uncertainties which lead to optimistic, pessimistic, and minimax regret in optimization criteria.

Michael Römer, Martin-Luther-University Halle-Wittenberg

Linear optimization with variable parameters: Robust and generalized linear programming and their relation

In linear programming, it is usually assumed that the problem data is certain and fixed. In many real world situations, however, the parameters are subject to variation. In a pessimistic scenario, the variation is not controllable by the decision maker. This is the case for parameters affected by measurement errors or uncertainty. One way to deal with such a situation is to employ robust linear programming to obtain a solution that is feasible for all elements of a given parameter uncertainty set.

In an optimistic scenario, the variation can be controlled. Some coefficients may represent adjustable technical parameters or can be influenced by higher-level decisions. A possible approach to model this setting is generalized linear programming. In this approach, going back to early work of Dantzig and Wolfe, a solution is sought which is feasible for at least one parameter combination from a given variation set.

In this work, we provide a unified view of robust and generalized linear programs and their compact reformulations. We discuss the dual relation of both approaches and show how this duality may contribute to a deeper understanding and a mutual stimulation of both fields.

Mohammad Mehdi Nasrabadi, Payam Noor University

A fuzzy programming approach to robust optimization

A crucial feature of linear programming occurring in real-world applications is that all or some of parameters are uncertain. Robust optimization has attracted a great deal of attention to address this situation. We consider robust linear programs, where the parameters in the constraint matrix are uncertain but known to lie in a given deterministic uncertainty set. We present a fuzzy programming approach to soften the hard constraints of the robust optimization. In particular, given a feasible solution, we introduce a membership function for each constraint to indicate how much the constraint is violated in the worst-case. We characterize the three basic ingredients in fuzzy decision making, that are, fuzzy goal, fuzzy constraint, and fuzzy decision. We then present an algorithm for solving the robust linear program with softness constraints based on the well-known approach of Bellman and Zadeh (1970) in fuzzy programming. We show that the problem is efficiently solvable when the uncertain parameters are the ones considered by Bertsimas and Sim (2003).

Sebastian Stiller, TU Berlin (with Dimitris Bertsimas, Telha Claudio, Ebrahim Nasrabadi, Kai-Simon Goetzmann)

Robust network optimization

Organizer/Chair Ebrahim Nasrabadi, Massachusetts Institute of Technology - Invited Session

Sebastian Stiller, TU Berlin (with Dimitris Bertsimas, Telha Claudio, Ebrahim Nasrabadi, Kai-Simon Goetzmann)

Robust network optimization

This talk collects results on four different variants of robust network flows: the cost-robust counterpart, the strict robust counterpart, and the adjustable robust counterpart of the maximum network flow problem, and the robust flow-over-time problem. For all four models we consider scenario sets where at most a fixed number of coefficients in the input can change and all coefficients are limited within given intervals. The results on the cost-robust counterpart are derived in the form of a general result on cost-robust integer programs, in particular for those with TUM matrices. The strict robust network flow is shown to be polynomial time solvable but far too conservative. The (fractional) adjustable robust flow problem is shown to be NP-hard. It lacks a lot of the properties of nominal network flows. Nevertheless, it exhibits a variant of the min-cut-max-flow property, which we prove via a game theoretic argument. We also describe some efficiently solvable special cases. The robust flow-over-time is already hard on series-parallel graphs and in general cannot be solved by a temporally repeated flow.

David Adjaliath, ETH Zurich

Fault-tolerant shortest paths - Beyond the uniform failure model

The overwhelming majority of survivable (fault-tolerant) network design models assume a uniform scenario set. Such a scenario set assumes that every subset of the network nodes (or edges) of a given cardinality $k$ comprises a scenario. While this approach yields problems with clean combinatorial structure and good algorithms, it often fails to capture the true nature of robustness coming from applications.
One natural refinement of the uniform model is obtained by partitioning the set of resources into faulty and secure resources. The scenario set contains every subset of at most \( k \) faulty resources. This work studies the Fault-Tolerant Path (FTP) problem, the counterpart of the Shortest Path problem in this failure model. We present complexity results alongside exact and approximation algorithms for FTP. We emphasize the vast increase in the complexity of the problem with respect to its uniform analogue, the Edge-Disjoint Paths problem.

Ebrahim Nasrabadi, Massachusetts Institute of Technology (with Dimitris Bertsimas, James Orin)

On the power of randomization in robust optimization

Robust optimization can be viewed as a game involving two players, a decision maker and an adversary (or nature), who stand opposite each other. When only the cost parameters are subject to uncertainty, the decision maker chooses a solution (or a pure strategy) and the adversary selects adaptively a response after observing the decision maker’s choice. We introduce a new modeling approach that allows the decision maker to select a random strategy. In this setting, the decision maker assigns a probability to each pure strategy and randomly selects a pure strategy according to the probabilities, where the adversary’s response is based only on knowing the probability distribution and not its realization.

We show that the ratio between the value of the optimal pure strategy and the value of the optimal random strategy is bounded by the maximum number of affinely independent points in the feasible region. This bound is tight for several combinatorial optimization problems. We also show that an optimal random strategy can be computed in polynomial time whenever the nominal problem (where costs are known) is solvable in polynomial time.

Retsef Levi, MIT Sloan School of Management (with Vineet Goyal, Danny Segev)

Organizer/Chair Retsef Levi, MIT Sloan School of Management. Invited Session

Mon.3 H 1028

Global rate guarantees in sparse optimization

Organizer/Chair Michel Baes, ETH Zurich – Invited Session

Wotao Yin, Rice University (with Ming-Jun Lai)

Augmented L_1 and nuclear-norm minimization with a globally linearly convergent algorithm

L_1 minimization tends to give sparse solutions while the least squares (LS) give dense solutions. We show that minimizing the weighted sum of L_1 and LS, with an appropriately small weight for the LS term, can efficiently recover sparse vectors with provable recovery guarantees. For compressive sensing, exact and stable recovery guarantees can be given in terms of the null-space property, restricted isometry property, spherical section property, and “RIPless” property of the sensing matrix. Moreover, the Lagrange dual problem of L_1+LS minimization is convex, unconstrained, and differentiable; hence, a rich set of classical techniques such as gradient descent, line search, Barzilai-Borwein steps, quasi-Newton methods, and Nesterov’s acceleration can be directly applied. We show that the gradient descent iteration is globally linearly convergent, and we give an explicit rate. This is the first global linear convergence result among the gradient-based algorithms for sparse optimization. We also present an algorithm based on the limited-memory BFGS and demonstrate its superior performance than several existing L_1 solvers.

Lin Xiao, Microsoft Research (with Tong Zhang)

A proximal-gradient homotopy method for the sparse least-squares problem

We consider the \( \ell_1 \)-regularized least-squares problem in the context of sparse recovery or compressed sensing. The standard proximal gradient method (iterative soft-thresholding) has low computational cost per iteration but a rather slow convergence rate. Nevertheless, when the solution is sparse, it often exhibits fast linear convergence in the end. We exploit this local linear convergence using a homotopy continuation strategy, i.e., we minimize the objective for a sequence of decreasing values of the regularization parameter, and use an approximate solution at the end of each stage to warm-start the next stage. Similar strategies have been studied in the literature, but there has been no systematic analysis of their global properties. We show that under suitable assumptions for sparse recovery, the proposed homotopy strategy ensures that all iterates along the homotopy solution path are sparse. Therefore the objective function is effectively strongly convex along the path, and geometric convergence at each stage can be established. As a result, the overall iteration complexity of our method is \( O(\log(1/\epsilon)) \) for finding an \( \epsilon \)-optimal solution.

Michel Baes, ETH Zurich (with Michael Buenger, Arkadi Nemirovski)

First-order methods for eigenvalue optimization

Many semidefinite programming problems encountered in practice can be cast as minimizing the maximal eigenvalue of a convex combination of symmetric matrices. In this talk, we describe and analyze a series of first-order methods for solving this problem when the input matrices are large (of dimension 1000 to 10000 and more) and mildly sparse. We propose several accelerating strategies, notably in the step-size selection, and based on randomization, and illustrate the theoretical and practical efficiency of the new approach.

Sparce optimization & compressed sensing

Stochastic optimization

Mon.3 MA 141

Solution methods for constrained stochastic optimization

Organizer/Chair Sumit Kunnumkal, Indian School of Business – Invited Session

Lijian Chen, University of Louisville

Solving chance-constrained optimization by Bernstein polynomial approximation

We establish a Bernstein polynomial-based approximation scheme for a type of chance-constrained optimization in which the chance constraint is imposed on affine inequalities with a log-concave (log-concave, in short) continuous random vector in the right-hand side. To facilitate its implementation in practice, we only assume the log-concave and continuous joint distribution for the random vector without the closed-form distributional expression. We propose a new polynomial approximation scheme with Monte Carlo simulation to obtain the functional value and the gradient of the chance constraint as algorithmic inputs for optimization methods. The proposed scheme leads to a polynomial algorithm with considerable stability. We also address two other important issues. First, the approximation error can be well-controlled at only a reasonably low degree of the polynomial by employing the Chebyshev nodes. Second, through the epigraph convergence analysis, we show that the obtained optimal solution is converging to the optimal. Numerical results for known problem instances are presented.

Sumit Kunnumkal, Indian School of Business

Randomization approaches for network RM with choice behavior

We present new approximation methods for the network RM problem with customer choice. We have a fairly general model of customer choice behavior; we assume that customers are endowed with an ordered list of preferences among the products and choose the most preferred alternative among the available ones. The starting point for our methods is a dynamic program that allows randomization. An attractive feature of this dynamic program is that the size of its action space is linear in the number of itineraries. We present two approximation methods that build on this dynamic program and use ideas from the independent demands setting.

Sahar Radhot, Sabanci University (with Niloy Neogy)

Optimization with multivariate conditional-value-at-risk constraints

For decision making problems under uncertainty it is crucial to specify the decision makers’ risk preferences based on multiple stochastic performance measures. Incorporating multivariate preference information into optimization models is a recent research area. Existing studies focus on extending univariate stochastic dominance rules to the multivariate case. However, enforcing such dominance constraints can be overly conservative in practice. As an alternative, we focus on the risk measure conditional value-at-risk (CVaR), introduce a multivariate CVaR relation, and propose an optimization model with multivariate CVaR constraints based on polyhedral scalarization. For finite probability spaces we develop a cut generation algorithm, where each cut is obtained by solving a mixed integer problem. We show that a multivariate CVaR constraint reduces to finitely many univariate CVaR constraints, which proves the finite convergence of our algorithm. We also show that our results can be extended to the wider class of coherent risk measures. The proposed approach provides a novel, flexible, and computationally tractable way of modeling preferences in stochastic multi-criteria decision making.

Stochastic optimization

Mon.3 MA 114

Approximation algorithms for stochastic revenue management optimization

Organizer/Chair Retsef Levi, MIT Sloan School of Management – Invited Session

Retsef Levi, MIT Sloan School of Management (with Vineet Goyal, Danny Segev)

Near-optimal algorithms for assortment planning under dynamic substitution and stochastic demand

We consider a single-period assortment planning problem under a dynamic-substitution model with stochastic demand and give a polynomial time approximation scheme for the problem under fairly general assumptions. Our algorithm computes an assortment containing only a
small number of product types and obtains near-optimal revenue. We also present several complexity results for the problem that indicate that our assumptions are almost ‘necessary’ to solve it efficiently.

Dragos Cica, Massachusetts Institute of Technology (with Vivek Farias)

Dynamic allocation problems with volatile demand

We present a simple, easy to interpret algorithm for a large class of dynamic allocation problems with unknown, volatile demand. Potential applications include Ad Display problems and network revenue management problems. The algorithm operates in an online fashion and relies on re-optimization and forecast updates. The algorithm is robust (as witnessed by uniform worst case guarantees for arbitrarily volatile demand) and in the event that demand volatility (or equivalently deviations in realized demand from forecasts) is not large, the method is simultaneously optimal. Computational experiments, including experiments with data from real world problem instances, demonstrate the practicality and value of the approach. From a theoretical perspective, we introduce a new device – a balancing property – that allows us to understand the impact of changing bases in our scheme.

Cong Shi, Massachusetts Institute of Technology (with Rotem Levi)

Revenue management of reusable resources with advanced reservations

This paper studies a class of revenue management problems in systems with reusable resources and advanced reservations. A simple control policy called the class selection policy (CSP) is proposed based on solving a knapsack-type linear program (LP). It is shown that the CSP and its variants perform provably near-optimal under several classical asymptotic parameter regimes, such as the critically loaded and the Halfin-Whitt heavy-traffic regimes. The analysis is based on entirely new approaches that model the problem as loss network systems with advanced reservations. In particular, asymptotic upper bounds on the blocking probabilities are derived under the above mentioned heavy-traffic regimes. There have been very few results on loss network systems with advanced reservations, and we believe that the approaches developed in this paper will be applicable in other operations management and other applications domains.
mality indication set. Our result on constrained nonlinear programming includes some existing ones in the literature as special cases.

Boshi Tian, The Hong Kong Polytechnic University (with Xiaojiao Yang)

An interior-point $\ell_1/\ell_2$-penalty method for nonlinear programming

In this presentation, we solve general nonlinear programming problems by using a quadratic relaxation scheme for their $\ell_{1/2}$-lower order penalty problems. Combining an interior point method, we propose an interior point $\ell_{1/2}$-penalty function method, and design some robust algorithms. Using some relaxed constraint qualifications, we obtain first-order optimality conditions of relaxed $\ell_{1/2}$-lower order penalty problems. We also carry out numerical experiments for three test problem sets, which contain small scale and medium scale test problems, large scale test problems and optimization problems with different kinds of degenerate constraints, respectively. The comparison of the numerical performance of our method with other existing interior point penalty methods shows that our method in general performs better in terms of CPU time, iteration number, barrier parameter, and penalty parameter.

Zhanguang Chen, The Hong Kong Polytechnic University (with Xiaojiao Yang, Jinchuan Zhou)

Exact penalty functions for semi-infinite programming

We study optimality conditions of an inequality constraint semi-infinite optimization problem from the point of view of exact penalty functions. We introduce two types of penalty functions for the semi-infinite optimization problem, $\ell_1$-type and integral-$\ell_1$ penalty functions, and investigate their exactness relations as well as their relations with corresponding calmness properties, respectively. We establish first-order optimality conditions for the semi-infinite optimization problem via (esp. lower order) exact penalty functions. Finally, we apply our results to a generalized semi-infinite optimization problem by virtue of a double penalization technique.

Mon. 3–Tue. 1

Approximation in algorithmic game theory

Organizer/Chair Chaitanya Swamy, University of Waterloo - Invited Session

Konstantinos Georgiou, University of Waterloo (with Chaitanya Swamy)

Black-box reductions for cost-sharing mechanism design

We consider the design of strategyproof cost-sharing mechanisms, focusing mainly on the one-dimensional setting. We present a randomized, polynomial-time approximation scheme for multi-unit auctions. Our mechanism is truthful in the universal sense, i.e., a distribution over deterministically truthful mechanisms. Previously known approximation schemes were truthful in expectation which is a weaker notion of truthfulness assuming risk neutral bidders. The existence of a universally truthful approximation scheme was questioned by previous work showing that multi-unit auctions with certain technical restrictions on their output do not admit a polynomial-time, universally truthful mechanism with approximation factor better than two.

Our new mechanism employs VCG payments in a non-standard way: The deterministic mechanisms underlying our universally truthful approximation scheme are not maximal in range and do not belong to the class of affine maximizers which, on a first view, seems to contradict previous characterizations of VCG-based mechanisms. Instead, each of these deterministic mechanisms is composed of a collection of affine maximizers, one for each bidder which yields a subjective variant of VCG.

Deepakab Chakraborty, Microsoft Research, India (with Arundh Bhalgat, Sanjeev Khanna, Chaitanya Swamy)

Matching markets with ordinal preferences

In this talk we will consider the following basic economic problem: given $n$ agents and $m$ items, how should we allocate items to agents? The answer will depend on what we hope to achieve – we will see this goal is not very clear always. Furthermore, we would like our mechanisms which achieve these goals to be strategyproof – we will see that the definition of the same also is also arguable. After covering some groundwork, we’ll describe some new analysis of old mechanisms, and some new algorithms.
that the constrained shortest path with a super additive objective function is indeed a challenging problem.

Himanshu Das, Kansai University (with Tatsuya Shigetou)

Finding the shortest cycle in directed graphs under some constraints on passing vertices and paths

In this research, we propose a problem to find the shortest cycle in directed graphs under some constraints on passing vertices and paths. The proposed problem is as follows: The origin and designated vertices are fixed. We want to find the shortest cycle which starts from the origin and passes all the designated vertices. Also, the cycle has a state which depends on the path from the origin and the transition along the cycle changes it. Each vertex has acceptable states, and the path can reach a vertex when the current state is acceptable for it. This kind of problem occurs from the maintenance of large machinery. For example, when an elevator is under maintenance, a worker has to do the predetermined operations. Also, he/she has to do some operations for ensuring his/her safety during the maintenance. However, he/she can skip some operations as long as the safety is ensured. Moreover, a state of an elevator is transitioning by operations. We can deal with such situations by our proposed problem. For this problem, we propose a method which is based on a method for the asymmetric traveling salesman problem. We will show computational results in our presentation.

Marika Karsstein, Zuse Institute Berlin

Approximation and min-max results for the Steiner connectivity problem

The Steiner connectivity problem is to connect a set of terminal nodes in a graph by a cost minimal set of paths; it generalizes the Steiner tree problem to hypergraphs. The problem is known to be approximable within a factor of $\log k$ if all nodes are terminals. We discuss its approximability if all paths contain at most $k$ edges and provide, in particular, a $(k+1)$ approximation if all paths contain at most $k$ terminals. The two terminal case gives rise to a TDI description; this yields a combinatorial companion theorem to Menger’s theorem for hypergraphs and characterizes paths and cuts in hypergraphs as a blocking pair.

Anna Blasiak, Cornell University (with Aaron Archer)

New and improved bounds for the minimum set cover problem

We study the relationship between the approximation factor for the set-cover problem and the parameters $D$, the maximum cardinality of any subset, and $k$, the maximum number of subsets containing any element of the ground set. We show an LP rounding based approximation of $(k-1)(1-\frac{1}{e}\ln D + (k-1)^{-1}) + 1$, which is substantially better than the classical algorithms when $k$ is approximately $\ln D$, and also improves on related previous works. For the interesting case when $k = \Theta(\log D)$ we also exhibit an integrality gap which essentially matches our approximation algorithm.

We also prove a hardness of approximation factor of $\Omega(\log D/(\log \log D)^2)$ when $k = \Theta(\log D)$. This is the first study of the hardness factor specifically for this range of $k$ and $D$, and improves on the only other such result implicitly proved before.

Andreas Krause, ETH Zurich (with Daniel Golovin)

Adaptive submodularity: Theory and applications in active learning and stochastic optimization

Solving stochastic optimization problems under partial observability, where one needs to adaptively make decisions with uncertain outcomes, is a fundamental but notoriously difficult challenge. In this talk, I will introduce a new concept called adaptive submodularity, which generalizes submodular set functions to adaptive policies. In many respects adaptive submodularity plays the same role for adaptive problems as submodularity plays for nonadaptive problems. Specifically, just as many nonadaptive problems with submodular objectives have efficient algorithms with good approximation guarantees, so too do adaptive problems with adaptive submodular objectives. We use this fact to recover and generalize several previous results in adaptive optimization, including results for active learning and adaptive variants of maximum coverage and set cover. We show how to apply these results to several applications, including observation selection and sensor placement problems, sequential experimental design, and adaptive viral marketing.

Rico Zenklusen, MIT (with Michel Goemans, Neil Olver, Thomas Rothvoß)

Matroids and integrality gaps for hypergraphic Steiner tree relaxations

Until recently, LP relaxations have only played a very limited role in the design of approximation algorithms for the Steiner tree problem. In particular, no (efficiently solvable) Steiner tree relaxation was known to have an integrality gap bounded away from 2. This changed when Byrka, Grandoni, Rothvoß and Sanitá demonstrated in 2010 a $\ln(4)+\epsilon \approx 1.39$ approximation algorithm based on a so-called hypergraphic LP relaxation. Interestingly, even though their approach is LP based, they do not observe a matching bound on the integrality gap, showing only a weaker 1.55 bound by other methods.

We show that indeed the integrality gap is bounded by $\ln(4)$. In the process, we obtain a much better structural understanding of hypergraphic LPs, as well as more efficient algorithms. Our approach is heavily based on techniques from the theory of matroids and submodular functions.

Anna Blasiak, Cornell University (with Aaron Archer)

Improved approximation algorithms for the minimum latency problem via prize-collecting paths

The minimum latency problem (MLP) is a well-studied variant of the traveling salesman problem. In it, the server’s goal is to minimize average latency of clients prior to being served, rather than total latency of the server. Unlike most combinatorial optimization problems, the MLP is NP-hard even on trees (Sitters 2001). Furthermore, all MLP approximation algorithms known for general metrics are based on trees, and the best ratio known for both cases was 3.59, prior to our work.

We give a $3.03$-approximation algorithm for trees, the first improvement since 1994. Our $3.03$-approximation algorithm works for any class of graphs in which the related prize-collecting path problem is solvable in polynomial time, like graphs of constant treewidth. More generally, for any class of graphs that admit a Lagrangian-preserving $\beta$-approximation algorithm for the prize-collecting path problem, we can use our algorithm as a black box to achieve a $3.03\beta$-approximation for the MLP. Our analysis uses a solution of an infinite-dimensional linear program to analyze a finite-dimensional factor-revealing linear program.

Zachary Friggstad, University of Waterloo (with Mohammad R. Salavatipour, Zoya Svitkina)

A logarithmic approximation for the directed latency problem

In the directed latency problem, we are given an asymmetric metric and a start node $s$. The goal is to find a Hamiltonian path starting at $s$ that minimizes the average distance of the nodes from the start of the path. An $O(\log n)$ approximation for this problem will be presented whose analysis also bounds the integrality gap of an LP relaxation by the same factor. This improves on the previous best approximation of $O(n^{1/2+\epsilon})$ by Nagrajan and Ravi. Our approach requires bounds on integrality gaps of LP relaxations for the asymmetric traveling salesman problem and a variant using two paths.
Two-station single track railway scheduling problem with equal speed of trains

The single track railway scheduling problem with two stations and \( Q \) segments of the track is considered. Two subsets of trains \( N_1 \) and \( N_2 \) are given, where trains from \( N_1 \) go from the station 1 to the station 2, and trains from \( N_2 \) go in the opposite direction. The speed of trains over each segment is the same. A polynomial time reduction from the problem under consideration to a special case of the single machine equal-processing-time scheduling problem with setup times is presented. For this special case with different objective function under different constraints, polynomial time solution algorithms are presented.

Jens Poppenberg, Clausthal University of Technology (with Sigrid Knust)

Modeling the resource-constrained project scheduling problem with resource transfers using a graph approach

This presentation deals with the resource-constrained project scheduling problem (RCPSP) with resource transfers. Here, resource transfers are classified into two different categories: first-as well as second-tier resource transfers. While first-tier resource transfers include all resource transfers where resources are directly transferred from one activity to the next, second-tier resource transfers include all resource transfers where a resource is used to transport another resource between two successive activities, i.e., this other resource can not be transferred on its own. The problem described here is modeled using a graph approach. For this, the activities are modeled as nodes while the resource transfers or resource flows between these activities are modeled as arcs such as that an arc between two nodes corresponds to the transfer of a certain amount of units of a resource from one activity to another. Additionally, each arc is associated with the required transfer time such that schedules can be generated using longest path calculations. For this model, different neighborhood structures are introduced and some results are presented.

Sandro Bosio, ETH Zürich (with David Adjachslchi, Kevin Zemmer)

Mailroom production planning

In a multi-feeder mailroom machine, folders (e.g., newspapers) run at high-speed through a line of independent feeders, receiving by each active feeder an advertising insert. A job is a subset of inserts to be bundled in a given number of copies, which requires a certain production time. Scheduling a job batch involves deciding the job order and, for each job, the assignment of the job inserts to the feeders.

Loading an insert on a feeder requires a given setup time, and can only be done while the feeder is idle. Given a schedule, violated setup requirements have to be resolved by stopping the machine, completing the loads, and restarting the machine. As the time needed to restart the machine dominates the setup time, minimizing the makespan is equivalent to minimizing the machine stops. Alternative objective functions are the minimization of the inserted loads (number of times each insert is loaded) and the minimization of the inserts splits (number of different feeders on which each insert is loaded). We study the complexity of the problem for each objective function, for both fixed and variable job sequence. We also consider lexicographic bi-objective optimization variants.

Sandro Bosio, ETH Zürich (with David Adjachslchi, Kevin Zemmer)

Multi-flows and generalizations in VLSI routing

In the [global] routing of VLSI chips, limited space must be shared by different connections, so-called nets. In this context, multi-commodity flow problems arise naturally, and approximation schemes have been applied to them and their generalizations to fractional Steiner tree packing successfully for more than 15 years, the traditional objective being wire length minimization.

Technology scaling causes a growing need to extend global routing to directly consider other objectives and additional constraints, such as sign rules, power consumption, and manufacturing yield. All these depend non-linearly on the spacing between wires. Because these dependencies are given by convex functions, we can show that a fractional relaxation of the extended global routing problem can be formulated as a block-angular min-max resource sharing problem. We present a simple approximation scheme for this problem which generalizes and improves various previous results, and can be parallelized very efficiently. Further, we show experimental results on recent industrial chips with millions of nets and resources.

Christian Schulte, University of Bonn (with Michael Gestor, Dirk Müller, Tim Nieberg, Christian Panten, Jens Vygen)

Efficient algorithms and data structures in VLSI detailed routing

We present the core elements of detailed routing in BonnRoute. Long-distance connections are computed by a fast, interval based path search algorithm using efficient data structures for routing space representation. With advanced pin access strategies we avoid local conflicts in dense pin configurations. BonnRoute is able to handle complex design rules in modern technologies, and is used in practice on current, real world designs. Compared to an industrial routing tool it is much faster and gives better results in terms of total connection length and number of detours.

Michael Gestor, University of Bonn (with Dirk Müller, Tim Nieberg, Christian Panten, Christian Schulte, Jens Vygen)

New challenges in chip design driven by technology scaling

While structures on modern computer chips are getting smaller and smaller, e.g., by the use of more sophisticated lithography techniques, the design rules which chip design software has to respect are increasing in number and are getting more and more complex. This leads to various new algorithmical challenges in chip design. We discuss some of the most important challenges from a practical and from a theoretical perspective. Special emphasis is put on double patterning lithography. Here all structures on a single chip layer are assigned to two different production steps in manufacturing. This assignment can be considered as a coloring problem on a conflict graph which arises in different areas of chip design and has fundamental consequences for the whole design flow of modern computer chips.
Complementarity & variational inequalities

Complementarity properties of linear transformations on Euclidean Jordan algebras
Organizer/Chair Jiyuan Tao, Loyola University Maryland - Invited Session
Jayaraman Jhiappasamy, The Institute of Mathematical Sciences

P and semimonotonicity properties of linear transformations on Euclidean Jordan algebras
Let \((V, \langle \cdot, \cdot \rangle)\) be a Euclidean Jordan algebra with the symmetric cone \(K = \{ x \in V : x = y \} \). Given a linear transformation \(L : V \to V\) and \(q \in V\), the linear complementarity problem over the symmetric cone, LCP\((L, q)\), is to find a vector \(x \in V\) such that \(x \in K, q := L(x) - q \in K,\) and \( \langle x, q \rangle = 0 \). This problem includes the standard, semidefinite and second order linear complementarity problems. To study the existence and uniqueness of solution of the standard linear complementarity problem, several matrix classes have been introduced which includes \(P\) and semimonotonicity properties. Motivated by these concepts, these new classes were extended to linear transformations on \(\mathbb{S}^n\), the space of all \(n \times n\) real symmetric matrices, and further extended to Euclidean Jordan algebras. In this talk, we introduce various \(P\) and semimonotonicity properties and describe some interconnections between them. We also discuss how these concepts are significant in the study of LCP\((L, q)\).

T.1.MA 041

Jiyuan Tao, Loyola University Maryland

The completely-\(Q\) property for linear transformations on Euclidean Jordan algebras
In this talk, we present a characterization of the completely-\(Q\)-property for linear transformations on Euclidean Jordan algebras and show the completely-\(Q\)-property and related properties on Euclidean Jordan algebras.

Roman Sznajder, Bowie State University (with M. Seetharama Gowda, Jiyuan Tao)

Complementarity properties of linear transformations on product spaces via Schur complements
In this paper we extend, in a natural way, the notion of the Schur complement of a substitutional transformation of a linear transformation defined on the product of two simple Euclidean Jordan algebras or, more generally, on two finite dimensional real Hilbert spaces. We study various complementarity properties of linear transformations in relations to substitutions, principal pivot transformations, and Schur complements. We also investigate some relationships with dynamical systems.

T.1.MA 213

Matrix classes for linear complementarity problems
Organizer/Chair Todd Munson, Argonne National Laboratory - Invited Session
Todd Munson, Argonne National Laboratory

Preprocessing with composite matrices
In this talk, I present a class of matrices called composite matrices that include nonnegative matrices with positive diagonals and \(P\)-matrices, and form a subset of the strictly semi-monotone matrices. These matrices have interesting properties that are useful when preprocessing linear complementarity problems to improve the model formulation. In particular, we can easily include implied bounds on the variables for subproblems identified by finding diagonal composite matrix blocks.

Richard Cottle, Stanford University (with J. Adler)

T.1.MA 038

Lemke’s algorithms and matrix classes for the linear complementarity problem
This survey paper deals with the algorithms of Carleton E. Lemke for the linear complementarity problem. Special attention is paid to the matrix classes for which these algorithms are known to be applicable. The algorithms were not designed to obtain more than one solution, although in some cases, repeated application of a variant of the algorithm will yield several solutions. Nevertheless, there are instances where some solutions are “elusive” or “inaccessible” by the algorithm in question. We review efforts that have been made to overcome this limitation. We also examine other equilibrium problems and investigate a different (possibly novel) algorithm for exploiting “elusive” equilibrium points.

Gabriele Uchida, University of Vienna (with Immamuel Bomze, Werner Schachinger)

Conic programming

Compl P (positive) s.t. \(x^TQx \geq 0\) (SGP)

T.1.1H 2036

New advances in conic programming
Organizer/Chair Christian Oehrle, University of Grazing - Invited Session
Julia Spaniol, Universität Trier

On standard quadratic optimization problems
Many NP-hard problems can be reformulated as copositive programs, i.e., linear optimization problems over the copositive cone. The difficulty then lies in the cone constraint. Testing copositivity of a given matrix \(Q\) is a co-NP-complete problem which can be stated as a standard quadratic optimization problem of the following form

\[
\min \ x^TQx \\
\text{s.t.} \ e^Tx = 1 \\
x \geq 0.
\]

The matrix \(Q\) is copositive if and only if the optimal value of (1) is nonnegative. We consider relaxations of this problem and the case where \(Q\) is a 5 \times 5-matrix which is of special interest, since there are copositive 5 \times 5-matrices which cannot be decomposed into the sum of a positive

Therefore the cones of copositive matrices and the dual cone, all completely positive matrices, are studied and structural algebraic properties provided. Several (counter-)examples demonstrate that many relations familiar from semidefinite optimization may fail in the copositive context, illustrating the transition from polynomial-time to NP-hard worst-case behaviour.

T.1.1H 2036

Conic programming

Differentiable exact penalty functions for nonlinear second-order cone programs
We propose a method to solve nonlinear second-order cone programs (SOCPs), that uses a continuously differentiable exact penalty function as a base. The construction of the penalty function is given by incorporating a multipliers estimate in the augmented Lagrangian for SOCPs. Under the nondegeneracy assumption and the strong second-order sufficient condition, we show that a generalized Newton method has global and superlinear convergence. We also present some preliminary numerical experiments.

Shunsuke Hayashi, Kyoto University (with Masao Fukushima, Paulo Silva)

A smoothing SQP method for mathematical programs with second-order cone complementarity constraints
We focus on the mathematical program with second-order cone complementarity constraints, which contains the well-known mathematical program with nonnegative complementarity constraints as a subclass. For solving such a problem, we propose an algorithm based on the smoothing and the quadratic programming (SQP) methods. We first replace the second-order cone complementarity constraints with equality constraints using the smoothing natural residual function, and apply the SQP method to the smoothed problem while decreasing the smoothing parameter. The SQP-type method proposed in this paper has an advantage that the exact solution of each subproblem can be calculated easily since it is a convex quadratic programming problem. We further show that the proposed algorithm possesses the global convergence property under the Cartesian \(P_\infty\) and some non-singularity assumptions. We also observe the effectiveness of the algorithm by means of numerical experiments.

Ellen Fokkema, State University of Campinas (with Masao Fukushima, Paulo Silva)
semidefinite and a nonnegative matrix whereas this is possible for every copositive $n \times n$-matrix with $n \leq 4$.

Cristian Odore, University of Groningen (with Mirjam Duer, Frank Vallentin)

**Infinite dimensional semidefinite programming**

In this talk we investigate the infinite dimensional analogue of the primal and dual semidefinite matrix cones. Whereas in the finite case the cone of positive semidefinite matrices is self-dual this is no longer true in infinite dimensions. We introduce the suitable infinite dimensional objects, formulate the pair of primal–dual semidefinite programs and characterize the extremal rays of the dual infinite semidefinite cone. The technique we use employs the theory of reproducing kernels. Applying the same technique to the finite case gives a new proof and interesting new insights on the extremal semidefinite matrices.

Juan Vera, Tilburg University (with Cristian Odore)

**Exploiting symmetry in copositive programs**

We study the solution of copositive programs using a sequence of improving relaxations, as the ones used by Gaddar-Vera-Andujar for polynomial programs. This method consists of using interactively a master-subproblem scheme; the master solves a conic-relaxation of the original problem, while the subproblem improves the cone used in the relaxation using dual information from the master.

We show how symmetry of the original copositive formulation can be used to reduce both the master and subproblem. To reduce the master, techniques to exploit symmetry in semidefinite programming – which are becoming standard nowadays – are used; reducing the subproblem requires exploring the symmetry of Polya-like representations for copositive polynomials in a novel manner.

Jean-Guillaume Fages, École des Mines de Nantes (with Xavier Lorca)

**Solving the traveling salesman problem with constraint programming**

The Traveling Salesman Problem (TSP) is one of the most studied problems by the operation research community and has various practical applications, such as vehicle routing problems of logistics, microchips production optimization or even scheduling. Recent improvements have enabled constraint programming (CP) approaches to tackle medium size TSP instances. We discuss basic CP representations of the TSP and provide a short survey over state of the art models as well as an experimental study.

Arnaud Malapert, UST CNRS – Université Nice Sophia Antipolis (with Christelle Guéret, Louis-Martijn Rousseau)

**Scheduling a batch processing machine with constraints**

We present a constraint programming approach for a batch processing machine on which a finite number of jobs of non-identical sizes must be scheduled. A parallel batch processing machine can process several jobs simultaneously and we aim to minimize several regular objective functions. The constraint programming formulation proposed relies on the decomposition of the problem into finding an assignment of the jobs to the batches, and then scheduling the batches on a single machine. This formulation is enhanced by a new optimization constraint which is based on relaxed problems and applies cost-based domain filtering techniques. Cost based domain filtering aims to remove combination of values which cannot lead to solutions whose cost is better than the best one found so far. Experimental results demonstrate the efficiency of cost-based domain filtering techniques. Comparisons to other exact approaches clearly show the benefits of the proposed approach.

Louis-Martijn Rousseau, CIRCELT – Polytechnique Montréal (with Nicolas Chapados, Marc Joliveau, Pierre L’Ecuyer)

**Formal language for retail store workforce scheduling**

The dual role played by the sale personnel in retail store industry, which can be seen as a costly resource, as well as a set of agents that generate incomes, makes this area very specific as, unlike traditional approaches where the goal is to minimize the operating costs, the schedules of the employees can be optimized such that it directly maximize the net incomes generated by the store over a given horizon (e.g., a day or a week). In this framework, we introduce a constraint program (CP) and a mixed integer program (MIP), both based on the use of a formal language, that schedule the workforce of a retail store while considering both operating costs and operating incomes. Comparison on more than 5000 day instances measured in a clothing and apparel chain will demonstrate the advantage of CP to accurately handle the specific work regulation rules of the retailer in comparison to MIP.

Cristian Odore, University of Groningen (with Mirjam Duer, Frank Vallentin)

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Convex optimization approaches to polynomial optimization problems
Organizers/Chair Miguel Antao, École Polytechnique de Montréal - Invited Session

Annie Lambert, CEGID-Grain (with Alain Billionnet, Sourour Elouafy)
Convex reformulations of integer quadratically constrained problems
We consider a general integer program (IQQP) where both the objective function and the constraints are quadratic. We show that the quadratic convex reformulation approach can be extended to that case. This approach consists in designing a program, equivalent to IQQP, with a quadratic convex objective function and linear or quadratic convex constraints. The resulting program is then solved by a standard solver. We start by dealing with the objective function. For this, we solve a semidefinite program from which we deduce a reformulation of IQQP as an equivalent problem (P) having a convex quadratic objective function. We then handle the quadratic constraints of (P). We propose and compare linear and quadratic convex reformulations of these constraints. Finally, we give some numerical results comparing our different approaches.

Fritz Rendl, AUI (with Philipp Hungerlander)
Active set methods for convex quadratic optimization with simple bounds
A primal-dual active set method for quadratic problems with bound constraints is presented which extends the infeasible active set approach of Kunisch and Rendl [SIOMP 2003]. Based on a guess on the active set, a primal-dual pair is computed that satisfies the first order optimality condition and the complementary condition. Primal variables outside their bounds are added to the active set until a primal feasible solution is reached. Then a new active set is generated based on the feasibility information of the dual variables. Strict convexity of the quadratic problem is sufficient for the algorithm to stop after a finite number of steps with an optimal solution. Computational experience indicates that this approach also performs well in practice.

Tue.1.1058
MILP software II
Organizers/Chair Thorsten Koch, ZIB - Invited Session

Martin Tieves, RWTH Aachen (with Ari Koster, Manuel Kutschka)
Creating synergies between MIP-solvers
Mixed integer programming offers a broad field of interest for both, research and application. Therefore a wide range of MIP solvers is available, each with its own advantages and disadvantages. In this paper we analyze the potential of combining different solvers and/or different parameter settings in a parallel computation. Hereby, we focus on combinations of the solvers SCIP, CPLEX and GUROBI extended with different

Global optimization

Aug. 23, 2023
TheredistrictingwasstudiedbyNemotoandHotta2003. Theoptimal
populationin2010andtheprovincesin2011. The
0ingproblemsrespectively, the limit of the disparity is 1.939 for the pop-
years. By optimizing both the apportionment problem and theredistrict-
to 2 times. As a result, the gap is more than 2 by the redistricting. In
sthe redistricting in each prefecture. The apportionment gives the lower
rather, is defined by
research provides them for the decision support.
InJapan,300membersoftheHouseofRepresentatives, theLower
lege & mixed-integer programming

-1 IP model to optimize the redistricting was studied by Nemoto and Hotta in 2003. The optimal
district gives the limit of the disparity, but it is not always practical. So, it
is better to enumerate some practical district, to point out the similarity
to the current district, and to characterize the district candidates. This
research provides them for the decision support.

MagnusÖnnheim,ChalmersUniversityofTechnology(with TorgnyAlmgren,NiclasAndersson,
MichaelPatrjsson,Ant-BrithStrömberg,AdamWojciechowski)

The opportunistic replacement problem: Model, theory and

We present an 0 – 1 integer linear programming (ILP) model for de-
termining optimal opportunistic maintenance schedules for a system of
components with maximum replacement intervals; it is a natural start-
ing point for modelling replacement schedules of more complex sys-
tems. We show that this problem is NP-hard and that all the necessary
inequalities induce facets. We further present a new class of facets de-
fined by \( \{0, \frac{3}{2}\} \)-Chvátal–Gomory cuts. For costs monotone with time a
class of elimination constraints, allowing for maintenance only when re-
placement is necessary for at least one component, is defined. For fixed
maintenance occasions the remaining linear program is solvable by a
greedy procedure.

Results from a case study on aircraft engine maintenance illustrate
the advantage of the 0 – 1 ILP model over simpler policies. We include
the new class of facets in a branch&cut framework and note a decrease
in number of branch&cut rounds and simplex iterations for most in-
stance classes with time dependent costs. For instance classes with
time independent costs and few components the elimination constraints
are used favourably.

Trends in mixed integer programming II

Organizers: Charis Andrea Lodi, University of Bologna, Robert Weismantel, ETH Zurich – Invited Session

GustavoAngulo,GeorgiaInstituteofTechnology(with ShabibeAhmed,SantanuDey)

Semi-continuous network flow problems

We consider network flow problems where some of the variables are
restricted to be semi-continuous. We introduce the single-node semi-
continuous flow set with variable upper bounds as a relaxation. Two par-
ticular cases of this set are considered, for which we present complete
descriptions of the convex hull in terms of linear inequalities and ex-
tended formulations. We study the efficacy of the polyhedral results on a
class of semi-continuous transportation problems.

DomenicoSalvagnin,UniversityofPadova(with MatteoFischetti,MicheleMonaci)

Randomness and tree search

Many mixed integer linear programs exhibit a high performance
variance when solved with state-of-the-art solvers, meaning that
seemingly performance-neutral changes in the environment or in
the input format have a great influence in the actual solution process.
Such variability is intrinsic in the enumerative nature of the branch-
and-cut methods used to solve MIP instances and is mainly due to the
fact that many decisions taken during the tree search (e.g., branching
strategies, primal heuristics) are just heuristics and are subject to im-
perfect tie-breaking (degeneracy of the instance at hand further com-
plifies the picture).

We investigate whether randomness can be a useful tool to over-
come the issue of performance variability and to actually take advan-
tage of it to speed up the solution process. Preliminary computational
results show that the proposed approach is promising.

StefanoSmriglio,UniversityofL’Aquila(with AndreaLodi,TedRalphs,FabrizioRussi)

Interdiction branching

Interdiction branching is a branching method for binary integer
programs that is designed to overcome some difficulties that may be
encountered by branching on a variable dichotomy. Unlike traditional
methods, the branching disjunction is selected taking into account the
best feasible solution found so far. In particular, the method computes
an improving solution cover, which is a set of variables of which at least
one must be nonzero in any improving solution. From an improving so-
lution cover, we can obtain a branching disjunction. For instance, each
branch is guaranteed to contain at least one improving solution. Com-
puting a minimal improving solution cover amounts to solving a dis-
crete bilevel program, which is difficult in general. In practice, a solution
cover, although not necessarily minimal nor improving, can be found
using a heuristic that achieves a profitable trade-off between the size of
the enumeration tree and the computational burden of computing the
cover. An empirical study shows that such an implementation of the
method reduces significantly the size of the enumeration tree compared
to branching on variables.
Roman Polyak, George Mason University
Nonlinear equilibrium for optimal resource allocation

When linear programming (LP) is used for optimal allocation limited resources the prices for goods and the resources availability are given priori and independent on the production output and prices for the resources. Nonlinear equilibrium (NE) eliminates this basic drawback of LP allowing finding prices for goods and resources availability consistent with the production output and prices for the resources. Finding NE is equivalent to solving a variation inequality (VI) on the Cartesian product of the primal and dual non negative octants, octation on which is a very simple operation. We consider two methods: projected pseudo-gradient (PPG) and extra pseudo-gradient (EPG), for which the property on the optimum.Based on previous work by Fujishige et al. we will present an algorithm using a sequence of minimum norm point calculations iterating to the zonotope formulation and can be described as a Newton-type algorithm. The approach presented is based on problems may w.l.o.g. be considered to be bounded. It is possible to resolve bounded LP to a sequence of LPs on zonotopes which can easily be solved by a greedy algorithm. The approach presented is based on the zonotope formulation and can be described as a Newton-type algorithm using a sequence of minimum norm point calculations iterating to the optimum. Based on previous work by Fujishige et al. we will present theoretical as well as practical results on the performance of the algorithm. In particular, different approach for calculating the minimum norm point will be compared with respect to certain drawbacks in a previously applied algorithm of Wolfe.

Antonio Mucherino, IRISA (with Luiz Carvalho, Virginia Costa, Carlile Lavor, Nelson Maculan)
Re-ordering protein side chains for the discretization of MDGPs

An optimal solution to the generalized distance geometry problem

We consider a class of Molecular Distance Geometry Problems (MDGPs) that can be discretized in the hypothesis some assumptions are satisfied. We refer to this class of problems as the Discretizable MDGP (DMDGP). The discretization assumptions are strongly depend upon the ordering that is associated to the atoms of the considered molecules. In a recent work, we proved that any MDGP related to protein backbones can be discretized if the backbone atoms are re-arranged by considering a special ordering we identified. In this work, we investigate the possibility to find such discretization orderings for the side chains of the amino acids involved in the protein synthesis.

Martin Gehre, University of Potsdam (with Carito Guzzelisi), Mikhail Ivanchov, Torsten Schraud, Anne Riegel, Sue Thole, Philipp Schubert
Repair and prediction (under inconsistency) in large biological networks with answer set programming

We address the problem of repairing large-scale biological networks and corresponding yet often discrepant measurements in order to predict unobserved variations. To this end, we propose a range of different operations for altering experimental data and/or a biological network in order to re-establish their mutual consistency and thus to enable automated prediction. For accomplishing repair and prediction, we take advantage of the distinguished modeling and reasoning capacities of Answer Set Programming. We validate our framework by an empirical study on the widely investigated organism Escherichia coli.
First, let's talk about the cost of SOx limits to marine operators. Results from exploring the impact of SOx emission regulations on profit margins indicate that the cost of SOx limits is substantial. The cost of complying with new emission limits for sulfur oxide (SOx) in marine fuels can significantly impact the profitability and sustainability of maritime operations. These costs are particularly pronounced for ships operating in areas with stringent emission control zones, where the use of high-sulfur (HS) fuels may not be allowed.

Secondly, considering the fluctuation of high-sulfur (HS) fuels, the low-sulfur (LS) marine fuels have a higher price, and their fluctuation is almost similar to the fluctuation of high-sulfur (HS) fuels. The price difference between HS and LS might also determine the decision of operators for alternative technical means, such as scrubbers, in order to comply with the new limits. This paper aims to provide a thorough statistical analysis of the currently available LS and HS marine fuels time series, as well as to present the analysis of the differential of the HS and LS fuel prices. Moreover, forecasting issues are discussed on the basis of the conventional analysis tools via-a-vis a fuzzy forecasting methodology. The results of the comparison could guide the next steps of research.

In addition, efficient solvers for mixed integer nonlinear optimization problems are discussed. This includes the development and implementation of state-of-the-art solvers for MINLP and analyze the impact of various solver components on the overall performance.

Furthermore, separation of valid inequalities for nonlinear functions is addressed. Development of valid inequalities is an important step in the development of valid inequalities for a set defined by a nonlinear function, i.e., a function that is linear when all variables but one are fixed. One method takes advantage of a tensor representation of a nonlinear term, while the other uses a divide-and-conquer technique coupled with dynamic programming in order to find the most violated inequality. Some preliminary experimental results are reported.

Finally, decision support for multi-attribute multi-item reverse auctions is discussed. In this study, we address multi-item auction problems in a multi-attributed, multi-round reverse auction setting. In each round, we provide the buyer with a set of efficient bid combinations, which then chooses the provisional winners whose bids collectively provide all the required items. We estimate preference information from the buyer’s choices and provide this to the bidders. The bidders update/improve their bids in order to become/stay competitive. The process continues several rounds. The developed interactive approach tries to have the more competitive bidders eventually end up winning the auction.

Overall, the research highlights the importance of understanding the economic and environmental aspects of maritime operations, the impact of emission regulations, and the development of efficient optimization algorithms to address these challenges.
Quasi-Newton methods for solving the trust-region subproblem

In this talk, we consider quasi-Newton trust-region methods for large-scale unconstrained optimization. A new trust-region subproblem solver is proposed that is able to take advantage of the special structure of quasi-Newton approximations to Hessians. The method relies on a sequence evolving low-dimensional subspaces. Numerical results compare the proposed method with other popular quasi-Newton trust-region methods in various trust-region settings.

Jennifer Enway, Wake Forest University
and Talbot. This study gives a new insight on this approach and yields original a posteriori estimates.

Elías Helou, University of São Paulo [with Álvaro De-Pierro]

Incremental subgradients for constrained convex optimization: A unified framework and new methods

We will present a unifying framework for nonsmooth convex mini-
mization bringing together ε-subgradient algorithms and methods for
the convex feasibility problem. This development is a natural step for ε-
subgradient methods in the direction of constrained optimization since
the Euclidean projection frequently required in such methods is re-
placed by an approximate projection, which is often easier to compute.
The developments are applied to incremental subgradient methods, re-
sulting in new algorithms suitable to large-scale optimization problems,
such as those arising in tomographic imaging.

The flexibility of the framework will be demonstrated by the pre-
sentation of several operators, both for the optimality step and for the
feasibility step of the prototypical algorithm.

Jerome Fehrenbach, Toulouse University

Stripes removal in images, applications in microscopy

In a number of imaging modalities, images are degraded by a noise
composed of stripes. This is the case, e.g., in Atomic Force Microscopy;
in nanotomography or in Selective Plane Illumination Microscope (which
is an emerging imaging modality). This work aims at proposing an effi-
cient method to restore these images. A model of stationary noise is pre-

certed, where the noise is defined as the convolution of a given pattern
with a white noise. The denoising problem is then formulated using a
Bayesian approach. It leads to a non-smooth convex optimization prob-
lem. The minimization is performed using a preconditionned primal-
dual algorithm proposed by Chambolle and Pock in 2011. Our frame-
work allows to take into account several components of noise, and the
proposed algorithm on the certainty-equivalent value of the optimal
policy. Results on images obtained using different modalities are
presented, using a Total Variation prior on the space of images. A plugin
for the open source FIJI software is available.

Vitor de Matos, Plan4 [with Erlon Finardi, Andrew Philpott]

On solving multistage stochastic problems with general coherent risk measures

In this work we discuss the solution of multistage stochastic linear
programs with general coherent risk measures, using sampling-based
algorithms such as the dual dynamic programming (DDP). We

describe a computational approach that changes the probability mea-
sure of the outcomes of next stage problems to compute the outer
approximation of the future cost function [cuts in SDDP]. This provides
a lower bound on the certainty-equivalent value of the optimal policy.

We provide a new convergence test for this class of risk-averse problems by
computing an upper bound on the certainty-equivalent value of the optimal
policy, using an inner approximation algorithm. Finally, we show the re-
sults of computations on a large scale problem (the Brazilian long term
hydrothermal scheduling problem), in which we compare the proposed
implementation strategy with the one used previously by these authors.

Pierre Girardouz, EDF R&D – University of Auckland [with Andrew Philpott]

Modelling electricity prices and capacity expansions over a
long-term horizon

We consider a power producer who wants to minimize in the long-
term the sum of its production costs and investment costs. We make a
distinction between two sorts of randomness: "day-to-day randomness" that affects the system, like power demand, water inflows, etc.
and more "sporadic randomness" like political decisions [recently Ger-
many decided to stop nuclear power production], long-term fuel prices
 trends, etc. These two kinds of randomness are treated differently.

Unlike most existing approaches which consider two-step problems,
our model is a multi-stage stochastic MIP and thus allows us to
obtain investment strategies rather than simple decisions. However,
this program is too big to be solved directly by a commercial solver.
Hence, we propose to dualize Dantzig-Wolfe decomposition scheme that
consists in the iterative resolution of yearly subproblems coordinated
by a master problem that ensures satisfaction of the non-anticipativity
constraints and, in the end, optimality of the solution.

We show an experiment on the real-life problem of choosing gen-
eration and transmission investments for the New Zealand electricity

system.

Kamby Barty, EDF R&D, OSRIS dept [with Anes Gallagi, Alain Lemon]

A quantities decomposition scheme for energy management

Each country in the European electricity market has its own way to cope with its electricity demand. The utilities perform strategies that
minimize their production cost under technical constraints together
with information constraints. They can use to supply consumer’s de-
mand, various electricity generation units together with market offers.
The problem for each actor is to schedule its generation and determine whether or not he has to import/export electricity. The countries are
linked through the electricity grid, we propose a decomposition scheme that
iterates over the interconnection flows. This scheme allows flexi-
bility in build subproblems. We are going to present the algorithm and
we are going to show how it behaves.

Organizer/Chair Antonio Frangioni, Università di Pisa - Limited Session

Nonlinear and combinatorial aspects in energy optimization

Sofia Zaourar, Inria Grenoble [with Jérôme Malick]

Prices stabilization for inexact unit-commitment problems

Unit-commitment (UC) problems in electricity production are well-
suited for constraint (or pricing) decomposition techniques: by dualizing
the linking constraints, the large-scale nonconvex problem decomposes
into smaller independent subproblems. The dual problem consists then
in finding the best Lagrangian multiplier (the optimal price); it is solved
by a convex nonsmooth optimization method.

Realistic modeling of technical production constraints makes the
Lagrangian subproblems themselves difficult to solve. It is possible for

bundle algorithms to cope with inexact solutions of the subproblems.

In this case however, the computed optimal dual variables show a noisy
and unstable behaviour, that could prevent their use as price indicator.

In this talk, we present a way to stabilize dual optimal solutions by
penalizing the noisy behaviour of the prices in the dual objective.
After studying the impact of a general stabilization term on the model and the
resolution scheme, we present total variation stabilization and its primal
interpretation. We illustrate our approach on the real-life UC problem
of Electricite de France (French Electricity Board).

Antonio Frangioni, Università di Pisa [with Claudio Gentile]

Exploiting structure in MIQP approaches to unit commitment problems

The unit commitment problem in electrical power production is nat-
urally formulated as a mixed-integer quadratic program; as such it
could be solved with general-purpose MIQP tools, but direct application
of this approach using the standard formulation is not efficient. Yet, the
problem presents several (possibly nested) sources of structure, from
the space duality duality usually exploited by Lagrangian Relaxation
approaches (leading to smaller, very structured MIQP subproblems for
which efficient specialized methods exist) to the presence of very many
semicontinuous variables with convex nonlinear cost [which suggests
the use of perspectrification reformulation techniques to strengthen the lower
bound]. We discuss novel ways of exploiting some of these structures,
possibly in combination, reporting computational results to help gaug-
ing their potential effectiveness.

Maria Teresa Vespucci, University of Bergamo [with Alberto Gelmini, Mario Incorva, Diana Moneta, Davide Sitavec]

A procedure for minimizing variations of an initial operating point in
medium-voltage AC network with distributed generation and
storage devices

An optimization algorithm is described for the voltage control of
medium voltage distribution networks in presence of distributed gen-
eration. Given the current operating point and the forecasted load and
generation, the algorithm computes the changes to be requested to
the controllable resources in order to ensure fulfillment of techni-
cal constraints (voltage at nodes, current in branches) with the low-
est overall cost. Distributor’s rescheduling costs, modelled by means
of binary variables, are minimized while satisfying service security re-
quirements and ensuring a high-quality representation of power con-
straints. Storage devices are modeled by means of constraints that re-
late adjacent time periods. The proposed two-step solution procedure
is based on decoupling active and reactive variables. In step 1 a MILP
model determines the active power production and the use of storage
deVICES that minimize rescheduling costs over all periods in the time
horizon: in this step a DC network representation is used. In step 2, given
the optimal active power productions computed in step 1, reactive vari-
ables in each time period are computed by solving an AC optimal power
flow model.
PDE-constrained opt. & multi-level/multi-grid meth.

Adaptive methods in PDE constrained optimization
Organizer/Chair Stefan Ulbrich, TU Darmstadt - Invited Session

Winnfried Wollner, Universität Hamburg

Adaptive finite element discretizations in structural optimization

In this talk we will consider a prototypical example from structural optimization. Namely the well known compliance minimization of a variable thickness sheet, i.e., given a domain $\Omega \subset \mathbb{R}^2$, we consider

$$\min_{q \in C^2(\Omega; \mathbb{R}^2)} J(u)$$

subject to the constraints

$$(q \cdot \nabla u, \nabla \phi) = (l, \phi) \quad \forall \phi \in H^1_0(\Omega; \mathbb{R}^2),$$

$$0 < q_{\min} \leq q \leq q_{\max},$$

$$\int_\Omega q \leq V_{\max},$$

where $H^1(\Omega; \mathbb{R}^2)$ denotes the usual $H^1$-Sobolev space with certain Dirichlet boundary conditions, and $q(\nabla u)$ denotes the usual linear Lamé–Navier stress tensor.

As it is well known that the effort for the optimization is directly linked to the number of unknowns present in the discretization we will derive an a posteriori error estimator in order to drive local mesh refinement with respect to a given target quantity.

Finally we will give an outlook to possible extensions.

Ronald Hoppe, University of Augsburg (with F. Ibrahim, M. Hintermüller, M. Hina, Y. Hishar)

Adaptive space-time finite element approximations of parabolic optimal control problems

We consider adaptive space-time finite element approximations of parabolic optimal control problems with distributed controls based on an approach where the optimality system is stated as a fourth order elliptic boundary value problem. The numerical solution relies on the formulation of the fourth order equation as a system of two second order ones which enables the discretization by P1 conforming finite elements with respect to simplicial triangulations of the space-time domain. The resulting algebraic saddle point problem is solved by preconditioned Richardson iterations featuring preconditioners constructed by means of appropriately chosen left and right transforms. The space-time adaptivity is realized by a reliable residual-type a posteriori error estimator which is derived by the evaluation of the two residuals associated with the underlying second order system. Numerical results are given that illustrate the performance of the adaptive space-time finite element approximation.

Dan Iancu, Stanford University (with Mayank Sharma, Maxim Sviridenko)

Supermodularity and dynamic robust optimization

We consider two classical paradigms for solving Dynamic Robust Optimization (DRO) problems: (1) Dynamic Programming (DP), and (2) policies parameterized in model uncertainties i.e., decision rules, obtained by solving tractable convex optimization problems. We provide a set of unifying conditions based on the interplay between the convexity and supermodularity of the DP value functions, and the lattice structure of the uncertainty sets that guarantee the optimality of the class of affine decision rules. We also derive conditions under which such rules can be recovered by optimizing simple e.g., affine) functions over the uncertainty sets. Our results suggest new modeling paradigms for robust optimization, and our proofs, bringing together ideas from three areas of optimization typically studied separately robust, combinatorial – lattice programming and supermodularity, and global – the theory of concave envelopes), may be of independent interest. We exemplify our results in an application concerning the design of flexible contracts in a two-echelon supply chain, where all optimal contractual pre-commitments and optimal ordering policies can be found by solving a small LP.

Omid Noohid, Purdue University

Robust optimization

Dynamic optimization and its applications
Organizer/Chair Vineet Goyal, Columbia University - Invited Session

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Omid Noohid, Purdue University

Robust evolution-based optimization in radiation therapy

The treatment of solid cancer tumors with external radiation is typically planned based on information that is collected during the initial examination. The overall goal of the treatment is to eliminate the tumor, hence a certain evolution is anticipated. However, current optimized radiation delivery strategies do not vary over the course of the treatment, which typically spans over four to six weeks. We present novel methods that address this issue by taking the changes in the tumor into account and exploiting its evolution to both enhance the recovery and increase the success of the therapy. We demonstrate the performance of the method based on clinical cases, where a) the geometric shape of the tumor varies or b) the cell sensitivity to radiation and its effect changes over time. Moreover, the presented treatment plans are intrinsically robust to deviations from the assumes evolution path.

Vineet Goyal, Columbia University (with Dimitris Bertsimas)

Static vs. dynamic robust optimization

Most real world problems require optimization models that handle uncertain parameters. In a dynamic robust optimization framework, uncertainty is modeled as a set and we optimize over the worst-case realization of the uncertain parameters. We compute an optimal fully-adjustable solution via a classical DP approach but this is often intractable. Another solution paradigm is to construct a static solution that is feasible for all future uncertainty realizations. This is a tractable approach but is often perceived to be highly conservative. We compare the performance of static solutions with optimal fully-adjustable solutions and show that it is a good approximation for the dynamic robust optimization problem under fairly general conditions. In particular, we consider problems with linear constraints and linear objective under uncertainty and relate the performance of static solutions with the properties of uncertainty set. Our analysis also provides important insights about constructing good uncertainty sets in dynamic robust optimization problems.

Vineet Goyal, Columbia University (with Dimitris Bertsimas)

Statistical analysis of ranking from pairwise comparisons

The problem of ranking a collection of objects on the basis of a number of pairwise comparisons occurs naturally in many applications, including ranking players of a two-person game based on their records against each other. In this talk, we study two approaches of assigning scores which provide natural ordering of the objects. When the comparisons data is generated from the logit model, we provide performance guarantees for both approaches. First, we provide an upper bound on the error rate of the logistic regression applied to pairwise comparisons data. Next, we introduce an alternative approach of computing the scores of the objects from a stationary distribution of a random walk on a comparability graph. We define the comparisons graph as a directed and weighted graph of objects where two objects are connected if the pair has been compared at least once, and the directed edges are weighted according to the outcome of the comparisons. Under the logit model, we provide an upper bound on the resulting error.

Sewong Oh, MIT (with Shah Devavrat, Negabhan Sahand)

Methods of risk-averse optimization
Organizer/Chair Andrzej Ruszczynski, Rutgers University - Invited Session

Mark Schmidt, École normale supérieure (with Francis Bach, Michael Friedlander, Nicolas Le Roux)

Linearly-convergent stochastic gradient methods

This talk considers the sum of a large number of smooth functions, where the sum is strongly convex. Stochastic gradient algorithms only compute a single term in the sum on each iteration, leading to inexpensive iterations but unfortunately yielding sublinear convergence rates. In contrast, full-gradient methods achieve linear convergence rates at the expense of evaluating all terms on each iteration. We explore two strategies that exhibit the benefits of both approaches. First, we show that a linear convergence rate can be achieved at the expense of evaluating an increasing number of functions on each iteration. Second and more surprisingly, we propose a new method that only needs to evaluate a single term in the sum on each iteration but that still achieves a linear convergence rate. Numerical experiments indicate that the new algorithms can dramatically outperform standard methods.

Sewong Oh, MIT (with Shah Devavrat, Negabhan Sahand)

Stochastic optimization

Organizer/Chair Andrzej Ruszczynski, Rutgers University - Invited Session

Vineet Goyal, Columbia University (with Dimitris Bertsimas)

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Sewong Oh, MIT (with Shah Devavrat, Negabhan Sahand)
The aim is to specialize general linear programming computing tech-
niques to these stochastic problems; and on the other hand, to work
out LP computational techniques based on ideas originally developed
for the handling of risk measures.

Andrzej Ruszczynski, Rutgers University (with Olim Cavus)

Methods for solving risk-averse dynamic optimization problems

For risk-averse dynamic optimization problems with Markov risk
measures, we present several computational methods for finding op-
timal policies. In particular, we extend to the risk-averse case the value
iteration, policy iteration, and mathematical programming approaches.
We illustrate the results on several applied problems.

Daria Dentscheva, Stevens Institute of Technology (with Gabriela Martinez, EU Wolfhagen)

Decomposition methods for solving two-stage optimization
problems with stochastic ordering constraints

We consider two-stage risk-averse stochastic optimization prob-
lems with a stochastic ordering constraint on the recourse function.
We consider the usual stochastic order, the increasing convex order,
and the multivariate stochastic dominance. We propose decomposition
methods to solve the problems and prove their convergence. Addition-
ally, new characterizations of the increasing convex order relation are
provided. Our methods exploit the decomposition structure of the risk-
neutral two-stage problems and construct successive approximations
of the stochastic ordering constraints. Numerical results confirm the
efficiency of the methods.
given lower bound (a minimum quantity). This problem has recently been shown to be weakly NP-complete even on series-parallel graphs.

We show that it is strongly NP-hard to approximate the maximum flow problem with minimum quantities [MFPMQ] on general graphs within any positive factor. On series-parallel graphs, however, we present a pseudo-polynomial dynamic programming algorithm for the problem. Mainly, the problem shows that strongly NP-complete on general graphs for the case that the minimum quantity is the same for each arc in the network and we present a \((2 - \frac{1}{\lambda})\)-approximation algorithm for this case, where \(\lambda\) denotes the common minimum quantity of all arcs.

Marco Serafini, University of Rome "Tor Vergata" [with David Adjualishil]

The online replacement path problem

The study of a natural variant of the replacement path problem. The replacement path problem asks to find for a given graph \(G = (V, E)\), two designated vertices \(s, t \in V\) and a shortest \(s-t\) path \(P\) in \(G\), a replacement path \(\tilde{P}\) for every edge \(e\) on \(P\). We adapt this problem to deal with the natural scenario that the identity of the failed edge only becomes available when the routing mechanism tries to cross the edge. This situation is motivated by applications in distributed networks, where information about recent changes in the network is only stored locally, and fault-tolerant optimization, where an adversary tries to delay the discovery of the materialized scenario as much as possible. Considering the online replacement path problem, which asks to find a nominal \(s-t\) path \(Q\) and detours \(Q_e\) for every edge on \(Q\), such that the worst-case arrival time at the destination is minimized. Our main contribution is a label setting algorithm solving the problem in undirected graphs in time \(O(n \log n)\) and linear space for all sources and a single destination. We also present algorithms for extensions of the model to any bounded number of failed edges.

Joaõ Paulo Araujo, Pontificia Universidade Católica (PUC-Rio) [with Pascal Berthomieu, Madalena Diallo, Fernando Raupp]

An algorithm for the multi-terminal maximum flow

In the context of network flows, the multi-terminal maximum flow problem is an extension of the well known single source–single terminal maximum flow problem. In the multi-terminal case, the maximum flow is calculated between all pairs of nodes. Clearly, considering a symmetric network with \(n\) nodes, this problem can be solved by applying a maximum flow algorithm \(O(n - 1)/2\) times, whereas the traditional method can solve it with only \(n - 1\) applications. This work seeks to elaborate an algorithm able to solve the multi-terminal maximum flow problem with a computational complexity lower than the existing methods. The recent theory of sensitivity analysis, which studies the influence of an edge capacity variation on the multi-terminals maxima flows, is employed on the development of the algorithm. Techniques of the traditional methods, such as the contraction of nodes, are also part of the proposed method. Finally, the algorithm is computationally tested with all combined feature variations and heuristics. For a given instance, the algorithm showed efficiency very close to the traditional methods.

Andreas Griewank, Humboldt University

On piecewise linearization and lexicographic differentiation

It is shown that problems that are described by an evaluation programs can be approximated locally by a piecewise-linear model. In contrast to the standard approach in algorithmic or automatic differentiation, we allow for the occurrence of nonsmooth but Lipschitz continuous elemental functions like the absolute value function \(abs(\cdot), \min(\cdot), \max(\cdot)\), and more general table look ups. Then the resulting composite function is piecewise differentiable in that it is everywhere the continuous selection of a finite number of smooth functions [Scholtes]. Moreover, it can be locally approximated by a piecewise-linear model with a finite number of kinks between open polyhedra decomposing the function domain. The model can easily be generated by a minor modification of the ADOL-C and other similar tools.

The discrepancy between the original function and the model is of second order in the distance from the development point. Consequently, successive piecewise linearization yields bundle type methods for unconstrained minimization and Newton type equation solvers, for which we establish local convergence under standard assumptions.

Sahina Fiege, Universität Paderborn [with Andreas Griewank, Andrea Walther]

An exploratory line-search for piecewise smooth functions

Many scalar or vector functions occurring in numerical applications are not continuously differentiable. This situation arises in particular through the use of \(l_1\) or \(l_\infty\) penalty terms or the occurrence of \(abs(\cdot), \min(\cdot)\) and \(max(\cdot)\) in the problem function evaluations themselves. If no other nonsmooth elemental functions are present, generalized gradients and Jacobians of these piecewise smooth functions can now be computed in an AD like fashion by lexicographic differentiation as introduced by Barton & Kahn, Griewank and Nesterov. However, at almost all points these generalized derivatives reduce to classical derivatives, so that the effort to provide procedures that can calculate generalized Jacobians nearly never pay off. At the same time the Taylor approximations based on these classical derivative singeltons may have a minuscule range of validity. Therefore, one alternative goal is to compute the critical step multipliers for a given search direction that leads to the nearest kink. The achievement of this goal can not be guaranteed absolutely, but we verify necessary conditions. We will present numerical results verifying the theoretical results.

Vittorio Colao, Università della Calabria

Equilibrium problems in Hadamard manifolds

Equilibrium problems in linear spaces had been widely investigated in recent years and by several authors. It had been proved that a broad class of problems, such as variational inequality, convex minimization, fixed point and Nash equilibrium problems can be formulated as equilibrium problems.

In this talk, I will deal with equilibrium problems in the setting of manifolds with nonpositive sectional curvature. An existence result will be presented, together with applications to variational inequality, fixed point for multivalued maps and Nash equilibrium problems. I will also introduce a firmly nonexpansive resolvent and discuss an approximation result for equilibrium points.

Laurentin Leustean, Simion Stoilow Institute of Mathematics of the Romanian Academy [with David Arco-Ruiz, Genaro Lopez-Acedo]

Firmly nonexpansive mappings in classes of geodesic spaces

Firmly nonexpansive mappings play an important role in metric fixed point theory and optimization due to their correspondence with maximal monotone operators. In this paper we do a thorough study of fixed point theory and the asymptotic behaviour of Picard iterates of these mappings in different classes of geodesic spaces, as uniformly convex\(W\)-hyperbolic spaces, Busemann spaces and CAT(0) spaces. Furthermore, we apply methods of proof mining to obtain effective rates of asymptotic regularity for the Picard iterations.

Paulo Oliveira, Federal University of Rio de Janeiro [with Gladston Beno, João Cruz Neto, Erik Ruiz]

Proximal and descent methods on Riemannian manifolds

This talk has two parts. In the first, it is analyzed the proximal point method applied in Hadamard manifolds, associated to the corresponding distance. The considered functions are locally Lipschitz quasi convex. Under reasonable hypothesis, it is proved the global convergence of the sequence generated by the method to a critical point. In the second part, we deal with the classical descent method, also known as Kurdyka-Lojasiewicz property. An abstract convergence analysis for inexact methods in Riemannian manifolds allows to obtain full convergence of bounded sequences applied to proximal method, associated to a quasi-distance (the usual distance without symmetry). The results are independent of the curvature of the manifold. A second application of the abstract theory is the convergence of inexact descent method for that class of functions on Hadamard manifolds. This extends known results for Riemannian manifolds with positive curvature. Finally, some applications are cited in related papers.

Variational analysis

Variational inequalities and optimization problems on Riemannian manifolds

Organizers/Chairs Genaro López, University of Seville; Chong Li, Zhejiang University - Invited Session

Vittorio Colao, Università della Calabria

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goal is to maximize the number of successful connections in arbitrary wireless networks where a transmission is successful only if the signal-to-interference-plus-noise ratio at the receiver is greater than some threshold. We study a game theoretic approach towards capacity maximization introduced by Andrews and Dinitz, where the key to the approximation lies in the use of low-regret algorithms. We prove vastly improved bounds for the game theoretic algorithm. In doing so, we achieve the first distributed constant factor approximation algorithm for capacity maximization for the uniform power assignment. When compared to the optimum where links may use an arbitrary power assignment, we prove a $O(\log^2 n)$ approximation, where $\Delta$ is the ratio between the largest and the smallest link in the network. This is an exponential improvement of the approximation factor compared to existing results for distributed algorithms. All our results work for links located in any metric space. In addition, we provide simulation studies clarifying the picture on distributed algorithms for capacity maximization.

David Phillips, U.S. Naval Academy (with Adam Carpenter, Lawrence Leemis, Alan Papir, Grace Phillips)

Scheduling and planning magnetic resonance imaging machines

We devise models and algorithms to estimate the impact of current and future patient demand for examinations on magnetic resonance imaging (MRI) machines at a hospital radiology department. Our work helps improve scheduling decisions and supports MRI machine personnel and equipment planning decisions. Of particular novelty is our use of approximation algorithms from scheduling to compute the competing objectives of maximizing examination throughput and patient-magnet utilization. We also use resource augmentation to show that our algorithm is an $O(1)$-speed algorithm for computing a bicriteria solution. We provide computational results demonstrating how our model can be used to both assess scheduling decisions as well as help guide planning decisions.

Stephen Vavasis, University of Waterloo (with Venkat Chandrasekaran, Xuan Vinh Doan)

Identifying large submatrices using convex programming

We consider the problem of identifying $k$ large approximately rank-one submatrices of a nonnegative data matrix. Stated in a certain manner, this problem is NP-hard, but has important applications in data mining. In particular it is a version of the well-known nonnegative matrix factorization, which has been applied to document classification, image decomposition, and analysis of biochemical experiments. We prove that if the data is constructed according to a certain randomized model, then the $k$ blocks can be recovered in polynomial time via convex relaxation.

João Gouveia, University of Coimbra (with Richard Robinson, Rekha Thomas)

Semidefinite lifts of polytopes

Recently, there has been a renewed interest in understanding the existence of small linear or semidefinite representations for polytopes. These representations, which are obtained by adding extra variables, are deeply connected to certain special factorizations of the slack matrix of the polytopes.

In this talk, we explore this connection to present some results on the size of semidefinite lifts of polytopes, with focus on examples, surveying what is known in the area.

François Glineur, UCL / CORE

Combinatorial optimization

Approximation algorithms for convex sets

Organizers/Chairs Pablo Parrilo, Massachusetts Institute of Technology; Rikha Thomas, University of Washington - Invited Session

Stephan Yasavias, University of Waterloo (with Venkat Chandrasekaran, Xuan Vinh Doan)

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François Glineur, UCL / CORE

Compact polyhedral approximations for convex sets defined by polynomials

Ben-Tal and Nemirovski proposed in 2001 a way to approximate second-order cone optimization problem with linear optimization. Their technique relies on a clever linear extended formulation for the two-dimensional regular $2^p$-gon. Since these polytopes approximate the two-dimensional disc, polyhedral approximations for any second-order cone optimization problem can be derived. These approximations are compact in the sense that they feature a number of vertices that is exponential in the size of their extended formulation.

In this talk, we present a generalization of this construction that provides new polyhedral approximations for a large class of convex sets defined by convex univariate polynomial inequalities. In doing so, we achieve the first compact extended formulation for a polyhedral approximation of a specific spectrahedron, namely the convex hull of the moment curve. This construction features links with cyclic polytopes and the trigonometric moment curve. We also report on numerical experiments demonstrating usefulness of this technique.
Reduced integrality gaps and improved approximations via lift-and-project methods

We consider natural convex relaxations of integer programs, such as linear programs (LP) and semi-definite programs (SDP), and examine how well they approximate various problems in combinatorial optimization. The “integrality gap” – the worst-case gap between the optimum of a convex relaxation and that of the integer program – can sometimes be reduced by considering a hierarchy of relaxations derived from lift-and-project methods.

We will look at different hierarchies, and some universal properties of the LP and SDP relaxations derived from them. Moreover, we will see how, for certain NP-hard optimization problems, we can achieve improved approximations using such strengthened relaxations while maintaining polynomial running time overall.

Monique Laurent, CWI, Amsterdam and U Tilburg (with Elisse de Klerk)

Error bounds for sums of squares relaxations of some polynomial optimization problems

We consider semidefinite programming relaxations for polynomial optimization problems based on sums of squares of polynomials and the dual relaxations based on moment matrices.

In particular, we discuss error bounds for optimization over the hypercube for the hierarchy of relaxations corresponding to the Positivstellensätze of Handelman and of Schmüdgen. These bounds are explicit and sharpen an earlier result of Schweighöfer (2004). We also discuss links to error bounds for optimization over the simplex and for the Lasserre hierarchy.

Madhur Tulsiani, Toyota Technological Institute at Chicago

Combinatorial optimization

Tue.2.H 3005

Combinatorics and geometry of linear optimization I

Organizers/Chairs: Antoine Deza, McMaster University; Jesús De Loera, University of California, Davis - Invited Session

Francisco Santos, Universidad De Cantabria

Counter-examples to the Hirsch conjecture

About two years ago I announced the first counter-example to the (bounded) Hirsch conjecture: a 43-dimensional polytope with 86 facets and diameter at least 44. It was based on the construction of a 5-prismatoid of “width” 6, with 48 vertices. Since then, some improvements or related results have been obtained: S.-Stephen-Thomas showed that prismatoids of dimension 4 cannot lead to non-Hirsch polytopes, and S.-Matschke-Weibel constructed smaller 5-prismatoids of length 6, now with only 25 facets. These produce counter-examples to the Hirsch conjecture in dimension 20.

But, all in all, the main problem underlying the Hirsch Conjecture remains as open as before. In particular, it would be very interesting to know the answer to any of the following questions:

(a) Is there a polynomial bound \( f(n) \) for the diameter of \( n \)-faceted polytopes? (‘Polynomial Hirsch Conjecture’).

(b) Is there a linear bound? Is \( f(n) = 2n \) such a bound?

A conjecture of Hähnle, suggested by the work of Eisenbrand et al. in the abstract setting of “connected layer sequences” would imply that \( nd \) is an upper bound.

Niccolò D’Aloisio, TU Berlin

An abstract view on the polynomial Hirsch conjecture

The question of whether a strongly polynomial algorithm for linear programming exists is one of the great mysteries of the field. It has motivated the polynomial Hirsch conjecture, which claims that the diameter of the vertex-edge graph of every polyhedron is bounded by a polynomial in the affine dimension and the number of facets.

The best known upper bound on the diameter of polyhedra is a quasi-polynomial bound due to Kalai and Kleitman. What properties of polyhedra make this upper bound work? What techniques could be useful in improving it? We present a purely combinatorial abstraction of the graph of a polyhedron as a way of understanding these questions better. In particular, we present an abstraction in which an almost quadratic construction is known, while the Kalai-Kleitman bound still holds with essentially the same proof.

We made the conjecture that an upper bound of \( d(n-1) \) holds for this abstraction. We present some evidence for and against this conjecture, and discuss open questions that could guide possible approaches to the polynomial Hirsch conjecture.

Yuriy Zinchenko, University of Calgary (with Antoine Deza, Tamás Terlaky)

Polytopes and arrangements: Diameter and curvature

We introduce a continuous analogue of the Hirsch conjecture and a discrete analogue of the result of Dedieu, Malajovich and Shub. We prove a continuous analogue of the result of Holt and Klee, namely, we consider a family of polytopes which attain the conjectured order of the largest total curvature, and a continuous analogue of a d-step equivalence result for the diameter of a polytope. Potential extensions of this work will be highlighted.

Combinatorial optimization

Tue.2.H 3012

Algorithms for transistor-level layout

Organizer/Chair: Stefan Hougardy, University of Bonn - Invited Session

Jan Schneider, University of Bonn (with Stefan Hougardy, Tim Nieberg)

BonnCell: Routing of leaf cells in VLSI design

In this talk, we present and discuss the routing engine of BonnCell. Given a placed leaf cell, the task at hand is to find an embedding of rectilinear Steiner trees which realizes a given netlist subject to various design rules. As a leaf cell is rather small compared to other structures usually present in VLSI design, all constraints have to be considered at the same time and as accurately as possible making leaf cell routing a very complicated problem in practice. The underlying algorithm of our solution uses a constraint generation approach based on a MIP model for packing Steiner trees in graphs and is extended to produce a problem specific formulation. While relaxing (some of) the constraints is not an option for the application, there are several ways to improve on the solution times. These include further strong valid inequalities and also some heuristic elements. Next to these, we also report on results for current real-world designs at the 22 nm chip production node.

Jan Schneider, University of Bonn (with Stefan Hougardy, Tim Nieberg)

BonnCell: Placement of leaf cells in VLSI design

The automatic layout of leaf cells in VLSI design requires significantly different algorithms than classical tools for the physical design of VLSI instances. While the number of placement objects in leaf cells is very small, at most a few dozen, the placement constraints are not covered by usual approaches. We present the placement engine of our tool BonnCell, which computes optimal placements for most real-world instances within seconds. Optimality is measured with respect to a target function that models the cell routability and proved to be very accurate in practice.

Stefan Hougardy, University of Bonn

Transistor level layout: Algorithms and complexity

In hierarchical VLSI design a leaf cell is a functional unit at the lowest level of the hierarchy. A leaf cell implements a specific function. It is built from a small number of transistors that are connected by wires.

The problem of automatically generating transistor level layouts of leaf cells has been studied for several decades. It requires the solution of hard problems as for example Steiner tree packing problems or linear arrangement problems. We give an overview of some of the algorithmic problems appearing in the transistor level layout of leaf cells and discuss why current VLSI technology requires new algorithms.

Combinatorial optimization

Tue.2.H 3013

Matching and related problems

Organizer/Chair: Gyula Pap, Eötvös University - Invited Session

Kristóf Bérczi, Eötvös Research Group, Eötvös Loránd University, Budapest

Restricted \( k \)-matchings

A \( C_k \)-free \( 2 \)-factor is a \( 2 \)-factor not containing cycles of length at most \( k \). Cornuéjols and Pulleyblank showed that deciding the existence of such a subgraph is NP-complete for \( k \geq 5 \). On the other hand, Hartvigsen proposed an algorithm for the triangle-free case \( k = 3 \). The existence of a \( C_3 \)-free or \( C_4 \)-free \( 2 \)-matching is still open (in the latter, triangles are allowed). Yet imposing the condition that the graph is subcubic (that is, the maximum degree of \( G \) is 3), these problems become solvable.
Combinatorial optimization

Samir作出了一个重要的贡献，使用了一种新的方法来解决一个组合优化问题。具体来说，Samir展示了一个算法来求解一个特定的组合优化问题。该算法通过使用一个特定的图来表示问题，进而通过一个特殊的排序来求解问题。这种方法在某些情况下可以显著地减少计算复杂度，从而提高了问题的可解决性。
Applications of semidefinite programming

Martin Lotz, The University of Edinburgh (with Dennis Amelunxen)

 Conditioning of the convex feasibility problem and sparse recovery

The problem of whether certain simple or sparse solutions to linear systems determined by matrices A of low rank can be efficiently found is of fundamental interest. For a fixed family of matrices A, the problem is polynomially solvable if the family of matrices A is contained in a fixed “semidefinite representable norm”. This is a closed convex set of matrices that is convex and is characterized by semi-definite programming (SDP) feasibility problems. The solution of such problems is known to be NP-hard in general.

A smooth primal–dual perceptron–von Neumann algorithm

We propose an elementary algorithm for solving a system of linear inequalities $A^T y > 0$ or its alternative $Ax \geq 0, x \neq 0$. Our algorithm is a smooth version of the perceptron and von Neumann’s algorithm.

Joint spectral radius, path-complete graphs, and semidefinite programming

The joint spectral radius (JSR) of a finite set of square matrices – a natural generalization of the notion of the spectral radius of a single matrix – characterizes the maximal growth rate that can be obtained by taking products, of arbitrary length, of all possible permutations of the matrices. Despite several undecidability and NP-hardness results related to computation (or approximation) of the JSR, the topic continues to attract attention because of a wide range of applications, including computation of the capacity of codes, robust stability of uncertain linear systems, Leontief input–output model of the economy with uncertain data, convergence of consensus algorithms, and many others.

In this talk, we present our novel framework of lazy clause generation for RCPSP

This is a talk about proposed an elementary algorithm for solving a system of linear inequalities $A^T y > 0$ or its alternative $Ax \geq 0, x \neq 0$. Our algorithm is a smooth version of the perceptron and von Neumann’s algorithm. Our algorithm retains the simplicity of these algorithms but has a significantly improved convergence rate.

A smooth primal–dual perceptron–von Neumann algorithm

We propose an elementary algorithm for solving a system of linear inequalities $A^T y > 0$ or its alternative $Ax \geq 0, x \neq 0$. Our algorithm is a smooth version of the perceptron and von Neumann’s algorithm. Our algorithm retains the simplicity of these algorithms but has a significantly improved convergence rate.
tion routines can help identify, characterize, reduce, and possibly eliminate uncertainty while drastically improving the usefulness of computational models and optimal solutions. Current approaches are in that they first identify optimal solutions and then, perform a series of UQ runs using these solutions. Although this approach can be effective, it can be computationally expensive or produce incomplete results. Model averaging, which takes advantage of intermediate optimization iterates can reduce the expense, but the sampling done by the optimization algorithms is not ideal. In this talk, we discuss a simultaneous optimization and UQ approach that combines Bayesian statistical models and derivative-free optimization in order to monitor and use sensitivity information throughout the algorithm’s execution.

Satyajith Amaran, Carnegie Mellon University (with Scott Bury, Nikolaos Sahinidis, Bikram Sharda)
A comparison of software and algorithms in unconstrained simulation optimization problems

Over the last few decades, several algorithms for simulation optimization (SO) have appeared and, along with them, diverse application areas for these algorithms. The algorithmic approaches proposed in the literature include ranking and selection, sample average approximation, metaheuristics, response surface methodology and random search. Application areas range from urban traffic control to investment portfolio optimization to operation scheduling. However, a systematic comparison of algorithmic approaches for simulation optimization problems from the literature is not available. At this juncture in the evolution of SO, it is instructive to review the size and kinds of problems handled as well as the performance of different classes of algorithms, both in terms of quality of solutions and number of experiments (or function evaluations) required. In this work, we use a library of diverse algorithms, and propose a method to assess their performance under homogeneous and heterogeneous variances on a recently-compiled simulation optimization test set. Discussions follow.

Yuying Li, University of Waterloo (with Thomas Coleman, Jiong Xi)
A novel method for computing an optimal VaR portfolio

Computing an optimal portfolio with minimum value-at-risk (VaR) is computationally challenging since there are many local minimizers. We consider a nonlinearly constrained optimization formulation directly based on VaR definition in which VaR is defined by a probabilistic inequality constraint. We compute an optimal portfolio using a sequence of smooth approximations to the nonlinear inequality constraint. The proposed sequence of smooth approximations gradually becomes more nonconvex in an attempt to track the global optimal portfolio. Computationally comparisons will be presented to illustrate the accuracy and efficiency of the proposed method.

Giang Lin, Carnegie Mellon University (with Javier Pena)
First-order algorithms for optimal trade execution with dynamic risk measures

We propose a model for optimal trade execution in an illiquid market that minimizes a coherent dynamic risk of the sequential transaction costs. The prices of the assets are modeled as a discrete random walk perturbed by both temporal and permanent impacts induced by the trading volume. We show that the optimal strategy is time-consistent and deterministic if the dynamic risk measure satisfies a Markov property. We also show that our optimal execution problem can be formulated as a convex program, and propose an accelerated first-order method that computes its optimal solution. The efficiency and scalability of our approaches are illustrated via numerical experiments.

Soumyen Mouzumi, Princeton University (with Thomas Coleman, Yuying Li)
Regularized robust optimization for optimal portfolio execution

An uncertainty set is a crucial component in robust optimization. Unfortunately, it is often unclear how to specify it precisely. Thus it is important to study sensitivity of the robust solution to variations in the uncertainty set, and to develop a method which improves stability of the robust solution to common issues. In this work, we focus on uncertainty in the price impact parameters in the optimalportfolio execution problem. We illustrate that a small variation in the uncertainty set may result in a large change in the robust solution. We then propose a regularized robust optimization formulation which yields a solution with a better stability property than the classical robust solution. In this approach, the uncertainty set is regularized through a regularization constraint. The regularized robust solution is then more stable with respect to variation in the uncertainty set specification, in addition to being more robust to estimation errors in the price impact parameters. We show that the regularized robust solution can be computed efficiently using convex optimization. We also study implications of the regularization on the solution and its corresponding execution cost.
finding global robust solutions of robust optimization problems

In our talk we discuss finding global robust solutions of robust optimization problems having a quadratic cost function and quadratic inequality constraints. The uncertainties in the constraint coefficients are represented using either universal or existential quantified parameters and interval parameter domains. This approach allows to model non-controlled uncertainties by using universally quantified parameters and controlled uncertainties by using existentially quantified parameters. While existentially quantified parameters could be equivalently considered as additional variables, keeping them as parameters allows maintaining the quadratic problem structure, which is essential for our algorithm.

The branch and bound algorithm we present handles both universally and existentially quantified parameters in a homogeneous way without branching on their domains, and uses some dedicated numerical constraint programming techniques for finding the robust, global solution. The algorithm’s worst-case complexity is exponential with respect to the number of variables only, even in the case of many and/or large parameters uncertainties.

Arnold Neumaier, University of Vienna (with Ferenc Domes, Mihaly Markot, Hermann Schichl)

Projective methods for constraint satisfaction and global optimization

Many constraint satisfaction problems and global optimization problems contain some unbounded variables. Their solution by branch and bound methods poses special challenges as the search region is infinitely extended. Most branch and bound solvers add artificial bounds to make the problem bounded, or require the user to add these. However, if these bounds are too small, they may exclude a solution, while when they are too large, the search in the resulting huge but bounded region may be very inefficient. Moreover, global solvers that provide a rigorous guarantee cannot accept such artificial bounds.

We present methods based on compactification and projective geometry to cope with the unboundedness in a rigorous manner. Two different versions of the basic idea, namely (i) projective constraint propagation and (ii) projective transformation of the variables, are implemented in the rigorous global solvers COCONUT and GloptLab.

Numerical tests demonstrate the capability of the new technique, combined with standard pruning methods, to rigorously solve unbounded global problems.

Most of the techniques are implemented in the Minion solver. I will give an overview of Minion’s features, strengths and weaknesses.

Guido Tack, MICTA / Monash University (with Sebastian Brand, Mark Brown, Thibaud Feydy, Julien Fischer, Maria García de la Banda, Peter Stuckey, Mark Wallace)

Towards MiniZinc 2.0

MiniZinc is a language for modelling combinatorial problems. It aims at striking the right balance between expressiveness on the one hand, and support for different solvers on the other. To this end, MiniZinc provides a library of predicates defining global constraints, and a generic translation to FlatZinc, a low-level language that is easy to support by different solvers.

Since its inception in 2006, MiniZinc has gained considerable momentum. In its current version 1.5, the G12 MiniZinc distribution provides a complete, stable, usable toolchain for modelling and solving combinatorial problems. Its library contains definitions of over 150 global constraints, and there are backends for a variety of different solvers, from constraint programming, to mathematical programming, to SAT and SMT. The next major milestone will conservatively extend the language with features from full Zinc, add more control over the search, and open up the toolchain to allow for customisation of the translation and easier integration into existing software.

This presentation gives an overview of the MiniZinc system, what is planned for version 2.0, and the techniques required to implement it.
function by studying MCCNFP over a grid network with a general non-negative separable concave function. We show that this problem is polynomial solvable when all source nodes are at the first echelon and all sink nodes are at the last echelon. The polynomiality argument relies on a combination of a particular dynamic programming formulation and a careful investigation of the extreme points of the underlying flow polyhedron. We derive an analytical formula for the infnorm of any non-zero extreme point, which generalizes Zangwill’s result for the multi-echelon lot-sizing problem.

Tamtam Kus, META SZITAKI

**Strengthening the MIP formulation of a bilevel lot-sizing problem**

In the talk, I will introduce the bilevel lot-sizing problem, and show how to formulate it as a MIP. In addition, I will present problem specific bounds and cuts, as well as mixed integer disjunctive cuts derived from two rows of the simplex tableau, one corresponding to an integer variable, the other to a continuous variable. I will also discuss the computational merits of the various strengthening methods.

Fabio Furini, Università di Bologna (with Manuel Iori, Silvano Martello, Mutsumi Yagura)

**Heuristic and exact algorithms for the interval min-max regret knapsack problem**

We present a generalization of the 0-1 knapsack problem in which the profit of each item can take any value in a range characterized by a minimum and a maximum possible profit. A set of specific profits is called a scenario. The interval min-max regret knapsack problem (IMRP) is then to find a feasible solution such that the maximum regret over all scenarios is minimized. The problem is extremely challenging both from a theoretical and a practical point of view. Its recognition version is complete for the complexity class $\Sigma_2^P$, hence it is most probably not in $\mathbb{NP}$. In addition, even computing the regret of a solution with respect to a scenario requires the solution of an $\mathbb{NP}$-hard problem. We examine the behavior of classical combinatorial optimization approaches when adapted to the solution of the IMRP. We introduce an iterated local search approach and a Lagrangian-based branch-and-cut algorithm, and evaluate their performance through extensive computational experiments.

Life sciences & healthcare

Bioinformatics and combinatorial optimization II

Organizers/Chair: Gunnar Klau, CWI - Invited Session

Johannes Köster, Universität Duisburg-Essen (with Sven Rahmann, Eli Zamir)

**Protein hypernetworks**

Protein interactions are fundamental building blocks of biochemical reaction systems underlying cellular functions. The complexity and functionality of such systems emerge not only from the protein interactions themselves but mainly from the dependencies between these interactions, e.g., due to allosteric regulation or steric hindrance. Therefore, a comprehensive approach for integrating and using information about such dependencies is required. We present an approach for drawing protein networks with interaction dependencies using propositional logic, thereby obtaining protein hypernetworks. As can be expected, this framework straightforwardly improves the prediction of protein complexes. We found that modeling protein perturbations in hyper-networks, rather than in networks, allows better inference also the functional necessity and synthetic lethality of proteins in yeast.

Gunnar Klau, CWI (with Stefan Cancer, Mohammed El-Kebir, Khalid Elbassioni, Daan Geerke, Alpesh Malde, Alan Mark, René Pool, Leen Stougie)

**Charge group partitioning in biomolecular simulations**

Molecular simulation techniques are increasingly being used to study biomolecular systems at an atomic level. Such simulations rely on empirical force fields, which represent the intermolecular interactions. Different set of assumptions and thus requiring different parametrization methods.

Rumen Andonov, INRIA and University of Rennes 1 (with Gunnar Klau, Inken Wohlers)

**Optimal DALI protein structure alignment**

We present a mathematical model and exact algorithm for optimally aligning protein structures using DALI score, which is an $\mathbb{NP}$-hard problem. DALI score is based on comparing the inter-residue distance matrices of proteins, and is the scoring model of a widely used heuristic. We extend an integer linear programming approach which has been previously applied for the related, but simpler, contact map overlap problem. To this end, we introduce a novel type of constraint that handles negative score values and relax it in a Lagrangian fashion. The new exact algorithm is thus applicable to any distance matrix-based scoring scheme. Using four known data sets of varying structural similarity, we compute many provably optimal alignments. Thus, for the first time, we evaluate and benchmark the popular heuristic in sound mathematical terms. The results indicate that usually the heuristic computes optimal or close to optimal alignments. However, we detect an important subset of small proteins for which DALI fails to generate any significant alignment, although such alignments do exist.

Julia Sender, TU Dortmund University (with Ivan Clausen)

**A local improvement heuristic for a hub location problem in wagonload traffic**

In wagonload traffic, single wagons with different origins and destinations are consolidated on their routes through the railway network. The consolidation of wagons decreases the transportation costs but increases additional costs due to establishing and operating hub facilities. We present a specific capacitated multiple allocation hub location problem for constraining network design of wagonload traffic developed together with our partner Deutsche Bahn AG. The model covers the main characteristics of wagonload traffic. Due to the difficulty to solve real-sized instances to near-optimality, we develop a new heuristic solution approach. The presented heuristic approach is based on local improvements (obtained, e.g., by relocation, opening, or closure of hub nodes or reallocation of non-hub nodes to hub nodes). We solve the problem with the heuristic approach and CPLEX on test data sets obtained from Deutsche Bahn. The computational results are presented and compared.

Vincenzo Armentano, Universidade Estadual de Campinas (with Ana Milanez)

**Tabu search for the hub covering problem**

Hub location is an important research area due to the use of hub networks in transportation and telecommunication systems that serve demand for goods or information between many origins and many destinations. Instead of serving every origin–destination demand with a direct link, hubs are used to switch and consolidate origin–destination flows, thus reducing the number of links in the network and allowing economies of scale to be exploited. As a consolidation point, flows from the same origin with different destinations are consolidated on their route to the hub and are combined with flows that have different origins but the same destination. We address the covering hub location problem which ensures that in hub networks goods between any origin and any destination are delivered within a given time limit, an important service constraint for less-than-truckload carriers. The objective is to minimize the number of hubs to be opened. Existing research on this problem has focused on the development of tighter integer programming models, which are solved by a solver. We propose a tabu search procedure for solving this problem, and the procedure is tested on instances from the literature.

Hisakhi Mohi, Waseda University

**Some extended network hub problems**

Network hub location (NHP), also called “hub network design problems”, have many applications in the real world especially, telecommunication and transportation. We would like to introduce some extended NHPs. In this presentation, we address NHPs with the following additional conditions independently.

(i) Network flow capacity on each arc.
(ii) The number of hubs should not be fixed a constant.
(iii) On each path for demand, i.e., commodity, hubs should be located within $k$-arcs from its sink and source.

Basically, this extended problem is something like “multi-commodity min flow problem” with “hub location problem”. We would like to show a general formulation for this problem and polynomial time algorithms for special graphs. And we shall show some results for some hierarchical NHPs.
We present efficiently computable disjunctive conic cuts for MISOCO problems. The novel disjunctive conic cuts may be used to design branch-and-cut algorithms for MISOCO. Finally, some illustrative, preliminary computational results as presented when disjunctive conic cuts are used in solving MICO problems.

Sarah Drewes, T Systems International GmbH (with Alper Atamtürk)

Cover inequalities and outer-approximation for mixed-0-1 SOCPs

We present how cover inequalities can be utilized in outer approximation based branch and bound algorithms for mixed 0 − 1 convex nonlinear programming problems in general and show more specific results for a class of mixed 0 − 1 second order cone programs. The discussed class of algorithms use an outer approximation of the mixed 0-1 problem arising from linearizations of the nonlinear functions. Based on this outer approximations, assignments for the binary variables are derived which give rise to valid cover inequalities. These inequalities can then be lifted to derive strong valid inequalities that tighten the continuous relaxation of the outer approximation problem. The potential of this approach is discussed considering a class of mixed 0 — 1 second order cone programs for which a computational study is provided.

Antonio Morsi, FAU Erlangen-Nürnberg, Discrete Optimization (with Björn Geisler, Alexander Martin, Lars Schewe)

Solving MINLPs on loosely coupled networks

Considering MINLPs defined on a network structure, such as nonlinearly-constrained network flow problems, we obtain dual bounds on the overall problem by a decomposition of the underlying graph into its connected and triconnected components and by the relaxation of the coupling constraints between these components. The dual bounds are further tightened by branching on violated nonconvex constraints. Branching candidates are obtained from an approximate primal solution to the master problem, which is solved by a bundle method. To solve the subproblems, in the case of factorable MINLPs, we use Chebyshev approximation to compute univariate piecewise linearizations (or piecewise polynomials) of the arising nonlinearities in advance. These approximations lead to MILP relaxations, or mixed integer polynomial relaxations, of the subproblems. We conclude with computational results of our approach for two real-world applications, water and gas network optimization.

Multi-objective optimization

Interactive multiobjective optimization

Organizer/Chair Kaisa Miettinen, University of Jyväskylä and KTH Royal Institute of Technology - Invited Session

Martin Geiger, Helmut-Schmidt-University (with Thibaut Barthélémy, Marc Sevaux)

Multi-objective inventory routing: Reference-point-based search, representations, and neighborhoods

The talk considers a multi-objective generalization of the inventory routing problem, a problem that facilitates efficient transport of goods. In our problem formulation, inventory levels and routing costs are not combined into an overall evaluation function but treated separately. The problem is solved by using metaheuristics, and numerical results are computed and reported. Particular emphasis has been laid on the representation of solutions from a practical point of view. In detail, individual frequency values are derived for each customer, implementing a recurring delivery policy. On the one hand, this leads to a relatively easy, understandable encoding of delivery policies. On the other hand however, the possibilities of the optimization approach are depending on the chosen representation, and interrelations with the chosen neighborhoods and search-optimization-strategies become apparent.

Our findings show that there is great potential for tradeoffs between the two objectives. Especially in tactical planning situations, this problem extension can provide useful insights. A DSS making use of multiple reference points has thus been realized.

Kaisa Miettinen, University of Jyväskylä and KTH Royal Institute of Technology (with Markus Hartikainen, Kathrin Klarmann)

Interactive Pareto Navigator method for nonconvex multiobjective optimization

This talk describes a new interactive method called Nonconvex Pareto Navigator which extends the convex Pareto Navigator method for non-convex multiobjective optimization problems. In the new method, a piecewise linear approximation of the Pareto optimal set is first generated using a relatively small set of Pareto optimal solutions. The decision maker (DM) can then navigate on the approximation and direct the search for interesting regions in the objective space. In this way, the DM can conveniently learn about the interdependencies between the conflicting objectives and possibly adjust one’s preferences. Besides non-convexity, the new method contains more versatile options for directing
the navigation. The Nonconvex Pareto Navigator method aims at supporting the learning phase of decision making. It is well-suited for computationally expensive problems because the navigation is computationally inexpensive to perform on the approximation. Once an interesting region has been found, the approximation can be refined in that region or the DM can ask for the closest actual Pareto optimal solution.

Hans Triebka, Fraunhofer ITWM

**Multi criteria decision support in real-time**

Integration of Project, Process and Knowledge Management. The business processes observed here affect various organizational units during evolving in successive phases. A few examples to that: surveillance and maintenance of ship equipment, transport logistics of wind wheel parts, and innovation of OLED technology. At certain stations of those processes several things have to be done: knowledge retrieval and storage, working out of prescribed context relevant documents or performing situation dependent programs, and exploring and evaluating various feasible scenarios. Again some examples: time- or cost-optimal remedying of a ship’s defect, selecting, assembling and tracking of conveyor chains, and designing and simulating product or shop floor prototypes. In finding “best paths” through such dynamic processes two tools, addressing the outstanding visual cognition of man, assist: “process-Board”, for designing, adapting, monitoring and controlling processes on a virtual board, and “knowCube”, for getting balanced decisions by using a graph method, applicable by non-experts, too. Both tools are combined in a web portal.

**Nonlinear programming**

**Methods for nonlinear optimization V**

Chair Marco Ružičić, Helmut-Schmidt-University Hamburg

Manuel Jaraczewski, Helmut-Schmidt-Universität - Universität der Bundeswehr Hamburg (with Marco Ružičić, Marcus Stiemer)

**Interior point methods for a new class of minimum energy point systems on smooth manifolds**

Point systems with minimum discrete Riesz energy on smooth manifolds are often considered as good interpolation and quadrature points. Their properties have intensively been studied, particularly for the sphere and for tori. However, these points do not optimally fast converge to the corresponding equilibrium distribution, since the continuous potential’s singularity is poorly reproduced. We, hence, propose an alternative point system that avoids this problem and we provide a method for its numerical identification via constrained optimization with an interior point method. The key idea is dividing the points into two classes and considering them as vertices of a graph and its dual, respectively. Geometric relations between primal faces and dual vertices serve as constraints, which additionally stabilize the optimization procedure. Further, a prior global optimization method as usually applied for computing minimum discrete Riesz energy points can be avoided. Finally, both the new determined extreme points both approximation properties and efficient determinability are studied and compared to those of the minimum discrete Riesz energy points.

Marco Ružičić, Helmut-Schmidt-University Hamburg (with Robert Appel, Marcus Stiemer)

**Interior point methods for the optimization of technological forming processes**

Recent results in forming technology indicate that forming limits of classical quasi-static forming processes can be extended by combining them with fast impulse forming. However, in such combined processes, parameters have to be chosen carefully, to achieve an increase in formability. In previous works a gradient based optimization procedure as well as a simulation framework for the coupled process has been presented. The optimization procedure strongly depends on the linearization of the full coupled problem, which has to be completely simulated for gradient- and function- evaluation. In order to gain insight into the structure of the underlying optimization problem we analyse parameter identification an elastic deformation problem. Within this framework all needed derivative information is analytically computable and optimality conditions can be proved. This is used to perform systematic studies of properties and behaviour of the problem. We show that replacing derivative information with finite difference approximations requires additional constraints in order to retain physical feasibility. Finally we extend the developed scheme by introducing a plasticity model.
asymptotic convergence of the proposed scheme on a receding horizon is given for the nonlinear discrete-time case. An upper bound on the allowable sampling time of the scheme and on the loss of optimality is derived.

Francesco Borrelli, UC Berkeley (with Masaki Jadboda, Yudong Ma)

Real-time stochastic predictive control applied to building control systems

The presentation will focus on the solution of linear stochastic model predictive control (SMPC) subject to chance constraints. We present two approaches. In the first approach, we introduce a set of unknowns representing the allowable violation for each constraint (the risk) and introduce a tailored interior point method. The second approach is based on the sample-based approach, a large number of stochastic samples is used to transform the SMPC problem into a deterministic one with the original constraints evaluated in each sample. The proposed methods are applied to a building control problem which minimizes energy usage while keeping zone thermal comfort by using uncertain prediction of thermal loads and ambient temperature. Extensive numerical and experimental tests are used to analyze the conservatism and the effectiveness of the proposed approaches.

Cosmin Petra, Argonne National Laboratory (with Mihai Anitescu, Miles Lubin)

Scalable stochastic optimization of power grid energy systems

We present a scalable approach for solving stochastic programming problems with application to the optimization of power grid energy systems with supply and demand uncertainty. Our framework, PIPS, has parallel capabilities for both continuous and discrete stochastic optimizations problems. The continuous solver uses an interior-point method and a Schur complement technique to obtain a scenario-based decomposition. With the aim of providing a scalable solution for problems with integer variables, we also developed a linear algebra decomposition strategy for simplex methods that is used in a parallel branch-and-bound framework.

We will also discuss application-specific algorithmic developments and computational results obtained on Intrepid Blue Gene/P system at Argonne when solving unit commitment problems with billions of variables.

Diego Klabjan, Northwestern University (with Frank Schneider, Ulrich Thonemann)

Day ahead stochastic unit commitment with demand response and load shifting

High costs for fossil fuels and increasing shares of intermittent energy sources are imposing big challenges on power grid management. Uncertainty in generation as well as in demand for electric energy call for flexible generation capacity and stochastic optimization of generation schedules. Emerging smart grid technology is one component believed to be a successful tool to increase efficiency in power generation and mitigate effects of increasing uncertainty. We focus on the potential of demand side resources (DSRs) that can be dispatched to reduce load at peak times. We present a stochastic dynamic programming model for the unit commitment problem in a day ahead market and include dispatch decisions for DSRs. We model the effect of load shifting to previous and subsequent periods that must be taken into account when making dispatch decisions. We also present an approximate dynamic programming algorithm embedded in a decomposition algorithm that enables us to capture effects of DSR dispatch on previous periods and to solve both problems concurrently. Lower bounds on the optimal solution are developed.

Basic Defformy, Princeton University (with Ethan Fang, Warren Powell, Hugo Simon)

A quantile-based approach to unit commitment with wind

Handling higher levels of uncertainty in the unit commitment problem (UC) is an important issue for the independent system operator (ISO) who is dealing with an increasing level of variable energy resources (VERs), and specifically energy from wind. Here, we focus on approximations that plan for uncertainty by adding to the original problem new penalties or constraints, and then view the weights of the new terms as tunable parameters. We investigate methods where the wind energy seen by the UC problem is a certain quantile of the forecasted wind distribution. The quantiles are then tuned based on a simulation of the recourse costs. The work is motivated by an analogy with newsvendor-type problems where the overage and underage costs of wind energy forecasts have to be estimated, given a day-ahead schedule.
ing the benefits and gains derived from their usage that have allowed X to be pioneer among others Latin America’s ISOs.

Raphael Gonçalves, UFSE – LattPlan (with Edson da Silva, Erwin Finardi)

Analyzing multistage stochastic optimization methods to solve the operation planning problem of hydrothermal systems

The operation planning of hydrothermal systems is, in general, divided into coordinate steps which have different horizons and prioritizes distinct details of the modeling. The medium-term operation planning (MOP) problem, one of the operation planning steps of hydrothermal systems and the focus of this work, aims to define the weekly generation for each plant, regarding the uncertainties related to water inflows to reservoirs, to obtain the minimum expected operational cost over a specific period. Solving this problem requires a high computational effort and, concerning the use of multistage stochastic programming algorithms. Therefore, the main purpose of this work is to present a comparative study about the performance of different multistage stochastic optimization methods applied to the MOP: Nested decomposition (ND) and the progressive hedging (PH) method. With respect to PH method, the algorithm properties and the problem features are studied to assess suitable decomposition schemes to obtain lower CPU time. To evaluate the performance of the both algorithm regarding its particularities, the Brazilian hydrothermal system is studied.

Michel Gendreau, École Polytechnique de Montréal (with Fabian Bastin, Pierre-Luc Carpentier)

Midterm hydro generation scheduling under inflow uncertainty using the progressive hedging algorithm

Hydro-Québec, one of the largest electric utilities in North America, generates virtually all of its power supply using hydro plants. A key problem faced by planners is the midterm generation scheduling problem (MGSP), solved on a weekly basis, in which generation targets must be set for controllable hydro plants in order to manage reservoir energy storage efficiently over the coming months. Reservoir inflows are the main source of uncertainty to account for in the decision-making process. In this paper, we model reservoir inflow uncertainty through scenario trees. We tackle the MGSP using the progressive hedging algorithm (PHA) (Rockafellar and Wets 1991). In our model, hydropower generation is given by concave piecewise-linear functions of the upstream reservoir storage and of water release. A key feature of our implementation of the PHA is a new penalty parameter update formula. We assess our model and algorithm on Hydro-Québec’s power system (21 large reservoirs and 7 hydro plants) over a 93-week planning horizon with several load levels. Reservoir inflow uncertainty is modeled by a 16-scenario tree. Computational results show that the proposed approach is promising.

Advances in numerical methods used to calculate the optimal coil voltage. Finally we present computations based on industrial flow meter geometries.

Olivier Teu, TU Kaiserslautern (with René Pinnau)

Optimal boundary control of natural convection–radiation model in melting furnaces

In this paper we present a comprehensive analysis of an optimal boundary control for a combined natural convection–radiation model, which has applications in the design of combustion chambers or for the control of melting processes in glass production or crystal growth. The model under investigation consists of the transient Boussinesq system coupled with a nonlinear heat equation and the SP² model for radiation. We present existence, uniqueness and regularity results of bounded states. We further state an analysis of an optimal control problem where we show the existence of an optimal control, derive the first-order optimality system and analyze the adjoint system. To underline the feasibility of the approach, we present numerical results based on a descent method using adjoint information.

.Application of robust optimization I

Applications of robust optimization I
Organizer/Chair Dick Den Hertog, Tilburg University - Invited Session

Ihsan Yankgolü, Tilburg University (with Dick Den Hertog)

Robust simulation-based optimization with Taguchi regression models

A Taguchi way to deal with uncertain environmental parameters in simulation-based optimization is to create a regression model in both the optimization variables and the uncertain parameters, and then formulate the explicit optimization problem in terms of expectations and variances, or chance constraints. The disadvantages of this approach are that one has to assume that the distribution function for the uncertain parameters is normally distributed, and that both the mean and variance are known. The final solution may be very sensitive to these assumptions. We propose a Robust Optimization approach that does not need these assumptions. Based on historical data, uncertainty regions for the distribution is generated, and tractable robust counterparts are generated. This approach can be used for many types of regression models: polynomials, Kriging, etc. The novel approach is illustrated through numerical examples. Finally, for those simulation-based optimization problems that contain ‘wait-and-see’ variables, we describe how to apply Adjustable Robust Optimization.

Yudong Chen, The University of Texas at Austin (with Constantine Caramanis, Shie Mannor)

Robust sparse regression and orthogonal matching pursuit

We consider support recovery in sparse regression, when some number $n_1$ but of $n_1 + n_2$ total covariate/response pairs are arbitrarily corrupted. We are interested in understanding how many outliers, $n_2$, we can tolerate, while identifying the correct support. As far as we know, neither standard outlier rejection techniques, nor recently developed robust regression algorithms [that focus only on corrupted response variables] provide guarantees on support recovery. Perhaps surprisingly, we also show that the natural sparse force algorithm that searches over all subsets of $n$ covariate/response pairs, and all subsets of possible support coordinates in order to minimize regression error, is remarkably poor, unable to correctly identify the support with even $n_1 = O(n/k)$ corrupted points, where $k$ is the sparsity, and $p$ is the dimension of the signal to be recovered. In this setting, we provide a simple algorithm that gives stronger performance guarantees, recovering the support with up to $n_2 = O(n/(\sqrt{k} \log p))$ corrupted points. Moreover, we compare our formulation with robustification, and demonstrate interesting connection and difference between them.

Tao Sheng Ng, National University of Singapore (with Sy Charle, Myunseok Cheong, Melvyn Sim, Lu Xu)

Target-oriented robust optimization for gas field development planning

Gas field development projects involve both investment and operation decisions, including field infrastructure installation, capacity expansions, and gas extraction planning. Many of these decisions are very expensive, difficult to reverse, and have long-term impacts on the company’s profitability. In this work we consider an offshore gas field development planning problem to achieve a target net present value at the end of the planning horizon as well as possible. This problem is severely plagued by endogenous uncertainty that is found in the efficacy of gas well reserves. Inspired by the idea of optimal planning, our approach maximizes the robustness of the development plan against uncertainty. The characteristics of the problem lead us to identify an equivalent deterministic mixed integer programming model of polynomial size, which enables us to obtain solutions to realistic size problems. Our computa-
A distributional interpretation of robust optimization, with applications in machine learning

Motivated by data-driven decision making and sampling problems, we investigate distributional interpretations of Robust Optimization (RO). We establish a connection between RO and Distributionally Robust Stochastic Programming (DRSP), showing that the solution to any RO problem is also a solution to a DRSP problem. Specially, we consider the case where multiple uncertain parameters belong to the same fixed dimensional space, and find the set of distributions of the equivalent DRSP. The equivalence that we derive enables us to construct RO formulations for sampled problems (as in stochastic programming and machine learning) that are statistically consistent, even when the original sampled problem is not. In the process, this provides a systematic approach for tuning the uncertainty set. Applying this interpretation in machine learning, we showed that two widely used algorithms — SVM and Lasso are special cases of RO, and establish their consistency via the distributional interpretation.

Boris Hasska, Imperial College London (with Moritz Diehl, Oliver Stein, Paul Steuermann)

Lifting methods for generalized semi-infinite programs

In this talk we present numerical solution strategies for generalized semi-infinite optimization problems (GSIP), a class of mathematical optimization problems which occur naturally in the context of design centering problems, robust optimization problems, and many fields of engineering science. GSIPs can be regarded as bilevel optimization problems, where a parametric lower-level maximization problem has to be solved in order to check feasibility of the upper level minimization problem. In this talk we discuss three strategies to reformulate a class lower-level convex GSIPs into equivalent standard minimization problems by exploiting the concept of lower level Wolfe duality. Here, the main contribution is the discussion of the non-degeneracy of the corresponding formulations under various assumptions. Finally, these non-degenerate re-formulations of the original GSIP allow us to apply standard nonlinear optimization algorithms.

Wolfram Wiesemann, Imperial College London (with Daniel Kuhn, Berc Rustem)

Robust Markov decision processes

Markov decision processes (MDPs) are powerful tools for decision making in uncertain dynamic environments. However, the solutions of MDPs are of limited practical use due to their sensitivity to distributional parameters, which are typically unknown and have to be estimated by the decision maker. To counter the detrimental effects of estimation errors, we consider robust MDPs that offer probabilistic guarantees in view of the unknown parameters. To this end, we assume that an observation history of the MDP is available. Based on this history, we derive a confidence region that contains the unknown parameters with a pre-specified probability $1 - \beta$. Afterwards, we determine a policy that attains the highest worst-case performance over this confidence region. By construction, this policy achieves or exceeds its worst-case performance with a confidence of at least $1 - \beta$. Our model involves the solution of tractable conic programs of moderate size.

Parallel block coordinate descent methods for huge-scale partially separable problems

In this work we show that randomized block coordinate descent methods can be accelerated by parallelization when applied to the problem of minimizing the sum of a partially block separable smooth convex function and a simple block separable convex function. We give a generic algorithm and several variants thereof, and show that on the way parallelization is performed. In all cases we prove iteration complexity results, i.e., we give bounds on the number of iterations sufficient to approximately solve the problem with high probability. Our results generalize the intuitive observation that in the separable case the theoretical speedup caused by parallelization must be equal to the number of processors. We show that the speedup increases with the number of processors and with the degree of partial separability of the smooth component of the objective function. Our analysis also works in the mode when the number of blocks being updated at each iteration is random, which allows for modeling situations with variable (busy or unreliable) number of processors. We include with some encouraging computational results applied to huge-scale LASSO and sparse SVM instances.

Martin Takac, University of Edinburgh (with Jakub Marecek, Peter Richtarik)

Block coordinate descent method for block-structured problems

We are concerned with very large scale convex optimization problems and an application of the Block Coordinate Descent (BCD) algorithm to determine their solution. We assume that the problems display a block-structure and show how this structure may be exploited to accelerate the BCD algorithm. At every iteration of the algorithm, the direction in each block-coordinate must be determined. We discuss the linear algebra techniques employed to accelerate this step. We also present a convergence analysis and a complexity result, which provide a linear algebra insight into the standard convex optimization techniques.

Rachael Tappenden, University of Edinburgh (with Jacky Gandzio, Peter Richtarik)
Stochastic optimization

Topics in stochastic programming
Organizer/Chair Gozde Bayraksan, University of Arizona - Invited Session

Johannes Royset, Naval Postgraduate School (with Roger Wets)

Nonparametric estimation using exponential epi-splines
We develop a flexible framework for nonparametric estimation of probability density functions that systematically incorporates soft information from human sources and experiences. The framework results in infinite dimensional stochastic optimization problems that are replaced by finite dimensional approximations based on exponential epi-splines. We show consistency of approximations as the order of the epi-spline grows as well as the sample size tends to infinity. We also discuss asymptotics and the implementation of soft information that dramatically improves the quality of the estimates.

David Morton, The University of Texas at Austin (with John Hasenbein, Jinho Lee)

Rapidly detecting an anomaly spreading stochastically on a network
We consider an anomaly that spreads according to stochastic dynamics on a network. Subject to a budget constraint, we install sensors on nodes of the network to maximize the probability we detect the anomaly by a time threshold. Using a Monte Carlo approximation of a stochastic integer program, we solve large-scale problem instances using data from a cell phone service provider.

Raghur Pasupathy, Virginia Tech (with Soumyadip Ghosh)

On interior-point based retrospective approximation methods for solving two-stage stochastic linear programs
We consider two-stage stochastic linear programs, the foundational formulation for optimization under uncertainty. The most general form lets the underlying distributions have infinite support. Approximate solutions to such problems are obtained by the sample average approximation approach of solving the program for a finite sample from the distribution. A recent thread of literature focuses on using interior point methods to efficiently solve two-stage programs for finite support random variables. Our contribution generalizes this formulation by incorporating it into a retrospective approximation (RA) framework. What results is an implementable interior-point solution paradigm that can be used to solve general two-stage stochastic linear programs to a desirable accuracy. After discussing some basic convergence properties, we characterize the complexity of the algorithm, leading to guidance on the optimal choice of the RA framework’s parameters as a function of the effort expended in solving the sub-problems and the effort expended in solving the master problem.

Organizer/Chair Jörg Rambau, Universität Bayreuth. Invited Session

Johannes Royset, Naval Postgraduate School (with Roger Wets)

Recoverable robust two level network design
Subramanian Raghavan, University of Maryland (with Eduardo Alvarez Miranda, Ivana Ljubic, Paolo Toth)

We consider the Steiner tree problem under a two-stage stochastic model with fixed recourse and finitely many scenarios. Thereby, edges are bought in the first stage when only probabilistic information on future edge costs and the set of terminals is known. In the second stage, one scenario is realized and additional edges are purchased to connect the now known set of terminals. The goal is to buy profitable edges in the first stage such that the overall expected costs are minimized, i.e., the sum of the first and expected second stage costs.

We discuss the strength of undirected, semi-directed, and directed cut-set based integer programming models with binary first and second stage variables. To solve this NP-hard problem to optimality, we suggest a branch-and-cut approach based on Benders decomposition and the derived Integer-L-shaped algorithm. By a simple modification of the optimal dual solution of the subproblems we show how to improve the generated optimality Cuts which reduce the running time significantly. In our experiments we compare the extended formulation and decomposition of the different models computationally.

Pedro Moura, CIO - University of Lisbon (with Luis Gouveia, Amaro Sousa)

Generalized degree constraints arising in wireless networks problems
We describe a minimum spanning tree problem with generalized degree constraints which arises in the design of wireless networks. In these networks, each link is implemented through a point-to-point wireless transmission system composed by a transmitter/receiver antenna and a signal processing unit at each side of the link. Each system works on different frequency channels chosen from a limited set of available channels. Possible overlapping may occur in a node, i.e., part of the transmitted signal on one channel is added as interference on the received signal on another channel. Due to propagation effects, the signal strength on the receiver side decreases as the distance between the transmitter and the derived Integer-L-shaped algorithm. By a simple modification of the optimal dual solution of the subproblems we show how to improve the generated optimality Cuts which reduce the running time significantly. In our experiments we compare the extended formulation and decomposition of the different models computationally.
least the lower level (secondary) technology. We are confronted with uncertainty regarding the set of primary customers, i.e., the set of nodes that need to be served by the higher level (primary) technology. A set of discrete scenarios associated to the possible realizations of primary customers is available. The network is built in two stages. One may decide to install the primary technology on some of the edges in the first stage, or one can wait to see which scenario will be realized, in which case, edges with the installed secondary technology may be upgraded to primary technology, but at higher recovery cost. The goal is to build a spanning tree in the first stage that serves all customers by at least the lower level technology, and maximizes the first stage installation plus the worst-case cost needed to upgrade the edges of that tree, so that the primary customers of each scenario can be served using the primary technology. We study the complexity of the problem on trees and provide MIP models and a branch-and-cut approach.

Variational analysis

Tue.2.R 3025
Control and optimization of impulsive systems I
Organizers/Chairs AramAuslanyan, Peoples' Friendship University of Russia; Fernando Pereira, Porto University-IFUP/Institute for Systems and Robotics Porto - Limited Session

Dmitry Karamzin, Computing Centre RAS [with Aram Auslanyan, Fernando Pereira]

Existence theorems and Pontryagin's Maximum Principle for impulsive control problems

This report addresses existence theorems and Pontryagin's Maximum Principle for constrained impulsive control problems with a new concept of impulsive control. This concept enables extra controls (conventional bounded controls) which act on the discontinuities of the impulsive system. Such type of impulsive controls can be encountered in different engineering applications in which, for example, it might be necessary to take into account rapid variations in mass distribution of a mechanical system during the short time when the impulse is being applied. There are, of course, many other applications. We provide a detailed example showing how these controls could be useful.

Geraldo Silva, UNESP - Universidade Estadual Paulista [with Valeriano Oliveira]

Optimal impulsive control problems under uncertainty

This work provides an approach to treat optimal impulsive control problems with uncertain parameters and provides necessary conditions in the form of a maximum principle. The uncertain parameter is a vector in the objective function and is chosen from a set $A$ which is taken to be a compact metric space. The necessary conditions obtained here is a generalization of the minimax maximum principle derived earlier for non-impulsive optimal control problems [Vinter04].

Valeriano de Oliveira, State University of São Paulo [with Geraldo Silva]

An Inexty Type Condition on Impulsive Optimal Control Systems

We discuss optimal control theory that the maximum principle furnishes necessary optimality conditions for an admissible process to be an optimal one. It is also well-known that if a process satisfies the maximum principle in a problem with convex data, the maximum principle turns to be likewise a sufficient condition. We here define an inexty type condition for impulsive optimal control problems. We then show that this is a sufficient optimality condition. Our definition was motivated by the one given by [Martin85], where a generalized inexty notion, called KT-inexty is introduced for mathematical programming problems. Martin took into account the KT conditions when he designed the KT-inexty. In this work we do the same, but with the Maximum Principle for optimal control problems in the impulsive setting.

Variational analysis

Tue.2.R 3026
Regularity and sensitivity in multicriteria optimization
Organizer/Chair Constantin Zalinescu, University Alexandria Ioan Cuza Iasi - Limited Session

Marius Durea, Al. I Cuza University of Iasi

Metric regularity and Fermat rules in set-valued optimization

We discuss several techniques for getting Fermat rules for set-valued unconstrained optimization. Among these techniques which are, in a sense, equivalent, we focus on a method based on the incompatibility between the metric regularity (or openness at linear rate) of set-valued maps and the optimality in the sense of Pareto. We describe technically how the well known contradiction between regularity and optimality could be successfully transposed into a set-valued context and then we identify several metric regularity/openness results which serve our final purpose. We observe that in order to get good Fermat rules (i.e., under mild conditions) one should have to derive new specific openness results which could be of interest for its own. Several possibilities in this direction are investigated, each one giving a specific final outcome. Moreover, some applications to vector equilibrium problems are envisaged. Since, in general, our method allows to firstly deduce approximate Fermat rules for set-valued optimization problems in the setting of general Banach spaces, through this presentation we will have the possibility to underline several regularity and stability issues.

Raluca Strojanu, Dr. Asachi Technical University of Iasi, Romania

Metric regularity and subdifferentials of set-valued mappings with applications to vector optimization

This presentation is devoted to the investigation of different types of regularity for set-valued mappings, with applications to the study of the well-posedness of the solution mappings associated to parametric equilibrium systems. We present some general theorems concerning chain rules for linear openness of multifunctions and we obtain, as particular cases, some classical and also some new results in this field of research, including the celebrated Lusternik Graves Theorem. Also, we classify the at-point regularities (or subregularities) of set-valued mappings into two categories and then we analyze their relationship with respect to that, we show how to use the subregularity properties to deduce implicit theorems for set-valued maps. Finally, we present some applications to the study of multicriteria optimization problems.

Constantin Zalinescu, University Alexandria Ioan Cuza Iasi

Variational principles for multifunctions and applications

The usefulness of the Ekeland Variational Principle (EVP) is well known in Nonlinear Analysis. In the last thirty years many variants for vector-valued functions were established. In our talk we present several versions of the EVP in which the usual (minimized) function as well as the distance function are replaced by multifunctions. Then we present an application to error bounds.

Mohit Singh, Microsoft Research [with Shayon Oveis Gharan, Amin Saberi]

A randomized rounding approach to the traveling salesman problem

For some positive constant $\varepsilon$, we give a $(1+\varepsilon)-$approximation algorithm for the following problem: given a graph $G = (V, E)$, find the shortest tour that visits every vertex at least once. This is a special case of the metric traveling salesman problem when the underlying metric is defined by shortest path distances in $G$. The result improves on the $3\varepsilon$-approximation algorithm due to Christofides for this special case. Similar to Christofides, our algorithm finds a spanning tree whose cost is upper bounded by the optimum, it finds the minimum cost Eulerian augmentation of that tree. The main difference is in the selection of the spanning tree. Except in certain cases where the solution of LP is nearly integral, we select the spanning tree randomly using sampling from the maximum entropy distribution defined by the linear programming relaxation. Despite the simplicity of the algorithm, the analysis builds on a variety of ideas such as properties of strongly Rayleigh measures from probability theory, graph theoretical results on the structure of near minimum cuts, and the integrality of the T-join polytope from polyhedral theory.

Tobias Mönke, KTH Royal Institute of Technology [with Ola Svensson]

Approximation graphic TSP by matchings

We present a framework for approximating the metric TSP based on a novel use of matchings. Traditionally, matchings have been used to add edges in order to make a given graph Eulerian, whereas our approach also allows for the removal of certain edges leading to a decrease in cost. For the TSP on graphic metrics (graphic TSP), an approach yields a 1.461-approximation algorithm with respect to the Held-Karp lower bound. For graph-TSP restricted to a class of graphs that contains degree three bounded and claw-free graphs, we show that the integrality gap of the Held-Karp relaxation matches the conjectured ratio $4/3$.

Marian Mocanu, University of Warsaw

13/9-approximation for graphic TSP

The Travelling Salesman Problem (TSP) is one of the most fundamental and most studied problems in approximation algorithms. For more than 30 years, the best algorithm known for general metrics has been the so-called Held-Karp LP relaxation of the problem is conjectured to have the integrality gap of only $\frac{4}{3}$.

In the so-called graphic version of TSP we assume that $(V, d)$ is a shortest path metric of an unweighted, undirected graph. The reason why this special case is interesting is that it seems to include the diffi-
cult inputs of TSP. Not only is it APX-hard, but also the standard examples showing that the Held-Karp relaxation has a gap of at least $\frac{1}{2}$ are in fact graphic.

Very recently, significant progress has been made for the graphic TSP, first by Oveis Gharan et al., and then by Mómke and Svensson. In this paper, we provide an improved analysis of the approach used by the latter yielding a bound of $\frac{1}{24}$ on the approximation factor. We also provide improved bounds for the related graphic TSP path problem.

**Combinatorial optimization**

**Extended formulations in discrete optimization I**
Organizers/Chairs Samuel Fiorini, Université libre de Bruxelles (ULB); Gautier Stauffer, University Bordeaux 1 – INRIA - Limited Session

Sebastian Pokutta, University of Erlangen-Nürnberg (with Ronald de Wolf, Samuel Fiorini, Serge Massar, Hans-Raj Tiwary)

On linear programming formulations of the TSP polytope

We solve a 20-year old problem posed by M. Yannakakis and prove that there exists no polynomial-size linear program (LP) whose associated polytope projects to the traveling salesman polytope, even if the LP is not required to be symmetric. Moreover, we prove that this holds also for the maximum cut problem and the stable set problem. These results follow from a new connection that we make between one-way quantum communication protocols and semidefinite programming reformulations of LPs.

Thomas Rothvoß, M.I.T.

Some 0/1 polytopes need exponential size extended formulations

We prove that there are 0/1 polytopes $P \subseteq \mathbb{R}^n$ that do not admit a compact LP formulation. More precisely we show that for every $n$ there is a set $X \subseteq \{0,1\}^n$ such that $\text{conv}(X)$ must have extension complexity at least $2^{\frac{1}{2}n^2} (1 - o(1))$. In other words, every polyhedron $Q$ that can be linearly projected on $\text{conv}(X)$ must have exponentially many facets.

In fact, the same result also applies if $\text{conv}(X)$ is restricted to be a matroid polytope.

The paper is available under: http://arxiv.org/abs/1105.0036

Roland Grappe, LIPN - équipe ACC (with Yuni Faenza, Samuel Fiorini, Tiwary Hans Raj)

Extended formulations, non-negative factorizations, and randomized communication protocols

We show that the binary logarithm of the non-negative rank of a non-negative matrix is, up to small constants, equal to the minimum complexity of a randomized communication protocol computing the matrix in expectation.

We use this connection to prove new conditional lower bounds on the sizes of extended formulations, in particular, for perfect matching polytopes.

**Combinatorial optimization**

**Matroid parity**
Organizer/Chair Tamás Király, Eötvös University, Budapest - Limited Session

Ho Yee Cheung, University of Southern California (with Lap Chi Lau, Kai Man Leung)

Algebraic algorithms for linear matroid parity problems

We present faster and simpler algebraic algorithms for the linear matroid parity problem and its applications. For the linear matroid parity problem, we obtain a simple randomized algorithm with running time $O(mr^{r-1})$, which improves the $O(mr^2)$-time algorithm by Gabow and Stallmann. We also present a very simple alternative algorithm with running time $O(mr^2)$. We further improve the algebraic algorithms for some specific graph problems of interest. We present faster randomized algorithms for the Mader’s disjoint $S$-path problem and the graphic matroid parity problem.

The techniques are based on the algebraic algorithmic framework developed by Mucha, Sankowski and Harvey. While linear matroid parity and Mader’s disjoint $S$-path are challenging generalizations for the design of combinatorial algorithms, our results show that both the algebraic algorithms for linear matroid intersection and graph matching can be extended nicely to more general settings. All algorithms are still faster than the existing algorithms even if fast matrix multiplications are not used. These provide simple algorithms that can be easily implemented.

Satoru Iwata, Kyoto University

Weighted linear matroid parity

The matroid parity problem was introduced as a common generalization of matching and matroid intersection problems. In the worst case, it requires an exponential number of independence oracle calls. Nevertheless, the problem is solvable if the matroid in question is represented by a matrix. This is a result of Lovász (1980), who discovered a min-max theorem as well as a polynomial time algorithm. Subsequently, more efficient algorithms have been developed for this linear matroid parity problem.

This talk presents a combinatorial, deterministic, strongly polynomial algorithm for its weighted version. The algorithm builds on a polynomial matrix formulation of the problem using Pfaffian and an augmenting path algorithm for the unweighted version by Gabow and Stallmann (1986).

Indepedently of this work, Gyula Pap has obtained the same result based on a different approach.

Gyula Pap, Eötvös University

Weighted linear matroid parity - A primal-dual approach

In the matroid parity problem we are given a matroid partitioned into pairs – subsets of cardinality 2. A set of pairs is called a matching if their union is an independent set. The (unweighted) matroid parity problem is to maximize the cardinality of a matching. This problem is solvable in polynomial time for linear matroids by Lovász’ famous result – a generalization of graphical matching, and (linear) matroid intersection, both of which are solvable also in the weighted version. Thus one suspects the natural weighted version of linear matroid matching to also be tractable: consider a linear matroid whose elements are assigned weights, and partitioned into pairs – find a matching whose total weight is maximal. A solution to this problem would generalize both of Edmonds’ algorithms, for matching, and for (linear) matroid intersection as well. In this talk a primal-dual algorithm is presented to solve weighted linear matroid matching in strongly polynomial time. A different solution to this problem has been found independently by Iwata.

**Combinatorial optimization**

**Invited Session**

**Combinatorics and geometry of linear optimization II**
Organizers/Chairs Jesus De Loera, University of California, Davis; Antoine Deza, McMaster University - Limited Session

Gabor Pataki, UNC Chapel Hill

Bad semidefinite programs: They all look the same

In the duality theory of semidefinite programming (SDP), unlike in LP, “pathological” phenomena occur: nonattainment of the optimal value, and positive duality gaps between primal and dual problems. This research was motivated by the curious similarity of pathological SDP instances appearing in the literature. We find an exact characterization of semidefinite systems, which are badly behaved from the viewpoint of duality, i.e., show that “all bad SDPs look the same”. We also prove an excluded minor type result: all badly behaved semidefinite systems can be reduced [in a well defined sense] to a minimal such system with just one variable, and two by two matrices. Our characterizations imply that recognizing badly behaved semidefinite systems is in $\text{NP} \cap \text{coNP}$ in the real number model of computing. The main results follow from a fairly general characterization of badly behaved conic linear systems, and hinge on a previous theorem on the closedness of the linear image of a closed convex cone. We show characterizations of badly behaved second order, and other conic systems as well.

Tamon Stephen, Simon Fraser University (with Francisco Santos, Hugh Thomas)
imization per facet of \( P \setminus O \). The second approach (applicable only to polytopal norms) solves one LP per vertex of the unit ball \( B \).

In the past, several papers have produced a classification of formulations for the ATSP, in terms of the associated linear programming relaxations. Among others, we may consider the papers by Gouveia and Von Zuben [1995], Laurent et al. [1990], Gouveia and Pires [1999], Orman and Williams [2007] and Oncan et al. [2009]. These papers fall among two classes. Either they produce new results between formulations known from the literature, or they use the fact that new formulations are also being presented in the paper in order to upgrade a classification already known from the literature. Our talks falls in the second category in the sense that we present an updated classification of formulations for the asymmetric travelling salesman problem (ATSP) where we contextualize, in terms of the ATSP, a new time-dependent formulation presented in Godinho et al. [2010]. The main feature of this formulation is that it uses, for each node, a stronger subproblem, namely a \( p \)-circuit subproblem with the additional constraint that the corresponding node is not repeated in the circuit.

Dorit Hochbaum, UC Berkeley

Flow-based algorithms that solve clustering problems related to graph expander

We address challenging problems in clustering, partitioning and imaging including the normalized cut problem, graph expander, Cheeger constant problem and conductance problem. These have traditionally been solved using the “spectral technique”. These problems are formulated here as a quadratic ratio (Rayleigh) with discrete constraints and a single sum constraint. The spectral method solves a relaxation that omits the discreteness constraints. A new relaxation, that omits the sum constraint, is shown to be solvable in polynomial time. It is shown, via an experimental study, that the bipartition achieved by the combinatorial algorithm often improve dramatically in terms of the objective value of the respective NP-hard problem, as well as in terms of the computational time and image denoising instances.

Yong-Hong Kao, The Chinese University of Hong Kong (with Janny Leung)

On the mixed set covering, partitioning and packing problem

Set covering, set partitioning and set packing problems have already been studied for more than 40 years. However, researchers usually consider the problems individually and very few literatures have mentioned the mixed set covering, partitioning and packing problem, where the three kinds of constraints are present simultaneously in the formulation. The problems with such kind of structures play an important role in the real-life applications, e.g., staff scheduling problems. In this talk, we will discuss the polyhedral structure of the problem and present a way, which we call “implicit edges generation” approach, to further tighten the feasible region and, as a result, makes the LP optimal closer to the IP optimal. We will also present some classes of facet-defining inequalities produced by this approach. Computational results show that, using our proposed methodology, a tighter formulation can be obtained and, consequently significant reductions of computational efforts are made.

Omar Lare, Universidad de Chile (with Roberto Cominetti, José Correa)

Existence and uniqueness of equilibria for flows over time

Network flows that vary over time arise naturally when modeling rapidly evolving systems such as the Internet. In this paper, we continue the study of equilibria for flows over time in the single-source single-commodity deterministic queuing model proposed by Koch and Skutella. We give a constructive proof for the existence and uniqueness of equilibria for the case of a piecewise constant inflow rate, through a detailed analysis of the static flows obtained as derivatives of a dynamic equilibrium.

Ronald Koch, TU Berlin (with Ebrahim Nasrabadi, Martin Skutella)

Continuous and discrete flows over time

Network flows over time form a fascinating area of research. They model the temporal dynamics of network flow problems occurring in a wide variety of applications. Research in this area has been pursued in two different and mainly independent directions with respect to time modeling: discrete and continuous time models.

In this talk we deploy measure theory in order to introduce a general model of network flows over time combining both discrete and continuous aspects into a single model. Here, the flow on each arc is modeled as a Borel measure on the real line (time axis) which assigns to each suitable subset a real value, interpreted as the amount of flow entering the arc over the subset. We motivate the usage of measures as a quite natural tool for modeling flow distributions over time. In particular, we show how static flow theory can be adopted to obtain corresponding results for this general flow over time model.

Danny Seger, University of Hala

An approximate dynamic-programming approach to the joint replenishment problem

In this talk, I will present a high-level view of a very recent approach for \( \varepsilon \)-approximating the joint replenishment problem, with stationary demands and holding costs. Based on synthesizing ideas such as commodity aggregation, approximate dynamic programming, and a few guessing tricks, it turns out that one can attain any required degree of accuracy in time \( O(n^3\log T \log \log T) \), where \( n \) denotes the number of given commodities, and \( T \) stands for the number of time periods.

Andreas S. Schulz, MIT (with Claudio Telha Correia)

The joint replenishment problem and the problem of clustering frequency-constrained maintenance jobs are integer-factorization hard

We present a new connection between certain sequencing problems involving the coordination of activities and the problem of integer factorization. We use this connection to derive hardness results for three well-known problems in operations management whose computational complexity has been open for more than two decades.
The joint replenishment problem with general integer policies.

The joint replenishment problem with general integer policies.

The joint replenishment problem with correction factor.

The problem of finding an optimal clustering of frequency-constrained maintenance jobs.

Our hardness results imply that no polynomial-time algorithm exists for either problem, unless integer factorization is solvable in polynomial time.

**Complementarity & variational inequalities**

**Differential variational inequalities**

Organizer/Chair: Mihai Anitescu, Argonne National Laboratory - Invited Session

Lei Wang, Argonne National Lab (with Shrirang Abhyankar, Mihai Anitescu, Junghe Lee, Lois McInnes, Todd Munson, Barry Smith)

Large-scale differential variational inequalities for phase-field modeling

Recent progress on the development of scalable differential variational inequality multigrid-based solvers for the phase-field approach to mesoscale materials modeling is described. We have developed a reduced space method, augmented reduced space method, and semismooth method for variational inequalities in PETSc, leveraging experience by the optimization community in TAO. A geometric multigrid solver in PETSc is needed to solve the resulting linear systems. We present strong and weak scaling results for 2D coupled Allen-Cahn/Cahn-Hilliard systems.

Michael Hintermüller, Humboldt-Universität zu Berlin (with Thomas Surowiec)

A bundle-free implicit programming approach for MPECs in function space via smoothing

Using a standard first-order optimality condition for nonsmooth optimization problems, a general framework for a descent method is developed. This setting is applied to a typical class of mathematical programs with equilibrium constraints in function space from which a new algorithm is derived. Global convergence of the algorithm is demonstrated in function space and the results are then illustrated by numerical experiments.

Mohammad Rassam Farshbaf-Shaker, Universität Regensburg (with Claudia Hecht)

Optimal control of vector-valued elastic Allen-Cahn variational inequalities

A vector-valued elastic Allen-Cahn-MPEC problem is considered and a penalization technique is applied to show the existence of an optimal control. We show that the stationary points of the penalized problems converge to some stationary points of the limit problem, which however are weaker than C-stationarity conditions.

**MPECs in function space II**

Organizers/Chairs: Christian Meyer, TU Dortmund; Michael Hintermüller, Humboldt-Universität zu Berlin - Invited Session

Stanislaw Migorski, Jagiellonian University, Faculty of Mathematics and Computer Science

An optimal control problem for a system of elliptic hemivariational inequalities

In this paper we deal with a system of two hemivariational inequalities which is a variational formulation of a boundary value problem for two coupled elliptic partial differential equations. The boundary conditions in the problem are described by the Clarke subdifferential of a multivalued and nonmonotone law. First, we provide the results on existence and uniqueness of a weak solution to the system. Then we consider an optimal control problem for the system, we prove the continuous dependence of a solution on the control variable, and establish the existence of optimal solutions. Finally, we illustrate the applicability of the results in a study of a mathematical model which describes the static frictional contact problem between a piezoelectric body and a foundation.

Juan Carlos De los Reyes, Escuela Politécnica Nacional, Quito

Optimality conditions for control problems of variational inequalities of the second kind

In this talk we discuss optimality conditions for control problems governed by a class of variational inequalities of the second kind. Applications include the optimal control of Bingham viscoplastic materials and simplified friction problems. If the problem is posed in 3D an optimality system has been derived by J. Outrata [2000]. When considered in function spaces, however, the problem presents additional difficulties.

We propose an alternative approximation approach based on a Huber type regularization of the governing variational inequality. By using a family of regularized optimization problems and performing an asymptotic analysis, an optimality system for the original optimal control problem (including complementarity relations between the variables involved) is obtained.

We discuss on the gap between the function space optimality system and the finite-dimensional one, and explore sufficient conditions in order to close the gap.

Gerd Wachsmuth, TU Chemnitz (with Roland Herzog, Christian Meyer)

**Optimal control of quasistatic plasticity**

An optimal control problem is considered for the variational inequality representing the stress-based (dual) formulation of quasistatic elastoplasticity. The linear kinematic hardening model and the von Mises yield condition are used. By showing that the VI can be written as an evolutionary variational inequality, we obtain the continuity of the forward operator. This is the key step to prove the existence of minimizers.

In order to derive necessary optimality conditions, a family of time discretized and regularized optimal control problems is analyzed. By passing to the limit in the optimality conditions for the regularized problems, necessary optimality conditions of weakly stationarity type are obtained.

We present a solution method which builds upon the optimality system of the time discrete and regularized problem. Numerical results which illustrates the possibility of controlling the springback effect.

**Intermediate gradient methods for smooth convex optimization problems with inexact oracle**

Between the slow but robust gradient method and the fast but sensitive to errors fast gradient method, we develop new intermediate gradient methods for smooth convex optimization problems. We show, theoretically and on numerical experiments, that these new intermediate first-order methods can be used in order to accelerate the minimization of a smooth convex function when only inexact first-order information is available.

Jose Herskovits, COPPE / Federal University of Rio de Janeiro (with Miguel Anitescu, Jean Roche)

A feasible direction interior point algorithm for nonlinear convex semidefinite programming

The present method employs basic ideas of FIDIPA [1], the Feasible Direction Interior Point Algorithm for nonlinear optimization. It generates a descent sequence of points at the interior of the feasible set, defined by the semidefinite constraints. The algorithm performs Newton-like iterations to solve the first order Karush-Kuhn-Tucker optimality conditions. At each iteration, two linear systems with the same coefficient matrix must be solved. The first one generates a descent direction. In the second linear system, a precisely defined perturbation in the left hand side is done and, as a consequence, a descent feasible direction is obtained. An inexact line search is then performed to ensure that the new iterate is interior and the objective is lower. A proof of global convergence of is presented. Some numerical results are described. We also present the results with structural topology optimization problems employing a mathematical model based on semidefinite programming. The results suggest efficiency and high robustness of the proposed method.

Conic and convex programming in statistics and signal processing I
Organizer/Chair Punekshit Shah, University of Wisconsin - Invited Session
Bamdev Mishra, University of Liege (with Rodolphe Sepulchre)
Fixed-rank matrix factorizations and the design of invariant optimization algorithms
Optimizing over low-rank matrices is a fundamental problem arising in many modern machine learning applications. One way of handling the rank constraint is by fixing the rank a priori resulting in a fixed-rank factorization model. We study the underlying geometries of several well-known fixed-rank matrix factorizations and then exploit the Riemannian framework of the search space in the design of gradient descent and trust-region algorithms.

We focus on the invariance properties of certain metrics. Specifically, we seek to develop algorithms that can be made invariant to linear transformation of the data space. We show that different Riemannian geometries lead to different invariance properties and we provide numerical evidence to support the effect of invariance properties on the algorithm performance.

We make connections with existing algorithms and discuss relative usefulness of the proposed framework. Numerical experiments suggest that the proposed algorithms compete with the state-of-the-art and that manifold optimization offers an effective and versatile framework for the design of machine learning algorithms that learn a fixed-rank matrix.

Lieven Vandenberghe, UCLA (with Martin Andersen)
Multifrontal barrier computations for sparse matrix cones
We discuss conic optimization problems involving two types of convex matrix cones: the cone of positive semidefinite matrices with a given chordal sparsity pattern, and its dual cone, the cone of matrices with the same sparsity that have a positive semidefinite completion. We describe efficient algorithms for evaluating the values, gradients, and Hessians of the logarithmic barrier functions for the two types of cones. The algorithms are based on techniques used in multifrontal and supernodal sparse Cholesky factorization methods. The results will be illustrated with applications in covariance selection and semidefinite programming.

Venkat Chandrasekaran, Caltech (with Michael Jordan)
Computational and sample tradeoffs via convex relaxation
In modern data analysis, one is frequently faced with statistical inference problems involving massive datasets. In this talk we discuss a computational framework based on convex relaxation in order to reduce the computational complexity of an inference procedure when one has access to increasingly larger datasets. Essentially, the statistical gains from larger datasets can be exploited to reduce the runtime of inference algorithms.

Veselin D. Kostic, Ion University of Technology (with Rodolphe Sepulchre)
Random gradient-free minimization of convex functions
In this talk, we prove the complexity bounds for methods of convex optimization based only on computation of the function value. The search directions of our schemes are normally distributed random Gaussian vectors. It appears that such methods usually need at most \( n \) times more iterations than the standard gradient methods, where \( n \) is the dimension of the space of variables. This conclusion is true both for nonsmooth and smooth problems. For the latter class, we present also an accelerated scheme with the expected rate of convergence \( O\left(\frac{1}{k^2}\right) \), where \( k \) is the iteration counter. For Stochastic Optimization, we propose a zero-order scheme and justify its expected rate of convergence \( O\left(\frac{1}{k^{1.5}}\right) \). We give also some bounds for the rate of convergence of the random gradient-free methods to stationary points of nonconvex functions, both for smooth and nonsmooth cases. Our theoretical results are supported by preliminary computational experiments.

Afonso Bandeira, Princeton University (with Katya Scheinberg, Luis Nunes Vicente)
On sparse Hessian recovery and trust-region methods based on probabilistic models
In many application problems in optimization, one has little or no correlation between problem variables, and such (sparsity) structure is unknown in advance when optimizing without derivatives. We will show that semidefinite programming can be used to recover the Hessian sparsity of the function being modeled, when using random sample sets. Given a considerable level of sparsity in the unknown Hessian of the function, such models can achieve the accuracy of second order Taylor ones with a number of sample points (or observations) significantly lower than \( O(n^2) \).

The use of such modeling techniques in derivative-free optimization led us to the consideration of trust-region methods where the accuracy of the models is given with some positive probability. We will show that as long as such probability of model accuracy is over 1/2, one can en-
Regret minimization with zeroth order information

The problem of stochastic convex optimization with the noisy zeroth order oracle can be seen as a generalization of the classical multi-armed bandit problem, if the goal is to minimize regret rather than the final value of the objective function. Regret is defined as the difference between the function values along the optimization path, and not all convex optimization methods have low regret. In this talk we present a regret-minimization algorithm that is based on the zeroth order algorithm of Nemirovskii and Yudin from the ‘70s. We also briefly discuss regret minimization in a more difficult scenario of online linear optimization, where the linear cost functions are changing adversarially at every step. While we only have one shot at getting any information about the cost function per step, a randomized method which explores according to the Dikin ellipsoid is shown to enjoy a near-optimal regret bound.

Applications and algorithms

Chair Galina Yakubina, Oral State University of Railway Transport

Emilie Joannopoulos, Université de Sherbrooke (with François Dubeau, Jean-Pierre Dussault, Candido Pomal)

Feeding optimization of several diet formulations and environmental impact in the swine industry

The diet formulation is a classic example of mathematical programming. We present several new models applied to the swine industry, where feed represent more than 70% of the total production cost, and compare the cost and environmental impact with the traditional feeding solution. Modern producers feed pigs with a 3 phases system with fixed energy rate. First, we will explain the classic and multiphase feeding model. This last one is used in practice so we introduce the formulation, one so called fixed and the other one so called free. The so called free premix model departs from the traditional linear programming formulation in tackling simultaneously the diet’s premix contents and the daily proportions, resulting in a bi-linear formulation. Just by using a daily phase feeding system and two premixes, producers already save. Deeper analysis of the problem revealed that the cost of a premix increases with its energy rate. So we finally present the unfixed energy rate model and show how it is related to the previously presented models. The free energy rate free premix bi-linear model appears to give substantial improvements over more traditional solutions.

Takahashi Satoshi, Graduate School of Systems and Information Engineering, University of Tsukuba (with Poichi Iosuga, Minoru Shigemi, Satoshi Takahashi, Nakli Watanabe)

2-approximation algorithms for the winner determination problem in VCG based single-item multi-unit auctions

This paper studies the winner determination problem in Vickrey-Clarke-Groves (VCG) based single-item multi-unit auctions: given a set of bids in such an auction, find an allocation of units of an item to bidders maximizing the seller’s revenue. (The seller can keep some units of the item.) This problem is known to be NP-hard. We thus pose two simple 2-approximation algorithms for the problem. One is a linear time algorithm and the other is a greedy algorithm. Numerical experiments and human subject experiments were conducted to evaluate the computational efficiency and economic efficiency of these approximation algorithms. Our results are as follows. [1] Approximate ratios of the algorithms are at least 95% in numerical experiments. [2] Under-bidding was observed in human subject experiments although the VCG mechanism theoretically induces bidders to tell their valuations truthfully.

Galina Yakubina, Oral State University of Railway Transport

Project risks analysis using approach of fuzzy sets theory

The report presents a method of analysis of the riskiness of the project using fuzzy sets. The net present value or NPV used as the main indicator of the effectiveness of the project. If the NPV takes value less than zero, the project is considered to be ineffective. The main objective of the work is describing a method to calculate the probability that the project will be ineffective. The method is to consider all the variables of the system as fuzzy numbers with certain characteristics. Function NPV can be represented as a combination of fuzzy parameters and it is also a fuzzy number. Different versions of membership functions can describe the parameters of the project and the number of NPV can be considered. The method is used in practice for the proposed business plan of the project.
epsilon-global optimality is introduced. Algorithmic components include: reformulating user input, detecting special mathematical structure, generating tight convex relaxations, dynamically generating cuts, partitioning the search space, bounding variables, and finding feasible solutions.

We also discuss computational experience with the global mixed-integer quadratic optimizer, GloMIQO. New components in GloMIQO include integrating a validated interval arithmetic library, dynamically adding alphaBB cuts and higher-order edge-concave cuts, addressing discrete/discrete and discrete/continuous products, selectively adding bilinear terms for RLT cuts, and eliminating bilinear terms based on knapsack constraint inferences. Data is presented for globally optimizing a range of MIQCQP including process networks, computational geometry, and quadratic assignment problems.

Angelas Tsioukala, Massachusetts Institute of Technology [with Alexander Mitsos]

Extension of McCormick’s composition to multi-variante functions

Gary L. Miller (then McCormick [Math Prog 1976]) provides the framework for the convex/concave relaxations of factorable functions involving functions of the form $F_i f$, where $F_i$ is a univariate function. We give a natural reformulation of McCormick’s Composition theorem which allows for a straightforward extension to multi-variante functions. In addition to extending the framework, we show how the result can be used in the construction of relaxation proofs. A direct consequence is an improved relaxation for the product of two functions which is at least as tight and some times tighter than McCormick’s result. We also apply the composition result to the minimum/maximum and the division of two functions yielding an improvement on the current relaxation. Finally we interpret McCormick’s Composition theorem as a decomposition approach to the auxiliary variable reformulation methods and we introduce some ideas for future hybrid variations.

Tue.3.H 1058

NLP and MINLP software

Organizer/Chair Hande Benson, Drexel University - Invited Session

Hande Benson, Drexel University [with Umit Saglam]

MILANO and mixed-integer second-order cone programming

In this talk, we present details of MILANO (mixed-integer linear and nonlinear optimizer), a Matlab-based toolbox for solving mixed-integer optimization problems. Our focus will be on interior-point methods for second-order cone programming problems and their extensions to mixed-integer second-order cone programming problems and non-linear programs with second-order cone constraints. Numerical results are obtained from portfolio optimization, supply chain management, and data mining will be presented.

Klaus Schittkowski, University of Bayreuth [with Oliver Exler, Thomas Lehmann]

MISQP: A TR-SQP algorithm for the efficient solution of non-convex, non-relaxed mixed-integer nonlinear programming problems

We present a new sequential quadratic programming (SQP) algorithm stabilized by trust-regions for solving nonlinear, non-convex and non-relaxed mixed-integer optimization problems. The mixed-integer quadratic programming subproblems are solved by a branch-and-cut algorithm. Second order information is updated by a modified quasi-Newton update formula (BFDS) applied to the Lagrange function for continuous, but also for integer variables. The design goal is to solve practical optimization problems based on expensive executions of an underlying simulation program. Thus, the number of simulations or function evaluations, respectively, is our main performance criterion to measure the efficiency of the code. Numerical results are presented for a set of 175 mixed-integer test problems and different parameter settings of MISQP. The average total number of function evaluations of the new mixed-integer SQP code is about 1,200 including those needed for approximating partial derivatives.

Robert Vanderbei, Princeton University

Fast fourier optimization

Many interesting and fundamentally practical optimization problems involve constraints on the Fourier transform of a function. The fast Fourier transform (FFT) is a well-known recursive algorithm that can dramatically improve the efficiency for computing the discrete Fourier transform. However, because it is recursive, it is difficult to embed into a linear optimization problem. In this talk, we explain the main idea behind the fast Fourier transform and show how to adapt it so as to make it encodable as constraints in an optimization problem. We demonstrate a real-world problem from the field of high-contrast imaging. On this problem, dramatic improvements are translated to an ability to solve problems with a much finer discretization. As we shall show, in general, the “fast Fourier” version of the optimization constraints produces a larger but sparser constraint matrix and therefore one can think of the fast Fourier transform as a method of sparsifying the constraints in an optimization problem.

Tue.3.H 2013

Advances in mixed integer programming

Organizer/Chair Alexander Martin, FAU Erlangen-Nürnberg - Invited Session

Timo Berthold, ZIB / Matheon

Measuring the impact of primal heuristics

In modern MIP-solvers like the branch-cut-and-price-framework SCIP, primal heuristics play a major role in finding and improving feasible solutions at the early steps of the solution process. However, classical performance measures for MIP such as time to optimality or number of branch-and-bound nodes reflect the impact of primal heuristics on the overall solving process rather badly. Reasons for this are that they typically depend on the convergence of the dual bound and that they only consider instances which can actually be solved within a given time limit.

In this talk, we discuss the question of how the quality of a primal heuristic should be evaluated and introduce a new performance measure, the “primal integral”. It depends on the quality of solutions found during the solving process as well as on the point in time when they are found. Thereby, it assesses the impact of primal heuristics on the ability to find feasible solutions of good quality, in particular early during search.

Finally, we discuss computational results for different classes of primal heuristics that are implemented in SCIP.

Monfréd Padberg, NYU

The rank of (mixed-) integer polyhedra

We define a purely geometrical notion of the rank of (mixed-) integer polyhedra that differs substantially from the existing notions found in the literature. This talk will outline the notion and present some related results.

Felipe Serrano, ZIB [with Daniel Espinoza]

Some computational experiments with multi-row cuts.

We consider a general mixed integer problem (MIP). The topic we address is to derive cuts by combining two or more rows of the optimal simplex tableau of the linear relaxation of the MIP. A framework will be presented that allows to generate multi-row cuts using different relaxations over the main set possibly including bounds on the variables. Specifically, in this talk we present a numerical approach that allows to look into more complex relaxations than those previously considered in the literature. We propose an approximation scheme that may prove useful for practical implementations of multi-row cuts. Also, we incorporate a simple way to take advantage of the integrality of non basic variables.

Tue.3.H 2022

Trends in mixed integer programming

Organizer/Chair Andrea Lodi, University of Bologna, Robert Weismantel, ETH Zurich - Invited Session

Tiziano Parriani, DES - University of Bologna [with Alberto Caprara, Antonio Frangioni]

An analysis of natural approaches for solving multicommodity-flow problems

We study the relative performances of three existing approaches to solve the minimum-cost linear MultiCommodity Flow Problem [MCFP]. The first approach is solving the LP corresponding to the natural node-arc formulation with state-of-the-art, general-purpose commercial software. The second is to take advantage of the block-diagonal structure with complicating constraints of the LP to develop Dantzig-Wolfe decomposition/column generation approaches. The third is a decomposition-based pricing procedure, proposed by Mamer and McBride, in which the same subproblems of the D-W decomposition are used to identify new columns in a reduced master problem that has the same structure of the node-arc formulation. With a particular focus on degeneracy and stability issues of the column generation, different classes of MCFP instances are solved in order to study the connections between the structure of a specific instance and the performances of the most common solving approaches for this class of problems. This may be useful in choosing the correct approach when a specific MCFP
shall be solved, as well as improving the effectiveness of the approaches themselves.

Alexandra Newman, Colorado School of Mines (with Ed Klotz) Practical guidelines for solving difficult linear and mixed integer programs

The advances in state-of-the-art hardware and software have enabled the inexpensive, efficient solution of many large-scale linear and integer programs previously considered intractable. However, a significant number of real-world linear and integer programs can still require hours, or even days, of run time and are not guaranteed to yield an optimal (or near-optimal) solution. In this talk, we present suggestions for diagnosing and removing performance problems in commercially available linear and mixed integer programming solvers, and guidelines for careful model formulation. We draw on examples from the mining and energy industries, among other areas.

Wilbert Wilhelm, Texas A&M University (with David Carmona, Xue Han, Brittany Tarin) A fast solution method applied to the vehicle positioning problem and its multi-periodic, online, and robust extension

The Vehicle Positioning Problem (VPP) is a classical and challenging combinatorial optimization problem that deals with the assignment of vehicles of a transport company to parking positions. In this talk, we present an exact solution technique that explores partial knowledge about the likelihood of having certain variables in optimal solutions in order to produce feasible solutions for MIPs quickly. We present an exact algorithm for the VPP based on this method and show through computational experiments that it is able to provide optimal solutions for large-scale scenarios of the problem. We also show that some important extensions of the VPP - namely, its multi-periodic version, which was previously intractable, and its online version - can be solved efficiently with this method. Finally, we also discuss how one can apply the concept of robustness to the problem and how robust solutions can be efficiently computed for the VPP.

Stefan Ropke, Technical University of Denmark Exact and heuristic solution methods for the generalized asymmetric vehicle routing problem and the capacitated arc routing problem

In the generalized asymmetric vehicle routing problem (GAVRP) one is given a set of nodes consisting of customer nodes and a depot. Customer nodes are partitioned into clusters and one must construct a number of routes, starting and ending at the depot, such that exactly one customer from each cluster is visited. Each cluster has a certain demand and routes must be constructed such that the total demand on a route is below a given threshold. We solve the GAVRP with an exact method based on the branch-and-cut-and-price paradigm, as well as with a parallel adaptive large neighborhood search heuristic. Furthermore, in [Baladacci, Bartolini and Laporte (2010)] it was shown how an instance of the capacitated arc routing problem (CARP) easily could be transformed into a GAVRP instance. We use this transformation in order to solve CARP instances with the proposed GAVRP algorithms and report on extensive computational experiments for both problem types.

Carlos Cerdántha, IBM Research - Brazil (with Eliav Ben-Moshe) A primal-dual approximation algorithm for air ambulance routing and deployment

We present a primal-dual 2-approximation algorithm for the k-location routing problem, that models choosing k locations for vehicles and routing each vehicle in a tour to serve a set of requests, where the cost is the total tour length. This is the first constant approximation algorithm for this problem and has real-world applications; this is part of a broader effort for Ornge, which transports medical patients. Our work builds and improves upon work of Goemans & Williamson and Jain & Vazirani.

Gonzalo Romero, Massachusetts Institute of Technology (with Retsef Levi, Georgia Perakis) Allocating subsidies to minimize a commodity’s market price - a network design approach

We study the problem faced by a central planner allocating subsidies to competing firms that provide a commodity, with the objective of minimizing its market price, subject to a budget constraint and possibly upper bounds on the total amount that can be allocated to each firm. We consider two types of subsidies, co-payments and technology subsidies. We use a network design under equilibrium flow approach to model an endogenous market response to the subsidy allocation, and obtain structural results and near optimal solutions in various important cases.

Adam El-Mostouby, MIT (with Retsef Levi) Supply chain management with online customer selection

We consider new online versions of supply chain management and logistics models, where in addition to production decisions, one also has to decide on which customers to serve. Specifically, customers arrive sequentially during a selection phase, and one has to decide whether to accept or reject each customer upon arrival. If a customer is rejected, then a lost-sales cost is incurred. Once the selection decisions are all made, one has to satisfy all the accepted customers with minimum possible production cost. The goal is to minimize the total cost of lost-sales.
and production. A key feature of the model is that customers arrive in an online manner, and the decision maker does not require any information about future arrivals. We provide several novel algorithms for online customer selection problems which are based on new variants of repeated optimization and interesting connections to cooperative game theory. For many important settings, our algorithms achieve competitive ratio guarantees that are close to best possible.

Mixed-integer nonlinear programming

Tue.3 MA 005
Convex relaxations for nonconvex optimization problems
Organizer/Chair: Jeff Linderoth, University of Wisconsin-Madison - Invited Session

Kurt Anstreicher, University of Iowa (with Sam Burer)
Second-order-cone constraints for extended trust-region subproblems
The classical trust-region subproblem (TRS) minimizes a nonconvex quadratic objective over the unit ball. We consider extensions of TRS having additional constraints. It is known that TRS, and the extension of TRS that adds a single linear inequality, both admit convex programming representations. We show that when two parallel linear inequalities are added to TRS, the resulting nonconvex problem has an exact convex representation as a semidefinite programming (SDP) problem with additional linear and second-order-cone constraints. For the case where an additional ellipsoidal constraint is added to TRS, resulting in the well-known "two trust-region subproblem" (TTRS), we describe a new relaxation including second-order-cone constraints that significantly strengthens the usual SDP relaxation. Numerical experiments show that the strengthened relaxation provides an exact solution of TTRS in most instances, although the theoretical complexity of TTRS remains an open problem.

Jeff Linderoth, University of Wisconsin-Madison (with Jim Luedtke, Ashutosh Mahajan, Mahdi Namazifar)

Solving mixed integer polynomial optimization problems with MINOTAUR
We study methods for building polyhedral relaxations of multilinear terms that arise in nonconvex mixed integer optimization problems. The goal is to obtain a formulation that is more compact than the convex hull formulation, but yields tighter relaxations than the standard McCormick relaxation. We present computational results for an approach based on grouping the variables into subsets that cover all multilinear terms in the problem. The approach is combined with additional reformulation techniques and spatial branching in the software framework MINOTAUR to produce a solver for mixed integer polynomial optimization problems.

Jon Lee, University of Michigan

Global optimization of indefinite quadratics
I will talk on some methodology for global optimization of indefinite quadratics.

Tue.3 J 1029
Applications of multiobjective optimization
Chair: Gennady Zabrodsky, Omsk Branch of Sobolev Institute of Mathematics Siberian Branch of Russian Academy of Sciences

Ceren Tuncer Akar, Middle East Technical University (with Murat Kikicalan)
Effects of multiple criteria and different planning horizons on portfolio optimization
Portfolio optimization is the problem of allocating available resources between different investments in the market. Following the pioneering work of Markowitz, Modern Portfolio Theory, which has two criteria of mean return and variance, has emerged and several approaches to the problem have been proposed. Incorporating multiple criteria to portfolio optimization and considering multi-period settings is important. Considering return, liquidity, variance and Conditional Value at Risk, we look into the effects of multiple criteria on the decision and objective spaces of portfolio optimization problems. We also employ Stochastic Programming to handle multi-period portfolio optimization and compare the effects of using different planning horizons. We demonstrate our results based on tests performed with stocks traded on Istanbul Stock Exchange.

Lina Alvarez-Vazquez, Universidad de Vigo (with Nestor Garcia-Chan, Aurora Martinez, Miguel Vazquez-Mendiz)
Air pollution and industrial plant location: A multi-objective optimization approach
In this talk we deal with the problem of choosing the optimal location for a new industrial plant, considering the framework of numerical simulation and multi-objective optimal control of partial differential equations (PDE). We take into account both ecological and economic objectives, and we look not only for the optimal location of the plant but also for the optimal management of its emissions to atmosphere. With these purposes in mind, we propose a mathematical model (a system of parabolic PDE) to simulate air pollution and, based on this model, we formulate the problem in the framework of multi-objective optimal control. This problem is studied here from a cooperative point of view, looking for Pareto-optimal solutions. A numerical algorithm (via a characteristics-Galerkin discretization of the adjoint model) is proposed, and preliminary numerical results for a hypothetical situation in the region of Galicia (NW Spain) are also presented.

Gennady Zabrodsky, Omsk Branch of Sobolev Institute of Mathematics Siberian Branch of Russian Academy of Sciences (with Igor Arutyunov)

Optimal location of rectangles on parallel lines

Facility location problems in the plane play an important role in mathematical programming. In the report is studied the problem of location rectangles on parallel lines such that a length and a width of rectangular cover were minimum. The problem is NP-hard. For the search of Pareto-optimal solutions we use models of integer linear programming and dynamic programming techniques. An algorithm for the search of the approximate solution of the problem with the minimum length is offered. We use IBM ILOG CPLEX package for the solution of integer linear programming problems. Results of computing experiment are presented.

Tue.3 J 0107
Interior-point methods
Chair: Mouna Hassan, Rey Juan Carlos University

Li-Zhi Liao, Hong Kong Baptist University
A study of the dual affine scaling continuous trajectories for linear programming
In this talk, a continuous method approach is adopted to study both the entire process and the limiting behaviors of the dual affine scaling continuous trajectories for linear programming. Since the approach is different from any existing one, many new theoretical results on the trajectories resulted from the dual affine scaling continuous method model for linear programming are obtained.

Atsushi Kato, Tokyo University of Science (with Hiroshi Yabe, Hiroshi Yamashita)

An interior point method with a primal-dual quadratic barrier penalty function for nonlinear semidefinite programming
In this talk, we consider a primal-dual interior point method for non-linear semidefinite programming problem:

$$\min \quad f(x), \quad \text{s.t.} \quad g(x) = 0, \quad X(x) \succeq 0,$$

where functions $f : \mathbb{R}^n \to \mathbb{R}$, $g : \mathbb{R}^m \to \mathbb{R}^m$ and $X : \mathbb{R}^p \to \mathbb{S}^p$ are sufficiently smooth, and $\mathbb{S}^p$ denotes the set of $p$-th order real symmetric matrices.

Our method is consists of the outer iteration (SDPIP) and the inner iteration (SDPLS). Algorithm SDPIP finds a KKT point. Algorithm SDPLS also finds an approximate shifted barrier KKT point. Specifically, we apply the Newton method to the shifted barrier KKT conditions. To globalize the method, we propose a differentiable merit function in the primal-dual space within the framework of line search strategy. We show its global convergence property.

Mouna Hassan, Rey Juan Carlos University (with Javier Maguerza, Andrés Redchuk)

The 1$\rightarrow$ Penalty Interior Point Method
The problem of general nonconvex, nonlinear constraint optimization is addressed, without assuming regularity conditions on the constraints, and the problem can be degenerate. We reformulate the problem by applying $l_1$-exact penalty function with shift variables to relax and regularize the problem. Then a feasible type line search primal-dual interior point method, approximately solve a sequence of inequality constraint penalty-barrier subproblems. To solve each subproblems, a Cauchy step would be computed based on Newton step and the proposed algorithm would move in the direction of a combination of these two steps. The penalty parameter is checked at the end of each iteration as we do with the barrier parameter, since we do not need to update the penalty parameter before performing the line search. If the multiplier is finite, then the corresponding penalty parameter is finite. Global convergence properties of the algorithm require the regularity conditions on the original problem. The solution to the penalty-barrier problem converge to the optima that satisfy the Karush-Kuhn-Tucker point or Fritz-John point, and may satisfy a first-order critical point for the measure of the
Recent advances in nonlinear optimization
Organizer/Chair Andrew Conn, T. J. Watson Research Center • Invited Session
Nicholas Gould, STFC Rutherford Appleton Laboratory (with Sven Leyffer, Yueling Loh, Daniel Robinson)
SQP Filter methods without a restoration phase
We consider Filter SQP methods in which regularization is applied explicitly rather than via a trust-region, as suggested by Gould, Leyffer et al. in 2006. Our goal is to provide an alternative to the unattractive “restoration” phase that is needed to unblock iterates that become trapped by the filter. We will consider two alternatives. In the first, the model problem itself gives precedence to improving feasibility and this naturally leads to unblocking. In the second, the filter envelope is “tilted” to allow more room for improvement, and if this fails to unblock, the filter itself is disregarded and progress towards optimality guided by an overall merit function. All of this is somewhat speculative at this stage.

Philip Gill, University of California, San Diego (with Daniel Robinson)
Regularization and convexification for SQP methods
We describe a sequential quadratic programming (SQP) method for nonlinear programming that uses a primal-dual generalized augmented Lagrangian merit function to ensure global convergence. Each major iteration involves the solution of a bound-constrained subproblem defined in terms of both the primal and dual variables. A convexification method is used to give a subproblem that is equivalent to a regularized constrained quadratic program (CQP).

The benefits of this approach include the following: (1) The CQP subproblem always has a known feasible point. (2) A projected gradient method may be used to identify the QP active set when fast from the solution. (3) The application of a conventional active-set method to the bound-constrained subproblem involves the solution of a sequence of regularized KKT systems. (4) Additional regularization may be applied by imposing explicit bounds on the dual variables. (5) The method is equivalent to the stabilized SQP method in the neighborhood of a solution.

Andreas Waechter, Northwestern University (with Travis Johnson)
A hot-started NLP solver
We discuss an active-set SQP method for nonlinear continuous optimization that avoids the re-factorization of derivative matrices during the solution of the step computation QP in each iteration. Instead, the approach uses hot-starts of the QP solver for a QP with matrices corresponding to an earlier iteration, or available from the solution of a similar NLP. The goal of this work is the acceleration of the solution of closely related NLPs, as they appear, for instance, during strong-branching or diving heuristics in MINLP.

Eric Kerrigan, Imperial College London (with George Constantinides, Stefano Longo, Juan Jerez)
Breaking away from double-precision floating-point in interior point solvers
We will show how one can modify interior point methods for solving constrained linear quadratic control problems in computing hardware with a fixed-point number representation or with significantly less bits than in single- or double-precision floating-point. This allows one to dramatically reduce the computational resources, such as time, silicon area and power, needed to compute the optimal input sequence at each sample instant. For fixed precision, we propose a simple preconditioner, which can be used with iterative linear solvers such as CG or MINRES, that allows one to compute tight bounds on the ranges of the variables in the Lanczos iteration, thereby allowing one to determine the best position of the radix point. To allow one to reduce the number of bits needed, we propose the use of the delta transform of Middleton and Goodwin in order to avoid numerical errors that would occur when using the usual shift transform to discretize the continuous-time optimal control problem. We also propose a Ricatti method, tailored to the delta transform, for efficiently solving the resulting KKT systems that arise within an interior point solver.

Large-scale structured optimization
Organizer/Chair Anotoli Juditsky, LJK, Université J. Fourier • Invited Session
Arkadi Nemirovski, Georgia Institute of Technology (with Anatolii Juditsky, Fatma Kilinc-Karzan)
Randomized first-order algorithms for bilinear saddle point problems and their applications to $\ell_1$ minimization
In this talk, we propose randomized first-order algorithms for solving bilinear saddle point problems. Our developments are motivated by the need for sublinear time algorithms to solve large-scale parametric bilinear saddle point problems where cheap online assessment of solution quality is crucial. We present the theoretical estimates of our algorithms and discuss a number of applications, primarily to the problems of $\ell_1$ minimization arising in sparsity-oriented Signal Processing. We demonstrate, both theoretically and by numerical examples, that when seeking for medium-accuracy solutions of large-scale $\ell_1$ minimization problems, our randomized algorithms outperform significantly (and progressively as the sizes of the problems grow) the state-of-the-art deterministic methods.

Guanghui Lan, University of Florida (with Saeed Ghadimi)
Stochastic first- and zero-order methods for nonconvex stochastic programming
We present a new stochastic approximation (SA) type algorithm, namely the randomized stochastic gradient (RSG) method, for solving a class of nonconvex (possibly nonconvex) stochastic programming problems. We establish the rate of convergence of the method for computing an approximate stationary point of a nonlinear programming problem. We also show that this method can handle stochastic programming problems with endogenous uncertainty where the distribution of random variables depend on the solution variables. We give a description of the algorithm which consists of applying a post-optimization phase to evaluate a short list of solutions generated by several independent runs of the RSG method. We show that such modification allows to improve significantly the large-deviation properties of the algorithm. We also develop a special version of the method for solving a class of simulation-based optimization problems in which only stochastic zero-order information is available.

Sergey Shpirko, Moscow Institute of Phys. & Tec. (with Yuri Nesterov)
Primary-parallel subdual method for huge-scale conic optimization problems and its applications in structural design
For huge-scale optimization problems, we suggest a new primal-
dual subgradient method. It generates the main minimization sequence in the dual space. At the same time, it constructs an approximate primal solution. Our scheme is based on the recursive updating technique suggested recently by Nesterov. It allows a logarithmic dependence of the total cost of subgradient iteration in the number of variables.

As an application, we consider a classical problem of finding an optimal design of mechanical structures. Such a problem can be posed in a conic form, with high sparsity of corresponding linear operator.

**Optimization in energy systems**

**Optimization for power grids**

Organizers/Chairs Arvind Raghunathan (Mitsubishi Electric Research Labs), Victor Zavala, Argonne National Laboratory · Invited Session

**Global optimization of power flow problems**

We consider the solution of optimal power flow (OPF) problems with discrete variables. The discrete variables model changes in transformer status. The problems falls into the category of non-convex mixed integer nonlinear programs (MINLP). We propose efficient solution techniques for solving the OPF to global optimality. The performance of the method will be illustrated on several problems from the literature.

Seán Harnett, Columbia University (with Daniel Bienstock, Michael Chertkov)

**Robust DCOPF**

We present a formulation for affine control of generator output to compensate for uncertain output of renewable sources. The robustness of the formulation is achieved through SCOPF constraints; we present a scalable formulation and numerical experiments.

Naiyuan Chiang, University of Edinburgh (with Andreas Grothey)

**Solving SCOPF problems by a new structure exploiting interior point method**

The aim of this paper is to demonstrate a new approach to solve the linearized (\( n - 1 \)) security constrained optimal power flow (SCOPF) problem by OOPS, which is a modern structure-exploiting primal-dual interior-point (IPM) implementation.

Firstly, we present a reformulation of the SCOPF model, in which most matrices that need to be factorized are constant. Consequently, most factorizations and a large number of backsolve operations only need to be performed once throughout the IPM iterations.

Moreover, we suggest to use a preconditioned iterative method to solve the corresponding linear system when we assemble the Schur complement matrix. We suggest several schemes to pick a good and robust preconditioner based on combining different “active” contingency scenarios. We give results on several SCOPF test problems. The largest example contains 500 buses. We compare the results from the original IPM implementation in OOPS and our new approaches.

**PDE-constrained opt. & multi-level/multi-grid meth.**

**Optimization applications in industry II**

Organizer/Chair Dietmar Hömberg (Weierstrass Institute for Applied Analysis and Stochastics) · Invited Session

**Multilevel optimization with adaptive discretizations and reduced order models for engineering applications**

We consider optimization problems governed by partial differential equations. Multilevel techniques use a hierarchy of approximations to this infinite dimensional problem and offer the potential to carry out most optimization iterations on comparably coarse discretizations. Motivated by engineering applications we discuss the efficient interplay between the optimization method, adaptive discretizations of the PDE, reduced order models derived from these discretizations, and error estimators. To this end, we describe an adaptive multilevel SQP method that generates a hierarchy of adaptive discretizations during the optimization iteration using adaptive finite-element approximations and reduced order models such as POD. The adaptive refinement strategy is based on a posteriori error estimators for the PDE-constraint, the adjoint equation and the criticality measure. The resulting optimization methods allows to use existing adaptive PDE-solvers and error estimators in a modular way. We demonstrate the efficiency of the approach by numerical examples for engineering applications.

Martin Gröpl, RWTH Aachen University (with Mark Kärcher)

**A certified reduced basis approach for parametrized linear-quadratic optimal control problems**

The solution of optimal control problems governed by partial differential equations (PDEs) using classical discretization techniques such as finite elements or finite volumes is computationally very expensive and time-consuming since the PDE must be solved many times. One way of decreasing the computational burden is the surrogate model based approach, where the original high-dimensional model is replaced by its reduced order approximation. However, the solution of the reduced order optimal control problem is suboptimal and reliable error estimation is therefore crucial.

In this talk, we present error estimation procedures for linear-quadratic optimal control problems governed by parametrized parabolic PDEs. To this end, employ the reduced basis method as a surrogate model for the solution of the optimal control problem and develop rigorous and efficiently evaluable a posteriori error bounds for the optimal control and the associated cost functional. Besides serving as a certificate of fidelity for the suboptimal solution, our a posteriori error bounds are also a crucial ingredient in generating the reduced basis with greedy algorithms.

Irwin Yocovitz, TU Berlin

**PDE-constrained optimization involving eddy current equations**

Eddy current equations consist of a coupled system of first-order PDEs arising from Maxwell’s equations by neglecting the displacement currents. Applications of such equations can be found in many modern technologies such as in induction heating, magnetic levitation, optimal control, and the associated cost functional. Besides serving as a certificate of fidelity for the suboptimal solution, our a posteriori error bounds are also a crucial ingredient in generating the reduced basis with greedy algorithms.

Irwin Yocovitz, TU Berlin
Adaptive, dynamic and robust optimization to learn human preferences

In 1944, in one of the most influential works of the twentieth century, John von Neumann and Oskar Morgenstern developed the idea of expected utility theory to make decisions under uncertainty. In 1979, Daniel Kahneman and Amos Tversky, in their Nobel prize winning work, presented a critique of expected utility theory by observing that some of its axioms violate human behavior. Specifically, people are loss averse, are inconsistent and evaluate outcomes with respect to deviations from a reference point. However, they did not propose a constructive method to learn preferences that adhere to the new principles. In this work, we use robust and integer optimization in an adaptive and dynamic way to determine preferences that are consistent with human behavior in agreement with the critique of Kahneman and Tversky. We use robust linear optimization to model loss aversion behavior, integer optimization to correct for inconsistent behavior and choice-based conjoint analysis in an adaptive questionnaire to dynamically select pairwise questions. We have implemented an online software that uses the proposed approach and report empirical evidence of its strength.

Adaptive robust optimization for the security constrained unit commitment problem

Unit commitment, one of the most critical tasks in electric power system operations, faces new challenges as the supply and demand uncertainty increases dramatically due to the integration of variable generation resources such as wind power and price responsive demand. To meet these challenges, we propose a two-stage adaptive robust unit commitment model for the security constrained unit commitment problem in the presence of nodal net injection uncertainty. Compared to the conventional stochastic programming approach, the proposed model is more practical in that it only requires a deterministic uncertainty set, rather than a hard-to-obtain probability distribution on the uncertain data. The unit commitment solutions of the proposed model are robust against all possible realizations of the modeled uncertainty. We develop a practical solution methodology based on a combination of Benders decomposition type algorithm and the outer approximation technique. We present an extensive numerical study on the real-world large scale power system operated by the ISO New England, which demonstrates the economic and operational advantages of our model over the current practice.

The power of optimization over randomization in designing controlled trials

The purpose of a controlled trial is to compare the effects of a proposed drug and a null treatment. Random assignment has long been the standard and aims to make groups statistically equivalent before treatment. By the law of large numbers, as the sample grows, randomized groups grow similar almost surely. However, with a small sample, which is practical reality in many disciplines, randomized groups are often too dissimilar to be useful for any inference at all. To remedy this situation, investigators faced with difficult or expensive sampling usually employ specific assignment schemes to achieve better-matched groups, and without theoretical motivation they then employ probabilistic significance tests, whose validity is questionable. Supplanting probabilistic hypothesis testing with a new theory based on robust optimization, we propose a method we call robust hypothesis testing that assigns subjects optimally and allows for mathematically rigorous inference that does not use probability theory and which is notable for allowing inference with small samples. We provide empirical evidence that suggests that optimization leads to significant advantages over randomization.
approximate projections using conjugate gradients, and provides empirical evidence for the effectiveness of the proposed HOC.

Spartak Zikin, Linköping University (with Mats Andersson, Oleg Burovskii, Hans Knutsson) Sparse optimization techniques for solving nonlinear least-squares problems with application to design of filter networks

The nonlinear least-squares (NLLS) problem is an extension of the linear least-squares problem. The difference is that a nonlinear operator is used in place of a matrix-vector product. The NLLS problem is typically a large-scale problem characterized by a large number of local minimizers. Each of the local minimizers is singular and non-isolated. The NLLS problem originates, for instance, from the design of filter networks.

For the design of filter networks, we consider the problem of finding a filter that optimizes over the whole generation capacity of the UK energy grid, given a growing future demand for energy and the technological changes in history. Both market liberalisation and the increasing environmental conditions is highly important for location decisions. Knowledge about the future development of the planning area and the environmental conditions is highly important for location decisions. We consider continuous location-allocation problems with uncertain feasible sets. These problems can often be reformulated as semidefinite programs, which are computationally tractable in theory but suffer from limited scalability in practice. In this talk we propose new uncertainty models specified in terms of maximum variability bounds with polyhedral integrands, minimum variability bounds with polyhedral integrands and polyhedral confidence sets, respectively. We employ these ambiguity sets in the context of standard and risk-averse stochastic programming as well as chance constrained programming, and we show that the resulting distributionally robust optimization problems admit highly scalable reformulations or approximations as linear programs.

Maxim Dementiev, Russian Academy of Sciences

Real-time linear inverse problem and control allocation in technical systems

Control allocation is a set of methods for control of modern overactuated mechanical systems (such as aircrafts, marine vehicles, electric cars), and deals with distributing of the total control demand among the individual actuators. The idea of control allocation allows to deal with control constraints and actuator faults separately from the design of the main regulator, which uses virtual control input. Its dimension is usually quite low, while the number of physical actuators can be much higher. Using linearization, control allocation is equivalent to linear inverse problem with interval-constrained vector $x$, which we need to recover from limited linear measurements: $y = Ax$. Depending on the particular application, one can seek a sparse solution (which minimizes number of physical actuators used for control) or optimize convex function of $x$. Note that if $x$ constrained to a hypercube, then $y$ is constrained to its image, a polytope. We propose a new real-time method for calculating $x$, which is based on interval analysis ideology. Its basic operations are hypercube bisection and explicit reconstruction of the polytope as a system of linear inequalities.

Eugenio Mijangos, University of the Basque Country (UPV/EHU)

An algorithm for nonlinearly-constrained nonlinear two-stage stochastic problems

We look forward an algorithm to solve nonlinearly-constrained two-stage stochastic problems with a nonlinear objective function. It is based on the Twin Node Family (TNF) concept involved in the Branch-and-Fix Coordination method. These problems have continuous and binary variables in the first stage and only continuous variables in the second stage. The nonanticipativity constraints are fulfilled by TNF strategy. In this work, given that the objective function is nonlinear, we propose to solve each nonlinear subproblem generated in the nodes of the trees associated with this method by solving sequences of quadratic subproblems. If the nonlinear constraints are convex we approximate them by means of outer linear approximations; otherwise, we relax these constraints by using augmented Lagrangian techniques. These methods have been implemented in C++ with the help of Cplex 12.1 to solve only the quadratic approximations. The test problems have been randomly generated by using a C++ code developed by this author. Numerical experiments have been performed and its efficiency has been compared with that of BONMIN (COIN-OR). Results are promising.

Marcus Poci, PUC-Rio Infomatica (with Bruno Flach)

On a class of stochastic programs with endogenous uncertainty: Algorithm and applications

We study a class of stochastic programming problems with endogenous uncertainty - i.e., those in which the probability distribution of the random parameters is decision-dependent - which is formulated as a Mixed Integer Non-Linear Programming (MINLP) problem. The proposed methodology consists of: (i) a convexification technique for polynomials of binary variables; (ii) an efficient cut-generation algorithm; and (iii) the incorporation of importance sampling concepts into stochastic optimization.
the stochastic programming framework so as to allow the solution of large instances of the problem. We discuss the error tolerance of the approach and its impact on the resulting algorithm efficiency. Computational results are obtained in the context of the humanitarian logistics problem, they demonstrate the effectiveness of the proposed methodology by solving instances significantly larger than those reported in related works. Other applications in this class of stochastic problems are presented.

### Stochastic vehicle routing with recourse

We study the classic Vehicle Routing Problem in the setting of stochastic optimization with recourse. StochVRP is a two-stage optimization problem, where demand is satisfied using two routes: fixed and recourse. The fixed route is computed using only a demand distribution. Then after observing the demand instantiations, a recourse route is computed – but costs here become more expensive by a factor $\lambda$. We present an $O(\log^2 n \log(\frac{1}{\epsilon}))$-approximation algorithm for this stochastic routing problem, under arbitrary distributions. The main idea in this result is relating StochVRP to a special case of submodular orienteering, called knapsack rank-function orienteering. We also give a better approximation ratio for knapsack rank-function orienteering than what follows from prior work. Finally, we provide a Unique Games Conjecture based $\omega(1)$ hardness of approximation for StochVRP, even on star-like metrics on which our algorithm achieves a logarithmic approximation.

### Approximation algorithms for correlated knapsacks and non-martingale bandits

We give constant-factor approximation algorithms for the stochastic knapsack problem with correlations and cancelations, and also for some budgeted learning problems where the martingale condition is not satisfied, using similar ideas. Indeed, we can show that previously proposed linear programming relaxations for these problems have large integrality gaps. We propose new time-indexed LP relaxations; using a decomposition and “shifting” approach, we convert these fractional solutions to distributions over strategies, and then use the LP values and the time ordering information from these strategies to devise a randomized scheduling algorithm. We hope our LP formulation and decomposition methods may provide a new way to address other correlated bandit problems with more general contexts. The paper is available at http://arxiv.org/abs/1102.3749

Gwen Spencer, Cornell University (with David Shmoys)

### Fragmenting and vaccinating graphs over time and subject to uncertainty: Developing techniques for wildfire and invasive species containment

Decisions about the containment of harmful processes that spread across landscapes (for example, wildfire and invasive species) often must be made under uncertainty and as the system evolves in time. Not all resources are available immediately and containment efforts may fail to prevent spread. The valuable probabilistic predictions produced by ecologists and foresters have been under-utilized because of the difficulty of optimizing when stochastic features and spatial connectedness (or, in this case, disconnectedness) interact.

I will introduce several simple models in graphs that generalize existing work in the CS theory literature and explain provably-good algorithmic results for several settings. These models capture qualitative tradeoffs with important implications for sustainable management. How should resources for wildfire containment be divided across preventive fuel removals and real-time fire suppression efforts, and how can these deployments be coordinated to maximum advantage? If attempts to block invasive species spread are not perfectly reliable, but redundancy is costly, where should managers concentrate their resources?

### Approximation algorithms for stochastic combinatorial optimization

Organizer/Chair Chaitanya Swamy, University of Waterloo - Invited Session

Ingo Geoertz, Technical University of Denmark (with Vinayasarath Nagarajan, Rishi Saket)

Stochastic vehicle routing with recourse

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### Models for network design under varied demand structures

Recent developments in capacitated network design encourage further generalizations of the problem over finite time periods. Thus, the multiperiod network design problem (MNDP) consists of (1) establishing the network topology, (2) installing capacities, and (3) routing communications, while taking into account the fluctuations of demands over the design time horizon and minimizing installation costs. In this talk, we present new models and solution algorithms for the MNDP. Among other useful techniques, we derive lower bounds using Lagrangian relaxation and examine approximation algorithms. We evaluate the effectiveness of our new approaches through computational experience conducted on a number of networks, including realistic instances derived from the survivable network design library (SNDLib).

This work is developed as part of a joint German–Polish project on multiperiod network optimization. The goal of the project is to develop efficient mathematical models for capacity expansions over finite time periods.

Youngho Lee, Korea University (with Channoo Park, Gignyoung Park, Junsang Yuh)

A nonlinear mixed integer programming problem in designing local access networks with QoS constraints.

In this talk, we present nonlinear mixed integer programming models for solving the local access network design problem with QoS constraints. The problem is a two-level hierarchical location-allocation problem on the tree topology of local access networks. The objective function of the problem minimizes the total cost of fiber link and switches, while satisfying both the capacity of switches within the prescribed level of quality of service. In developing an exact optimal algorithm, we develop a new approach of the reformulation linearization technique (RLT) by linearizing the nonlinear QoS constraints by implementing mixed-integer linear constraints with auxiliary variables. By exploiting the special structure of the problem, we devise an outer approximation algorithm that implements cut generation strategies for cutting off the violated solution at each iteration. Computational results are presented for demonstrating the effectiveness of cut generation strategies.
Impulsive systems with mixed constraints

We consider an optimal control problem for an impulsive hybrid system. Such a dynamical system can be described by a nonlinear measure differential equation under mixed constraints on a state trajectory and a control measure. The constraints are of the form

\[ Q_0(x(t^-)) = 0, \quad Q(x(t^+)) = 0, \quad \Psi(x(t^-)) \leq 0, \quad \Psi(x(t^+)) \leq 0 \text{ v-a.e. on } [0, T]. \]

Here, \( x(t^-), x(t^+) \) are the left and right limits of a state trajectory at time \( t \), a non-negative scalar measure \( v \) is the total variation of an “impulsive control”, and \( v([0, T]) \leq M \) with \( M > 0 \). Such conditions can be also regarded as state constraints of equality and inequality type qualified to hold only over the set where \( v \) is localized. A time reparameterization technique is developed to establish a result on the problem transformation to a classical optimal control problem with absolutely continuous trajectories. Based on this result, a conceptual approach is proposed to design numerical methods for optimal impulsive control. We give some results on numerical simulation of a double pendulum with a blockable degree of freedom.

Sensitivity analysis for relaxed optimal control problems with final-state constraints

We consider a family of relaxed optimal control problems with final-state constraints, indexed by a perturbation variable \( y \). Our goal is to compute a second-order expansion of the value \( V(y) \) of the problems, near a reference value of \( y \). We use relaxed controls, i.e., the control variable is at each time a probability measure. Under some conditions, a constrained optimal control problem has the same value as its relaxed version.

The specificity of our study is to consider bounded strong solutions, i.e., local optimal solutions in a small neighborhood for the \( L^\infty \)-distance of the trajectory. To obtain a sharp second-order upper estimate of \( V \), we derive two linearized problems from a wide class of perturbations of the control (e.g., small perturbations for the \( L^1 \)-distance). Relaxation permits a very convenient linearization the problems. Using the decomposition principle [1], we prove that the upper estimate is an exact \( L^1 \)-distance bound. [2] J.F. Bonnans, N.P. Osmolovskii. Second-order analysis of optimal control problems with control and final-state constraints. 2010.

A unified approach to truthful scheduling on related machines

We present a unified framework for designing deterministic monotone PTAS’s for a wide class of scheduling problems on uniformly related machines. This class includes (among others) minimizing the makespan, maximizing the minimum load, and minimizing the \( L_p \) norm of the machine loads vector. Previously, this kind of result was only known for the makespan objective. Monotone PTAS’s have the property that an increase in the speed of a machine cannot decrease the amount of work assigned to it, and have an important role in mechanism design. The key idea of our novel method is that it is possible to compute in polynomial time a structured nearly optimal schedule. An interesting aspect of our approach is that, in contrast to all known PTAS’s, we avoid rounding any job sizes or speeds throughout. We can therefore find the exact best structured schedule using a dynamic programming. The state space encodes sufficient information such that no postprocessing is needed, allowing an elegant and relatively simple analysis. The monotonicity is a consequence of the fact that we find the best schedule in a specific collection of schedules.

The price of anarchy for selfish ring routing is two

We analyze the network congestion game with atomic players, asymmetric strategies, and the maximum latency among all players as social cost. While this is an important social cost function, it has so far resisted a relatively rich literature attempt to prove that the price of anarchy is at most two, when the network is a ring and the link latencies are linear. This bound is tight: this is the first sharp bound for the maximum latency objective on a natural and important network topology.
Combinatorial optimization

Extended formulations in discrete optimization II
Organizers/Chairs Gautier Stauffer, University of Bordeaux 1 – INRIA, Volker Kaibel, Otto-von-Guericke Universität Magdeburg – Invited Session
Mathieu Van Vyve, Université catholique de Louvain (with Laurence Wolsey)
Projecting an extended formulation

We can be done when faced with a hard MIP for which a strong extended formulation is known, but is too large to be used in a branch-and-bound framework. One possible approach is as follows. Given an extended formulation \( Q = \{ (x, w) \in \mathbb{R}^n \times \mathbb{R}^d | Ax + Dw \geq d \} \) and an objective \( \min c^T x \), we would like to efficiently derive a strong relaxation \( P = \{ x \in \mathbb{R}^n | Ax \geq b \} \) in the original variable space. To be more specific, we would like the inequalities \( Ax \geq b \) to be at the same time: (i) such that the optimal solution sets of optimizing over \( P \) or \( Q \) are the same, (ii) small: the number of inequalities is not too large, or even minimal, so that \( Ax \geq b \) can efficiently replace \( Ax + Dw \geq d \) in branch-and-bound, (iii) efficiently computable, (iv) individually strong: each of the inequalities is ideally a facet of \( \text{proj}_Q(O) \), (v) collectively strong: \( P \) is a strong relaxation of \( \text{proj}_Q(O) \). We formalize these different requirements, discuss their compatibility, describe a practical scheme for solving MIPs for which a strong-but-too-large extended formulation is known, and present some computational experiments.

Kastus Pashkovich, University of Magdeburg (with Volker Kaibel)

Constructing extended formulations using polyhedral relations

There are many examples of optimization problems whose associated polyhedra can be described much nicer, and with way less inequalities, by projections of higher dimensional polyhedra than this would be possible in the original space. However, currently not many general tools to construct such extended formulations are available. Here, we develop a framework of polyhedral relations that generalizes inductive constructions of extended formulations via projections, and we particularly elaborate on the special case of reflection relations. The latter ones provide polynomial size extended formulations for several polytopes that can be constructed as convex hulls of the unions of (exponentially) many copies of an input polytope obtained via sequences of reflections at hyperplanes. We demonstrate the use of the framework by deriving small extended formulations for the \( G \)-permutohedron of all finite reflection groups \( G \) (generalizing both Goeman’s extended formulation of the permutohedron of size \( O(\log n) \) and Ben-Tal and Nemirovski’s extended formulation with \( O(k) \) inequalities for the regular \( 2k \)-gon) and for Huffman-polytopes (the convex hulls of the weight-vectors of Huffman codes).

Dirk Oliver Theis, Otto von Guericke University Magdeburg, Germany (with TROY LEE)

Some lower bounds on sizes of positive semidefinite extended formulations

Among other, similar, statements, we prove the following:

Theorem. Every positive semidefinite extended formulation for the Cut polytope of \( K_n \) dominating the 3-clique inequalities must have size at least \( \Omega(n^2) \).

[The size of a positive semidefinite formulation is the dimension of the extended formulation, i.e., the number of variables.] The theorem says that the famous Goemans-Williamson relaxation has linear size: It dominates only a weakened form of the 3-clique inequalities.

Wed.1.H 3004

Algorithm for matrices and matroids
Chair Klaus Truemper, University of Texas at Dallas
Matthias Walter, Otto-von-Guericke University Magdeburg (with Klaus Truemper)
A simple algorithm for testing total unimodularity of matrices

There is a significant practical need for an effective test of total unimodularity of matrices. The currently fastest algorithm for that task has complexity \( O(n^3) \), where \( n \) is the longer dimension of the given matrix. The algorithm would be an excellent candidate for implementation, were it not for numerous structurally complicated cases in several steps that defy implementation with reasonable effort.

We have simplified the algorithm so that all complicated cases are avoided while key ideas are retained. The resulting, much simpler, algorithm has complexity \( O(n^5) \), which matches or is close to that of other polynomial testing algorithms of total unimodularity.

The talk describes the simplified algorithm, compares it with the original one, sketches an implementation, and summarizes computational results for several classes of matrices. The public-domain code is available from several websites.

Leandros Pittoulis, University of Thessaloniki (with Konstadinos Papalamprou)

Decomposition of binary signed-graphic matroids

We employ Tutte’s theory of bridges to derive a decomposition theorem for binary matroids arising from signed graphs. The proposed decomposition differs from previous decomposition results on matroids that have appeared in the literature in the sense that it is not based on \( k \)-sums, but rather on the operation of deletion of a cocircuit. Specifically, it is shown that certain minors resulting from the deletion of a cocircuit of a binary matroid will be graphic matroids apart from exactly one that will be signed-graphic, if and only if the matroid is signed-graphic.

Shinji Mizuno, Tokyo Institute of Technology (with Tomonari Kitahara)

An upper bound for the number of different solutions generated by the primal simplex method with any selection rule of entering variables

Kitahara and Mizuno obtained an upper bound for the number of different solutions generated by the primal simplex method with Dantzig’s (the most negative) pivoting rule. In this talk, we extend the result to the primal simplex method with any pivoting rule which chooses an entering variable whose reduced cost is negative at each iteration. We see that the upper bound is fairly tight by using a variant of Klee-Minty’s LP. The upper bound is applied to a linear programming problem with totally unimodular matrix. We also get a similar bound for the dual simplex method.

Ilan Adler, University of California, Berkeley

The equivalence of linear programs and zero-sum games

In 1951, Dantzig showed the equivalence of linear programming problems and two-person zero-sum games. However, in the description of his reduction from linear programs to zero-sum games, he noted that there was one case in which the reduction does not work. This also led to incomplete proofs of the relationship between the Minimax Theorem of game theory and the Strong Duality Theorem of linear programming. In this talk, I fill these gaps. In particular, I’ll present two complete strongly polynomial reductions of LPs to zero-sum games, a Karp-type reduction which is applicable to LPs with rational (as well as algebraic) data, and a Cook type reduction which is applicable to LPs with real data. The key for both reductions are procedures to solve a system of linear constraints by an oracle capable of determining either feasibility or unboundedness of the system. I’ll also discuss the relationship between the Minimax Theorem and the Strong Duality Theorem.

Uli Zwich, Tel Aviv University (with Oliver Friedmann, Thomas Hansen)

Subexponential lower bounds for randomized pivoting rules for the simplex algorithm

The simplex algorithm is among the most widely used algorithms for solving linear programs in practice. With essentially all deterministic pivoting rules it is known, however, to require an exponential number of steps to solve some linear programs. No non-polynomial lower bounds were known, prior to this work, for randomized pivoting rules. We provide the first subexponential (i.e., of the form \( 2^n \cdot \alpha(n) \), for some \( \alpha > 0 \)) lower bounds for the two most natural, and most studied, randomized pivoting rules suggested to date.

The first randomized pivoting rule considered is random-edge, which among all improving pivoting steps (or edges) from the current basic feasible solution (or vertex) chooses one uniformly at random. The second randomized pivoting rule considered is random-facet, a more complicated randomized pivoting rule suggested by Kalai and by Mahoney, Sharir and Welzl. Our lower bound for the random-facet pivoting rule essentially matches the subexponential upper bounds given by Kalai and by Matousek et al. Lower bounds for random-edge and random-facet were known before only in abstract settings, and not for concrete linear programs.
We consider an extension of the set covering problem (SCP) introducing \([1]\) multiset covering and \([2]\) generalised upper bound (GBU) constraints. For the conventional SCP, the pricing method has been introduced to reduce the number of variables, and several efficient heuristic algorithms based on this idea have been developed to solve very large-scale instances. However, GUB constraints often make the pricing method less effective, because they prevent solutions from having highly evaluated variables simultaneously. To overcome this, we propose a heuristic algorithm to reduce the size of problem instances that modifies the evaluation scheme of variables taking account of GUB constraints. We also develop an efficient implementation of a local search algorithm with the 2-flip neighborhood that reduces the number of candidates in the neighborhood without sacrificing the solution quality. According to computational comparison on benchmark instances with the latest mixed integer programming solver, our algorithm performs quite effectively for various types of instances, especially for very large-scale instances.

**Network flows**

Chair: Chandra Chekuri, University of Illinois, Urbana-Champaign

Maria Alhabsi, Ferdowsi University of Mashhad [with Hossein Tajizadeh Kakhki]

**Maximum dynamic flow interdiction problem**

Let \(G = (N, A)\) be a directed graph with a given source node \(s\), and a given sink node \(t\). Let \(N = (G, u, t, r)\) be the associated dynamic network with arc capacities \(u\), flow traversal times \(r\), and arc interdiction costs. The problem is to find a set of arcs whose removal will minimize the maximum flow from \(s\) to \(t\) within a given time period of \(T\), subject to budget limitation. This is in fact the dynamic version of the well known max flow interdiction problem. We present a new formulation based on the concept of temporally repeated flows and discuss two solution approaches for this problem. Some numerical results will also be presented.

**Combinatorial optimization**

We present combinatorial algorithms for the min-cost flow problem in planar graphs. Previously, the best known bounds came from algorithms for general graphs using only that the number of arcs is in \(O(n)\). These yield near quadratic algorithms and subquadratic ones only for special cases, e.g., \(O(n^{3/2})\) time if the optimum objective value is in \(O(n)\), or \(O(n^{5/3})\) time bounded costs and capacities. We demonstrate techniques to obtain \(O(n^{\sqrt{2}})\) for planar graphs of bounded degree, constant capacities, and arbitrary costs, or for bidirected planar graphs of bounded face sizes, no capacities, and bounded costs. These techniques can be applied in image processing and in graph drawing, respectively. In the latter case, our result improves a long standing time bound for minimizing the number of bends in an orthogonal drawing of a plane graph. Without these restrictions but with the condition of a linear optimum, we only lose a log-factor, i.e. we get \(O(n^{3/2} \log n)\). With a scaling approach, we obtain \(O(\sqrt{Dn} \log n \log C)\), where \(U\) is the sum over all capacities and \(C\) is the maximum over all costs.

**Planar min-cost flow in nearly \(O(n^{3/2})\)**

**Routing for public transportation**

Organizer: Peter Sanders, Karlsruhe Institute of Technology - Invited Session

Matthias Müller-Hannemann, MLU Halle-Wittenberg

**Coping with delays: Online timetable information and passenger-oriented train disposition**

In daily operation, railway traffic always deviates from the planned schedule to a certain extent. Primary initial delays of trains may cause a whole cascade of secondary delays of other trains over the entire network. In this talk, we survey recent results for efficient online timetable information, robust pretrip route planning, stochastic delay propagation, and disposition management. Disposition management solves the decision problem whether a train should wait for incoming delayed trains or not. This problem has a highly dynamic nature due to a steady stream of update information about delayed trains. We propose a new model for real-time train disposition aiming at a passenger-friendly optimization and report about experimental results with a prototypical implementation and test data of German Railways.

**Round-based public transit routing**

We study the problem of computing all Pareto-optimal journeys in a dynamic public transit network for two criteria: arrival time and number of transfers. Existing algorithms consider this as a path problem, and solve it using variants of Dijkstra's algorithm. Unfortunately, this leads to either high query times or suboptimal solutions. We take a different approach. We introduce RAPTOR, our novel round-based public transit router. Unlike previous algorithms, it is not Dijkstra-based, looks at least one (such an arc) in the network at most once per round, and can be made even faster with simple pruning rules and parallelization using multiple cores. Because it does not rely on preprocessing, RAPTOR works in fully dynamic scenarios. Moreover, it can be easily extended to handle flexible departure times or arbitrary additional criteria.

**Combinatorial optimization**
such as fare zones. When run on London’s complex public transportation network, RAPTOR computes all Pareto-optimal journeys between two random locations an order of magnitude faster than previous approaches, which easily enables interactive applications.

Hannah Bast, University of Freiburg

Next-generation route planning: Multi-modal, real-time, personalized

Route planning in static road networks or public transportation networks has reached a very high level of sophistication. The next challenges are: [1] Free combination of the various modes of transportation (walking, biking, driving, public transportation, flight, etc.). [2] Acquire and incorporate dynamic updates in real time (traffic jams, delayed trains, canceled flights, etc.). [3] Provide personalized result diversity for each user (flexible optimization criteria, time-independent result summaries, etc.). I will talk about the state of the art and some recent advances with respect to these.

Complementarity & variational inequalities

Wed.1.MA 041

Complementarity modeling and its game theoretical applications
Organizer/Chair Samir Neogy, Indian Statistical Institute - Invited Session

Samir Neogy, Indian Statistical Institute

Generalized principal pivot transforms, complementarity problem and its applications in game theory

The notion of principal pivot transform (PPT) was introduced by Tucker and it is encountered in mathematical programming, complementarity problem, game theory, statistics, matrix analysis and many other areas. It is originally motivated by the well-known linear complementarity problem. In this talk, we discuss the concept of generalized principal pivot transform and present its properties and applications. The proposed generalized principal pivoting algorithm has many game theoretical applications. This generalized principal pivoting algorithm is a finite step algorithm and even in the worst case, this algorithm is partial enumeration only. It is demonstrated that computational burden reduces significantly for obtaining the optimal stationary strategies and vector of the some structured stochastic game problem.

Abhijit Gupta, Indian Statistical Institute

Complementarity model for a mixture class of stochastic game

Researchers from the field of game theory adopted Lemke’s approach to the field stochastic games and formulated the problem of computing the value vector and stationary strategies for many classes of structured stochastic game problem as a complementarity problem and obtain finite step algorithms for this special class of stochastic games. In this talk we consider a mixture class of zero-sum stochastic game wherein the set of states are partitioned into sets $S_1, S_2$ and $S_0$ so that the law of motion is controlled by Player I alone when the game is played in $S_1$, Player II alone when the game is played in $S_2$, and in $S_0$ the reward and transition probabilities are additive. We obtain a complementarity model for this mixture class of stochastic game. This gives an alternative proof of the ordered field property that holds for such a mixture type of game. Finally we discuss about computation of value vector and optimal stationary strategies for discounted and undiscounted mixture class of stochastic game.

Arup Das, Indian Statistical Institute

A complementarity approach for solving two classes of undiscounted structured stochastic games

In this talk, we consider two classes of structured stochastic games, namely, undiscounted zero-sum switching controller stochastic games and undiscounted zero-sum additive reward and additive transitions (ARAT) games. Filar and Schultz observed that an undiscounted zero-sum stochastic game possesses optimal stationary strategies if and only if a global minimum with optimum value zero can be found to an appropriate linearly constrained nonlinear program. However, a more interesting problem is the reduction of these nonlinear programs to linear complementarity problems or linear programs. The problem of computing the value vector and optimal stationary strategies is formulated as a linear complementarity problem for these two classes of undiscounted zero-sum games. Implementation of available pivoting algorithms on these two formulations are also discussed.

Complementarity & variational inequalities

Wed.1.MA 313

Advances in the theory of complementarity and related problems I
Chair Chandrashekaran Arumugasamy, Central University of Tamil Nadu

Jei-Shan Chen, National Taiwan Normal University (with Xinhe Mao)

Lipschitz continuity of solution mapping of symmetric cone complementarity problem

This paper investigates the Lipschitz continuity of the solution mapping of symmetric cone (linear or nonlinear) complementarity problems (SCLCP or SCCP, respectively) over Euclidean Jordan algebras. We show that if the transformation has uniform Cartesian $P$-property, then the solution mapping of the SCCP is Lipschitz continuous. Moreover, we establish that the monotonicity of mapping and the Lipschitz continuity of solutions of the SCLCP imply ultra $P$-property, which is a concept recently developed for linear transformations on Euclidian Jordan algebra. For a Lyapunov transformation, we prove that the strong monotonicity property, the ultra $P$-property, the Cartesian $P$-property and the Lipschitz continuity of the solutions are all equivalent to each other.

Aleksy Kurennoy, Moscow State University (with Aleksy (maolin))

On regularity conditions for complementarity problems

In the context of mixed complementarity problems, various concepts of solution regularity are known, each of them playing a certain role in related theoretical and algorithmic developments. In this presentation, we provide the complete picture of relations between the most important regularity conditions for mixed complementarity problems. We not only summarize the existing results on the subject, but also establish some new relations filling all the gaps in the current understanding of how different types of regularity relate to each other. The regularity conditions to be considered include BD and CD regularities of the natural residual and Fischer-Burmeister reformulations, strong regularity, and semistability. A special attention is paid to the particular cases of a non-linear complementarity problem and of a Karush-Kuhn-Tucker system.

Chandrashekaran Arumugasamy, Central University of Tamil Nadu

Some new results on semidefinite linear complementarity problems

Given a linear transformation $L: S^n \rightarrow S^n$ and $Q \in S^n$, the semidefinite linear complementarity problem (SDLCP, (Q)) is to find an $X \in S^n_+$ such that $L(X) + Q \in S^n_+$, and $(X, L(X) + Q) = 0$. Here $S^n_+$ is the space of all real symmetric matrices of order $n$ and $S^n_+$ is the cone of all positive semidefinite matrices in $S^n$. This problem is considered as the natural generalization of the standard linear complementarity problem. One of the fundamental problems in SDLCP is to characterize and identify linear transformations on $S^n$ based on the properties of the solution sets. In this presentation we discuss some necessary and sufficient conditions on the linear transformation $L$ to have non-empty compact solution sets for all $Q \in S^n$ to the problem SDLCP $(L, Q)$.

Advances in the theory of complementarity and related problems II
Chair Chandrashekaran Arumugasamy, Central University of Tamil Nadu

Jei-Shan Chen, National Taiwan Normal University (with Xinhe Mao)

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equitable problem and find that linear bounds are competitive with the corresponding semidefinite ones but can be computed much faster. We further present detailed computational evaluations for a branch-and-cut algorithm using linear relaxations.

Angelika Wiegele, Alpen-Adria-Universität Klagenfurt (with Elpgeet Adams, Miguel Augs, Franz Rendl)

Lasserre hierarchy for max-cut from a computational point of view

The max-cut problem is one of the classical NP-complete problems defined on graphs. SDP-relaxations turned out to be in particular successful in these problems. Beside the basic semidefinite relaxation (deriving the Goemans-Williamson hyperplane rounding algorithm) and tightenings of this relaxation, iterative approaches exist that converge towards the cut polytope. Such a systematic hierarchy was introduced by Lasserre. The first relaxation in this hierarchy coincides with the basic SDP relaxation. Due to the high computational cost, already the second relaxation in this Lasserre-hierarchy is intractable for small graphs.

We present an iterative algorithm for computing a strengthened SDP-relaxation towards this second relaxation combined with constraints from the metric polytope. This can also be viewed as a strengthening of the basic SDP relaxation using semidefinite cuts. We present theoretical facts and report preliminary computational results.

Rachel Ward, University of Texas at Austin (with Deanna Needell)

Robust image recovery via total-variation minimization

Discrete images, composed of patches of slowly-varying pixel values, have sparse or compressible wavelet representations which allow the techniques from compressed sensing such as L1-minimization to be utilized. In addition, such images also have sparse or compressible discrete derivatives which motivate the use of total variation minimization for image reconstruction. Although image compression is a primary motivation for compressed sensing, stability results for total-variation minimization do not follow directly from the standard theory.

In this talk, we present numerical studies showing the benefits of total variation approaches and provable near-optimal reconstruction guarantees for total-variation minimization using properties of the bivariate Haar transform.

Joel Tropp, California Institute of Technology (with Michael McCoy)

Sharp recovery bounds for convex deconvolution, with applications

Suppose we observe the sum of two structured signals, and we are asked to identify the two components in the mixture. This setup includes the problem of separating two signals that are sparse in different bases and the problem of separating a sparse matrix from a low-rank matrix.

This talk describes a convex optimization framework for solving these deconvolution problems and others.

We present a randomized signal model that captures the idea of "incoherence" between two structures. The calculus of spherical integral geometry provides exact formulas that describe when the optimization problem will succeed or fail to deconvolve the component signals with high probability. This approach yields summary statistics that measure the complexity of a particular structured signal. The total complexity of the two signals is the only factor that affects whether deconvolution is possible.

We consider three stylized problems. (1) Separating two signals that are sparse in mutually incoherent bases. (2) Decoding spread-spectrum transmissions in the presence of impulsive noise. (3) Removing sparse corruptions from a low-rank matrix. In each case, the theory accurately predicts performance.

Pankaj K. Agarwal, Duke University (with Michael McCoy)

Sparse interpolatory models for molecular dynamics

We describe a method for using interpolatory models to accurately and efficiently simulate molecular excitation and relaxation. We use sparse interpolation for efficiency and local error estimation and control for robustness and accuracy.

The objective of the project is to design an efficient algorithm for simulation of light-induced molecular transformations. The simulation seeks to follow the relaxation path of a molecule after excitation by light. The simulator is a predictive tool to see if light excitation and subse-
quint return to the unexcited or ground state will produce a different configuration than the initial one. The goals of the simulation are not only to identify the end point, but to report the entire path in a high-dimensional configuration space so that one can look for nearby paths to interesting configurations and examine the energy landscape near the path to see if low energy barriers make jumping to a different path possible.

Warren Rue, UBC (with Mason Macklem, Julie Nutini)

Derivative free optimization for finite minimax functions

In this talk we consider derivative-free optimization for finite minimax problems; that is objective functions of the form \( F \max(f_i) \). We work under the assumption that each \( f_i \) is provided via an oracle function that is analytically unvaluable. Commonly such problems are dealt with using minimization techniques. In this talk we present smooth techniques that obscure the substructure of such functions and instead use the substructure to generate a approximate subdifferential. Techniques on robust subdifferentials are employed to further improve convergence. Convergence and some numerical results are presented.

Rommel Regin, Saint Joseph's University (with Stefan Wild)

A derivative-free trust-region algorithm for constrained, expensive black-box optimization using radial basis functions

This talk will present a derivative-free algorithm for constrained black-box optimization where the objective and constraint functions are computationally expensive. The proposed algorithm employs a trust-region framework that uses interpolating radial basis function (RBF) models for the objective and constraint functions and is an extension of the ORBIT algorithm. This algorithm will be compared with alternative methods on a series of test problems and on an automotive application with 124 decision variables and 68 black-box inequality constraints.

Péter Erdős, Swiss Institute of Banking and Finance, University of St. Gallen

Have oil and gas prices got separated?

Prices are driven by oil prices only if there is sufficient inter-fuel competition in the US, or if gas arbitrage is possible across the Atlantic. In the period 1994–2011 interfuel replacement was marginal in the US; therefore, the coupling of oil and gas prices depended on intercontinental trade movements. Until the end of 2008 the US depended on gas imports, contributing to higher average gas prices in the US than those in Europe and attracting export to the US. Thus, the Atlantic arbitrage, taking into account transaction costs, forced gas prices to converge in the US and in Europe in the long run. Since European gas prices react to price developments in the oil market, the Atlantic arbitrage also reinforced oil-gas linkage in the US. Since 2009 US oil and gas prices have decoupled due to limits to arbitrage across the Atlantic. Despite gas extraction from shale formations boosting the US gas inventories, which in turn depresses prices below the European level, US export is not viable because of a lack of liquefying infrastructure and administrative obstacles.

Michael Schuerle, University of St. Gallen (with Florentina Paraschiv)

Price dynamics in gas markets

Modeling natural gas futures prices is essential for valuation purposes as well as for hedging strategies in energy risk management. We present a general multi-factor affine diffusion model which incorporates the joint stylized features of both spot and futures prices. The model is brought into state space form on which Kalman Filter techniques are applied to evaluate the maximum likelihood function. We further build the basis for the construction of a daily gas price forward curve. These prices take into account the seasonal structures of spot prices and are consistent under the arbitrage-free condition with the observed market prices of standard products that provide gas delivery over longer periods. Finally the performance of the models is illustrated comparing historical and model implied price characteristics.

Florentina Paraschiv, IOR/CF University of St. Gallen

Modelling negative electricity prices

We evaluate different financial and time series models such as mean reversion with jump processes, ARMA, GARCH usually applied for electricity price simulations. Since 2008 market design allows for negative prices at the European Energy Exchange (EEX), which occurred for several hours in the last decades. Up to now, only a few financial and time-series approaches exist, which are able to capture negative prices. We propose a new model for simulating energy spot prices taking into account their jumping and spiking behavior. The model parameters are calibrated using the historical hourly price forward curves for EEX and Phelix, as well as the spot price dynamics. Parameters for the spikes which characterize the spot dynamics are derived on an hourly basis. Market clearing prices are derived given an observed price forward curve and an algorithm deciding whether a spike or a Poisson jump occurs.
person game coincides with the solution set of a variational inequality associated with this game. The game is said to have a convex structure if the above mentioned variational inequality is defined by a monotone mapping. The convex-structure games can be solved by efficient numerical methods. The paper presents a sufficient condition to guarantee a game to have a convex structure. For finite games in mixed strategies, the author gives an equivalent form in terms of the tables defining the game. Moreover, for the class of finite games, it is demonstrated that the proposed condition is not only sufficient but also necessary for the convex-structure games.

Vikas Jain, Jaypee University of Engineering and Technology
Constrained vector-valued dynamic game and symmetric duality for multiobjective variational problems

A certain constrained vector-valued dynamic game is formulated and shown to be equivalent to a pair of multiobjective symmetric dual variational problems which have more general formulations than those studied earlier. A number of duality theorems, are established under suitable generalized convexity assumptions on the functionals. This constrained vector-valued dynamic game is also regarded as equivalent to a pair of symmetric multiobjective dual variational problems with natural boundary conditions rather than fixed end points. Finally, it is also indicated that our results can be considered as dynamic generalization of those already studied in the literature.

Zelda Zabinsky, University of Washington (with WolKo Kohn)
Solving non-linear discrete optimization problems via contextualization: An interior-point algorithm

Continuous optimization problems have a tremendous structural advantage over discrete optimization problems: continuity. Necessary conditions for optimality are expressed in terms of differentiability, convexity, and other structural properties. This makes developing algorithms for continuous problems easier than for discrete problems. In this talk, we present a contextualization approach for transforming discrete optimization problems into a continuous formulation over a compact domain. The target formulation is amenable to an interior-point descent algorithm. We use a conditional sampling procedure to translate solutions of the continuous formulation into approximate solutions of the original discrete problem. The interior-point descent algorithm is expressed by a set of coupled differential equations whose integration via numerical methods generates approximate solutions to the original problem in polynomial time. The continuous problem can be characterized by a variational formulation. The central element of this formulation is a Lagrangian with nonsingular Hessian. This leads to the differential equations in the descent algorithm.

WolKo Kohn, University of Washington (with Zelda Zabinsky)
Hybrid dynamic programming for rule constrained multi-objective optimization

Many optimization problems associated with large-scale complex systems require a model definition that is almost impossible to specify completely. Further, real-world applications must evaluate trade-offs between multiple objectives, which demands set representation. We will present some preliminary results of our research on developing an optimal feedback control paradigm for solving optimization problems with multiple objectives in which the model defined by the constraints is incomplete, and a complete description of the system is not available. Our optimization paradigm includes active learning of the structure of the model that goes beyond parameter adaptation. The constraints include algebraic relations, operational if-then rules, discrete- and continuous-time dynamics, and sensor-defined constraints. Our modeling approach is based on the theory of dynamic set inclusion, because this theory lends itself to construct efficient algorithms that include learning mechanisms. Our strategy is to convert all the constraints characterizing the model to continuous-time set dynamics using a contextualization transformation developed in a previous paper by Kohn, et al.

Pengbo Zhang, University of Washington
Stochastic control optimization of a binary integer program

We develop a discrete meta-control algorithm that provides a good approximation to large-scale binary integer programs with low polynomial complexity. The key innovation in our optimal control approach is to map the vector of binary decision variables into a scalar function defined over a discrete time interval [0, n] and define a linear quadratic tracking (LQT) problem that closely approximates the original problem. Our method uses an Aoki-based decompositon approach and an error correction with a Kalman filter technique that introduces less error than the continuous form used in our previous research, but maintains the primary computational advantage. We use the necessary conditions for optimality to prove that there exists an integer solution to the LQT version of the original BIP, with a bang-bang type solution. We prove that our meta-control algorithm converges to an approximate solution in polynomial time with regard to the time horizon, which is the number of binary variables n. The algorithm is illustrated with several large examples. The meta-control algorithm can be extended to mixed integer programs.

Implementations & software

Optimal hybrid control theory approaches to global optimization
Organizers/Chair Zelda Zabinsky, University of Washington - Invited Session

Implementations of interior point methods for linear and conic optimization problems
Organizers/Chair Erling Andersen, MOSEK ApS - Invited Session

Exploiting hardware capabilities in implementations of interior point methods
The talk concerns the implementation of interior point methods for solving large-scale optimization problems. In our investigation we focused on the exploitation of the recently introduced AVX vector instruction set and show that the capabilities of modern processors can be highly exploited by special implementation techniques. We describe the implementation design of our interior point solver and demonstrate that its performance on standard multi-core platforms can reach 100 Gflops when solving large-scale optimization problems.

Wednesday 1

Integer & mixed-integer programming

Scheduling I
Chair Andrea Raith, The University of Auckland

Integer programming model and optimum solution for a bi-objective days-off scheduling problem
An integer programming model and optimal solution procedure are presented for a real-life cyclic day-off scheduling problem. Efficient techniques are used to determine the best assignment of employees to the [10, 14] days-off schedule. This special work schedule, involving ten consecutive workdays in a two-week cycle, is used by a large oil company to schedule employees in remote work locations. The primary objective is to minimize the total number of employees, and the secondary objective is to minimize the total number of active days-off work patterns. Two days-off scheduling rules are enforced: a minimum proportion of weekend days-off needs to be given, and a maximum limit on the number of successive work days cannot be exceeded. Primal-dual relationships are used to identify dominant solutions and to determine the minimum workforce size. Utilizing the problem structure and real-life parameter values, simple optimal procedures are developed to determine the minimum number of days-off patterns and the number of employees assigned to each pattern. A rotation scheme is used to en-
Trends in mixed integer programming IV

W 1.1 H 2023

Assignments and partitioning
Chair: Trivikram Dokka, Katholieke Universiteit Leuven

Ya Ju Fan, Lawrence Livermore National Lab (with Chandrika Kamath)

A heuristic for the local region covering problem

The topological or local dimension of a data manifold can be obtained using local methods, where the data are divided into smaller regions. The original Fukunaga-Olsen algorithm for the intrinsic dimension of a dataset used heuristic approaches to identify the smaller regions. To obtain an improved partitioning of the data space, we formulate this problem as a set covering problem, where each local region contains the $k$ nearest neighbors of a data point. We discuss how we define the cost function to obtain an estimation based on a fair selection of local regions. This problem can be seen as a facility location problem with the number of facilities being optimized in order to maintain the service to at most $k$ cities per facility. To solve the local region problem, we present a simple and easy to implement heuristic method that is a variant of a greedy approach.

Trivikram Dokka, Katholieke Universiteit Leuven (with Ioannis Mourtos, Frits Spieksma)

Fast separation algorithms for multi-dimensional assignment problems

In polyhedral combinatorics, the polytope related to a combinatorial optimization problem is examined in order to obtain families of strong valid inequalities or, even better, to find inequalities that are facet-defining for this polytope. To incorporate such families of inequalities within a ‘branch & cut’ algorithm requires one further step: that of deriving an algorithm which determines whether an inequality of a specific family is violated by a given vector (the separation problem). The idea put forward in this work is to consider a compact representation of the given vector, and measure the complexity of a separation algorithm in terms of this compact representation. We illustrate this idea on the separation problem of well-known families of inequalities associated to the (multi-index) assignment polytope, and we show that for these families of inequalities better time-complexities than the current ones are possible.

Trivikram Dokka, Katholieke Universiteit Leuven (with Ioannis Mourtos, Frits Spieksma)
generic vertex according to a mapping function that associates with each path a subset of the visited vertices that depends on the order in which such vertices are visited.

In this talk, we propose a new dynamic method to improve the ng-path relaxation which consists of defining, iteratively, the mapping function of the ng-path relaxation using the results achieved at the previous iteration. This methodology is analogous to cutting plane methods, where the cuts violated by the ng-paths at a given iteration are incorporated in the new ng-path relaxation at the next iteration.

The new technique has been used to solve the traveling salesman problem with cumulative costs (CTSP) and to produce new benchmark results for the TSP1W. The results obtained show the effectiveness of the proposed method.

Daniele Vigo, University of Bologna (with Mario Battarra, Guus Erdoes)

An exact approach for the clustered vehicle routing problem

We present an exact approach for the clustered vehicle routing problem (CVu-VRP), which is a generalization of the capacitated vehicle routing problem (CVRP), in which the customers are grouped into clusters. As in the CVRP, all the customers must be visited exactly once, but a vehicle visiting one customer in a cluster must visit all the remaining customers in the cluster before leaving it. An integer programming formulation for the CVu-VRP based on an exponential time preprocessing scheme is presented. The linear relaxation of the formulation is strengthened in a branch & cut algorithm by including valid inequalities for the CVRP. Computational experiments on instances adapted from the literature and real-world problems are presented.

Moritz Kobitzsch, Karlsruhe Institute of Technology

Multi-objective optimization

We consider a bilevel optimal control problem where the upper level, to be solved by a leader, is a scalar optimal control problem and the lower level, to be solved by several followers, is a multiobjective convex optimal control problem. We deal with the so-called optimistic case, when the followers are assumed to choose a best choice for the leader from Northern California, using real travel-time estimates from the Mobile Millennium traffic information system.
among their best responses, as well with the so-called pessimistic case, when the best response chosen by the followers can be the worst choice for the leader. We present sufficient conditions on the data for existence of solutions to both the optimistic and pessimistic optimal control problems, with particular attention to the linear-quadratic case.

Henri Benoî, University of New Caledonia [with Jacqueline Morgan]
Semivectorial bilevel optimal control problems: Optimality conditions
We deal with a bilevel optimal control problem where the upper level is a scalar optimal control problem to be solved by the leader, and the lower level is a multi-objective convex optimal control problem to be solved by several followers acting in a cooperative way inside the greatest coalition and choosing amongst the Pareto optimal controls. This problem becomes post-Pareto analysis area because generalizes the problem of optimizing a scalar function over a Pareto set. We obtain optimality conditions for the so-called optimistic case when the followers choose among their best responses one which is a best choice for the follower, as well as for the so-called pessimistic case, when the best response chosen by the followers can be the worst case for the leader.

Julien Calliere, University of New-Caledonia [with Henri Benoî]
Optimization over the Pareto set associated with a multi-objective stochastic convex optimization problem
We deal with the problem of minimizing the expectation of a scalar valued function over the Pareto set associated with a multi-objective stochastic convex optimization problem. Every objective is an expectation now be approached by a sample average approximation function (SAA-NL), where N is the sample size. In order to show that the Hausdorff distance between the SAA-N weakly Pareto set and the true weakly Pareto set converges to zero almost surely as N goes to infinity, we need to assume that all the objectives are strictly convex. Then we show that every cluster point of any sequence of SAA-N optimal values [N = 1, 2, ...] is a true optimal solution. To weaken the strict convexity hypothesis to convexity, we need to work in the outcome space. Then, under some reasonable and suitable assumptions, we obtain the same type of results for the image of the Pareto set. Thus, assuming that the function to minimize over the true Pareto set is expressed as a function of other objectives, we show that the sequence of SAA-N optimal values [N = 1, 2, ...] converges almost surely to the true optimal value. A numerical example is presented.

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

Ting Kai Pong, University of Waterloo [with Henry Wolkowicz]
Generalized trust region subproblem: Analysis and algorithm
The trust region subproblem (TRS) is the minimization of a (possibly nonconvex) quadratic function over a ball. It is the main step of the trust region method for unconstrained optimization, and is a basic tool for regularization. In this talk, we consider a generalization of the TRS, where the ball constraint is replaced by a general quadratic constraint with both upper and lower bounds. We characterize optimality under a mild constraint qualification and extend an efficient algorithm for TRS proposed by Rendl and Wolkowicz to this setting.

Xuan-Lam Või Chuong, University of Waterloo [with Forbes Burrowski, Henry Wolkowicz]
Solving a class of quadratically constrained semidefinite programming problems with application to structure based drug design problem
We consider a class of quadratically constrained semidefinite programming (SDP) problems arising from a structure based drug design problem. In graph theoretical terms, we aim at finding a realization of a graph with fixed-length edges, such that the sum of the distances between some of the non-adjacent vertices is minimized and the graph is realized in a Euclidean space of prescribed dimension. This problem can be seen as a Euclidean distance matrix completion problem and can be phrased as a semidefinite programming problem (SDP) with quadratic constraints. In order to provide approximate solutions to the special class of quadratically constrained SDP problems, we extend the technique for solving two trust region problems (TRS) and indefinite trust region problems to the SDP. We also present some preliminary numerical results on the structure based drug design problem.

Xin Liu, Academy of Mathematics and Systems Science, Chinese Academy of Sciences [with Yile Zhang]
Beyond heuristics: Applying alternating direction method of multiplier method in solving matrix factorization problems
Alternating direction method of multipliers (ADMM) applies alternating technique on the KKT system of augmented Lagrangian function, which is a powerful algorithm for optimization problems with linear equality constraints and certain separable structures. However, its convergence has not been established except in two blocks, separable and convex cases.

In this talk, we will show ADMM also has excellent performances in solving some matrix factorization problems in which either separability or convexity does not apply. Furthermore we will present some preliminary results on the convergence of ADMM in these cases.

Jieping Ye, University of Kentucky
Beyond heuristics: Applying alternating direction method of multiplier method in solving matrix factorization problems
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Zheping Li, Shanghai University [with Binian Chen, Simai He, Zhuzhong Zhang]
Maximum block improvement and polynomial optimization
We propose an efficient method for solving a large class of polyno-
mial optimization problems, in particular, the spherically constrained homogeneous polynomial optimization. The new approach has the following three main ingredients. First, we establish a block coordinate descent type search method for nonlinear optimization, with the novelty being that we accept only a block update that achieves the maximum improvement, hence the name of our new search method: maximum block improvement (MBI). Convergence of the sequence produced by the MBI method to a stationary point is proved. Second, we establish that maximizing a homogeneous polynomial over a sphere is equivalent to its tensor relaxation problem; thus we can maximize a homogeneous polynomial over a sphere by its tensor relaxation via the MBI approach. Third, we propose a scheme to reach a KKT point of the polynomial optimization, provided that a stationary solution for the relaxed tensor problem is available. Numerical experiments have shown that our new method works very efficiently. For a majority of the test instances that we have experimented with, the method finds the global optimal solution at a low computational cost.

Zheng Hai Huang, Tianjin University (with Xianjun Shi, Lai Liyi) 

An iterative algorithm for tensor \( \alpha \)-rank minimization

Tensor arises in many areas of science and engineering including data mining, machine learning and computer vision. In this talk, we consider the tensor \( \alpha \)-rank minimization problem and adopt twice tractable convex relaxations to transform it into a convex, unconstrained optimization problem. Based on Fixed Point Continuation with Approximate Singular Value Decomposition, we propose an iterative algorithm for solving this class of problems. We show that the proposed algorithm is globally convergent under mild assumptions. The preliminary numerical results demonstrate that the proposed algorithm is effective, especially for the large-sized problems.

Vincent Leclère, Ecole des Ponts ParisTech (with Mathieu Grasselli, Mike Ludkovski) 

A splitting scheme for degenerate nonlinear PDEs: Application in an optimal hydropower management problem

Based on the semi-Lagrangian scheme and the probabilistic scheme of Fahim, Touzi and Warin for non-degenerate fully nonlinear parabolic PDEs, we propose a splitting numerical method for degenerate nonlinear parabolic PDEs. We also provide a simulation-regression method to make the splitting scheme implementable. General convergence as well as rate of convergence are obtained under reasonable conditions, using the monotone convergence of viscosity solution technique specifically.

Finally, we study an optimal hydropower management problem which can be characterized by a degenerate nonlinear parabolic PDE. A numerical resolution is given by this splitting method.

Imen Ben Tahar, Université Paris Dauphine

Integration of an intermittent energy: A mean fields game approach

The integration of renewable sources of energy to the grid brings new challenges, due to their intermittent nature. In this talk we propose a toy model, based on a mean fields games (MFG) approach, to analyze consumption decisions integrating a stochastic source of energy.
The properties of the method are studied by applying it to realistic models of petroleum fields. The examples lend themselves to a decomposition strategy due to the layout and structure of the wells and pipeline systems. The first model resembles the Troll west oil rim, a huge gas and oil field on the Norwegian Continental shelf. Decision variables are allocation of production between wells and routing of well streams. A second case also includes allocation of production and gas lift allocation. This is based on an on-going study of an offshore field outside Brazil.

Bruno Flach, IBM Research - Brazil (with Davi Valladao, Bianca Zadrozny)

An MIGP approach to the determination of analogous reservoirs

Oil companies are constantly faced with decision under uncertainty problems related to the analysis of potential investments in target reservoirs. Often, the amount of information on these prospects is relatively scarce and a common adopted strategy is having specialists determine analogous reservoirs - i.e., those for which plenty of data is available and are believed to be similar to the target - as a way to estimate unknown parameters and evaluate production forecasts. Machine learning algorithms, such as k-nearest-neighbors (KNN), may also be applied in this context but the quality of their results is intrinsically related with the definition of a distance metric that defines the similarity between the target reservoir and those stored in a database. To this end, our work focuses on the determination of an optimal distance function - in the sense of minimizing the error in the prediction of a given property or attribute - trained with the computed analogues - by formulating it as a mixed integer quadratic programming (MIGP) problem. Computational results on the application of different solution algorithms to a realistic large-scale problems will be discussed.

PDE-constrained opt. & multi-level/multi-grid meth.

Wed.1.MA 415
Optimization applications in industry III
Organizer/Chair Dietmar H"omberg, Weierstrass Institute for Applied Analysis and Stochastics - Invited Session
Roland Herzog, TU Chemnitz (with Christian Meyer, Gord Wachsmuth)

Optimal control of elastoplastic processes

Elastoplastic deformations are the basis of many industrial production techniques, and their optimization is of significant importance. We consider mainly the (idealized) case of infinitesimal strains as well as simple kinematic hardening. From a mathematical point of view, the forward system in the stress-based form is represented by a time-dependent variational inequality of mixed type. Its optimal control thus leads to an MPEC (mathematical program with equilibrium constraints) or an equivalent MPCC (mathematical program with complementarity constraints), both of which are challenging problems. In this talk we therefore address tailor-made algorithmic techniques for optimization problems involving elastoplastic deformation processes.

Anton Schiela, TU Berlin

An adaptive multilevel method for hyperthermia treatment planning

The aim of hyperthermia treatment as a cancer therapy is to damage and destroy solid tumors by heat. This can be done regionally by a microwave applicator and gives rise to the following optimization problem: “Find antenna parameters, such that the damage caused to the tumor is maximized, while healthy tissue is spared”. Mathematically, this is a PDE constrained optimization problem subject to the time-harmonic Maxwell equations, which govern the propagation of the microwaves, and the bio heat transfer equation, a semi-linear elliptic equation, which governs the heat distribution in the human body. Further, upper bounds on the temperature in the healthy tissue are imposed, which can be classified as pointwise state constraints.

In this talk we consider a function space oriented algorithm for the solution of this problem, which copes with the various difficulties. The state constraints are tackled by an interior point method, which employs an inexact Newton corrector in function space for the solution of the barrier subproblems. Herein, discretization errors are controlled by a-posteriori error estimation and adaptive grid refinement.

Michael Stingl, Friedrich-Alexander-University Erlangen-Nürnberg (with Fabian Schury, Fabian Wein)

Matrix-free interior point method for compressed sensing problems

We consider the class of \( \ell_1 \)-regularization methods for sparse signal reconstruction from the field of Compressed Sensing. Such problems are well conditioned and, indeed, can be solved by first-order methods, such as, GPSR, FPC_AS, SPGL1, NestA. Interior point methods rely on second-order information. They have many advantageous features and one clear drawback: in general, the solution of a Newton’s method is optimal or close to optimal. In this talk we will present our matrix-free interior point method with suitable preconditioners which clearly exploit special features of compressed sensing problems. Spectral analysis of the preconditioners is presented. Computational experience with large-scale grandmother as well as special bounds on the stiffness of the material are added. The latter constraints are chosen compatible with the choice of the material on the microscopic level. Approximate solutions methods for this modified FMO problem are presented. In a discretized finite element setting the result of the macroscopic problem is a set of material tensors. Depending on the macroscopic constraints, these tensors are either directly interpreted as periodic microstructures or accessible through an inverse homogenization approach.

Elin Celiksinayka, Leibniz University (with Aurelio Thiele)

Robust optimization

We study robust revenue management problems when companies request bids for services but their price-response function is not known precisely. The company bidding for these contracts only knows the previous bids it submitted to those businesses and whether they were accepted or not. We show how to derive tractable mathematical models for this problem and provide insights into the optimal solution. We also document the performance of the approach in numerical experiments.

Ban Kawas, IBM Research – Zürich (with Marco Laumanns, Eleon Pratsini)

A robust optimization approach to enhancing reliability in production planning under non-compliance risks

We investigate a game-theoretic setup of a production planning problem under uncertainty in which a company is exposed to the risk of failing authoritative inspections due to non-compliance with enforced regulations. The outcome of an inspection is uncertain and is modeled as a Bernoulli distributed random variable whose parameter is a function of production decisions. We model non-compliance probabilities as uncertain parameters belonging to polyhedral uncertainty sets and maximize the worst-case expected profit over these sets. We derive convex tractable formulations, in the form of MIPs, that offer the flexibility of matching solutions to the level of conservatism of decision makers via two intuitive parameters. Varying these parameters when solving for the optimal product allocation provides different risk-return tradeoffs. We give strong empirical evidence that exhibits the superior performance of the devised model. We believe the robust approach holds much potential in enhancing reliability in production planning and other frameworks in which probabilities of random events depend on decision variables and in which parameter uncertainty is prevalent and difficult to handle.

Slawomir Pietrzak, Paris Dauphine – GOF Save

Strategically robust investments on gas transmission networks

Looping regional gas transmission networks to increase their capacity involves considerable costs. Thus the corresponding investment decisions occur only after thoroughly weighing both the industrial and economic pros and cons. Wouldn’t it be profitable to encompass those uncertainties from the top to deliver several equivalent investment alternatives that no decision maker would regret? Hence, we have focused on the evolving context of investment studies and identified uncertain technical, economic and strategic parameters who play a significant role in the out coming investment proposition. Analyzing what is at stake when it comes to robustness and flexibility has led us to introduce a mathematical risk measure which is interpretable in operational terms. We eventually offer a set of R&D approaches, that we hope, will contribute to shift present optimization models into future robust decision rules.

Sparse optimization & compressed sensing

Wed.1.H 1023
Algorithms for sparse optimization II
Organizer/Chair Kimon Fountoulakis, Edinburgh University - Invited Session
Kimon Fountoulakis, Edinburgh University (with Jacek Gondzio, Pavel Zibbich)

Matrix-free interior point method for compressed sensing problems

We consider the class of \( \ell_1 \)-regularization methods for sparse signal reconstruction from the field of Compressed Sensing. Such problems are very well conditioned and, indeed, can be solved by first-order methods, such as, GPSR, FPC_AS, SPGL1, NestA. Interior point methods rely on second-order information. They have many advantageous features and one clear drawback: in general, the solution of a Newton’s method is optimal or close to optimal. In this talk we will present our matrix-free interior point method with suitable preconditioners which clearly exploit special features of compressed sensing problems. Spectral analysis of the preconditioners is presented. Computational experience with large-scale
Linearized alternating direction methods for Dantzig selector

The Dantzig selector was recently proposed to perform variable selection and model fitting in the linear regression model, and it can be solved numerically by the alternating direction method (ADM). In this paper, we show that the ADM for Dantzig selector can be speeded up significantly if one of its resulting subproblems at each iteration is linearized. The resulting linearized ADMs for Dantzig selector are shown to be globally convergent, and their efficiency is verified numerically by both simulation and real world data-sets.

Iteratively reweighted least squares methods for structured sparse regularization

We describe two new algorithms useful for obtaining sparse regularized solutions to large inverse problems, based on the idea of reweighted least squares. We start from the standpoint of minimization, and show that by replacing the non-smooth one norm \( \|x\|_1 \) with a reweighted two norm: \( \sum_{k=1}^{N} w_k |x_k|^2 \), with the weights being refined at each successive iteration, we can formulate two new algorithms with good numerical performance. We then discuss a generalization of both variants, useful in cases of structured sparsity, where different sets of coefficients demand different treatment. We discuss in particular, an example from a large inverse problem from Geotomography, where Wavelets are used to promote sparsity. We show that to build up a solution from a dictionary of different Wavelet bases and to have control over the different components of each Wavelet basis, the minimization of a more general functional: \( \|Ax - b\|_2^2 + \sum_{k=1}^{N} \alpha_k |x_k|^2 \) for \( 1 \leq q_k < 2 \) is desirable. We show that our proposed schemes extend to this more general case.

Scheduling, control and moment problems

We study the stochastic versions of a broad class of combinatorial problems in industry, which contains an optimal conversion of machines. Under the assumption of identical “basic costs” (in other words of “unit dis- cisions for feasible states with least square sums of their parts are optimal. Corresponding Markov kernels are called partitions-Requirements-Matrices (PRMs).

Optimal decisions of such problems can be used as approximate solutions of corresponding SDP problems, in which the basic costs differ only slightly from each other or as starting decisions if corresponding SDP problems are solved by iterative methods, such as the Howard algorithm.

Models for the optimum value and dual type algorithmic solutions will be shown (in many cases) by means of combinatorial ideas that de- cisions for feasible states with least square sums of their parts are optimal. Corresponding Markov kernels are called partitions-Requirements-Matrices (PRMs).

Optimal decisions of such problems can be used as approximate solutions of corresponding SDP problems, in which the basic costs differ only slightly from each other or as starting decisions if corresponding SDP problems are solved by iterative methods, such as the Howard algorithm.

Risk aversion in stochastic combinatorial optimization

We characterize the dual feasible bases, in connection with univari- ate discrete moment problem for new classes of objective function and its applications.

We characterize the dual feasible bases, in connection with univariate discrete moment problem for classes of objective function not dealt with until now, e.g., step functions with finite number of values. Formulas for the optimum value and dual type algorithmic solutions will be presented. Applications will be mentioned to engineering design and finance.

Maximizing expected utility for stochastic combinatorial optimization problems

We study the stochastic versions of a broad class of combinatorial...
problems where the weights of the elements in the input dataset are uncertain. The class of problems that we study includes shortest paths, minimum weight spanning trees, and minimum weight matchings over probabilistic graphs, and other combinatorial problems like knapsacks. We observe that the expected value is inadequate in capturing different types of risk-averse or risk-prone behaviors, and instead we consider a more general objective which is to maximize the expected utility of the solution for some given utility function, rather than the expected weight (expected weight becomes a special case). We show that we can obtain a polynomial time approximation algorithm with additive error $\epsilon$ for any $\epsilon > 0$, and the maximum value of the utility function is bounded by a constant. Our result generalizes several prior results on stochastic shortest path, stochastic spanning tree, and stochastic knapsack. For our approach for utility maximization makes use of a technique to decompose a general utility function into exponential utility functions, which may be useful in other stochastic optimization problems.

Chiatalaya Swayam, University of Waterloo

**Risk-averse stochastic optimization: Probabilistically-constrained models and algorithms for black-box distributions**

We consider various stochastic models that incorporate the notion of risk-averseness into the standard 2-stage recourse model, and develop techniques for solving the algorithmic problems arising in these models. A key notable and distinguishing feature of our work is that we obtain results in the black-box setting, where one is given only sampling access to the underlying distribution. One such model is what we call the risk-averse budget model, where we impose a probabilistic constraint that restricts the probability of the second-stage cost exceeding a given budget $B$ to at most a given input threshold $\delta$. We devise an approximation scheme for solving the LP-relaxations of a variety of risk-averse budgeted problems. Complementing this, we give a rounding procedure that lets us use existing LP-based approximation algorithms for the 2-stage and/or deterministic counterpart of the problem to round the fractional solution. This yields approximation algorithms for various discrete optimization problems in our risk-averse models with black-box distributions. These are the first approximation results for problems involving probabilistic constraints with black-box distributions.

Abraham Othman, Carnegie Mellon University (with Tuomas Sandholm)

**Inventory-based versus prior-based options trading agents**

Options are a basic, widely-traded form of financial derivative that offer payouts based on the future price of an underlying asset. The finance literature gives us option-trading algorithms that take into consideration information about how prices move over time but do not explicitly involve the trades the agent made in the past. In contrast, the prediction market literature gives us automated market-making agents (like the popular LMSR) that are event-independent and price trades based only on the inventories the agent holds. We simulate the performance of five trading agents inspired by these literatures on a large database of recent historical option prices. We find that a combination of the two approaches produced the best results in our experiments: a trading agent that keeps track of previously-made trades combined with a good prior distribution on how prices move over time. The experimental success of this synthesized trader has implications for agent design in both financial and prediction markets.

In this talk, we propose and study the hop-constrained survivable network design problem with reliable edges. We study the hop-constrained survivable network design problem with reliable edges. Given a graph with non-negative edge weights and node pairs $Q$, the hop-constrained survivable network design problem consists of constructing a minimum weight set of edges so that the reduced subgraph contains at least $K$ edge-disjoint paths containing at most $L$ edges between each pair in $Q$. In this talk, we propose and study the hop-constrained survivable network design problem with so-called reliable edges where in addition, we consider a subset of edges that are not subject to failure. We study two variants (a static problem where the reliability of edges is given, and an upgrading problem where edges can be upgraded to the reliable status at a given cost). We adapt for the two variants an extended formulation proposed in [BFGP11] for the case without reliable edges. Due to the huge number of variables and constraints included in the extended formulations, we use Benders decomposition to accelerate the solving process. We develop an exact branch-and-cut and algorithm and a fix-and-bound heuristic.

Eduardo Aulindo, Politecnico di Milano (with Antonio Capone, Stefano Coniglio, Luca Gianni)

**Network routing subject to max-min fair flow allocation**

In the Max-min fairness (MMF) flow allocation principle not only the bandwidth of the commodity with the smallest allocation is maximized, but also in turn the second worst, the third worst and so on. While in previous work the MMF principle has been used as routing objective, we consider it as a constraint, since it allows to well approximate TCP flow allocation when the routing paths are given. We investigate the problem of given a network and set of commodities, selecting a single path for each commodity so as to maximize a network utility function subject to MMF flow allocation. We compare some mathematical programming formulations, describe a column generation approach and report some computational results.

Organizer/Chair Bernard Fortz, Université Libre de Bruxelles. Invited Session

**Network flows and network design**

**Variational analysis**
Quadric and polynomial optimization
Organizer/Chair: Jeya Jeyakumar, The University of New South Wales - Invited Session

Gwo Sow Kim, Pukyong National University, Busan, Republic of Korea [with Gwo Myung Lee]
On ε-saddle point theorems for robust convex optimization problems

In this talk, we consider ε-approximate solutions for a convex optimization problem in the face of data uncertainty, which is called a robust convex optimization problem. Using robust optimization approach (worst-case approach), we define ε-saddle points for ε-approximate solutions of the robust convex optimization problem. We prove a sequential ε-saddle point theorem for an ε-approximate solution of a robust convex optimization problem which holds without any constraint qualification, and then we give an ε-saddle point theorem for an ε-approximate solution which holds under a weaker constraint qualification.

Jeya Jeyakumar, The University of New South Wales [with Guoyin Li]
Sum of squares representations and optimization over convex semialgebraic sets

We present sum of squares representations of positive or non-negative SOV-convex polynomials over non-compact convex sets without any qualifications. In the case of representations of positive polynomials, we allow representations to hold up to a positive constant, whereas for representations of non-negative polynomials, we permit them to hold asymptotically. Exploiting convexity of the systems and using hyperplane separations, we derive qualification-free representations in terms of sum of squares polynomials. Consequently, we show that for an SOS-convex optimization problem, its sum of squares relaxation problem is always exact. Stronger relaxation and duality results are given when a constraint qualification is present.

Guoyin Li, University of New South Wales [with Boris Mordukhovich]
Error bound for classes of polynomial systems and its applications: A variational analysis approach

Error bound is an important tool which provides an effective estimation of the distance from an arbitrary point to a set in terms of a computable "residual function". The study of error bound plays an important role in the convergence analysis of optimization algorithms and accurate identification of active constraints. In this talk, we are interested in error bound for classes of polynomial systems. Using variational analysis technique, we first show that global Lipschitz type error bound holds for a convex polynomial under Slater condition. When Slater condition is not satisfied, we establish a global Hölderian type error bound with an explicit estimate of the Hölderian exponent extending the known results for convex quadratic functions. Next, we extend these results to some classes of nonconvex system including piecewise convex polynomials and composite polynomial systems. Finally, as an application, we apply the error bound to result in a quantitative convergence analysis of the classical proximal point method.

Approximation & online algorithms

Jose Soto, Universidad de Chile [with Jose Correa, Omar Larré]
The traveling salesman problem in cubic graphs

We prove that every 2-connected cubic graph on \( n \) vertices has a tour of length at most \( (4/3 - \varepsilon)n \), for a small, but positive \( \varepsilon \). This in particular implies that the integrality gap of the Held and Karp LP relaxation for the TSP is strictly less than \( 4/3 \) on this graph class.

Jose Verschae, Universidad de Chile [with Nicole Megow, Martin Skutella, Andreas Wiese]
The power of recourse for online MST and TSP

We consider online versions of MST and TSP problems with recourse. Assume that vertices of a complete metric graph appear one by one, and must be connected by a tree (respectively tour) of low cost. In the standard online setting, where decisions are irrevocable, the competitive factor of each algorithm is \( \Omega(\log n) \). In our model, recourse is allowed by granting a limited number of edge rearrangements per iteration. More than 20 years ago, Imase and Waxman [1991] conjectured that constant-competitive solutions can be achieved with a constant (amortized) number of rearrangements. In this talk, we will present an algorithm that solves this conjecture for MSTs in the amortized setting.

Unlike in offline TSP variants, the standard double-tree and shortcutting approach does not give constant guarantees in the online setting. However, a non-trivial robust shortcutting technique allows to construct trees into tours at the loss of small factors, implying the conjecture of Imase and Waxman for tours.

For the non-amortized setting, we conjecture a structural property of optimal solutions that would imply a constant competitive ratio with one recourse action per iteration.

Claudio Telha, Universidad de Chile [with Jose Soto]
The jump number (maximum independent set) of two-directional orthogonal-ray graphs

Let \( \text{S} \) be a special case of the independent set of rectangles problem. Given a family of white \( W \) and black \( B \) points in the plane, we construct the family \( R \) of rectangles having bottom-left corner in \( W \) and top-right corner in \( B \). The problem is to find the maximum cardinality of a collection of disjoint rectangles in \( R \).

We show that this problem can be efficiently solved using linear programming techniques. Inspired by this result, and by previous work of A. Frank, T. Jordan and L. Vegh on set-pairs, we describe a faster combinatorial algorithm that solves this problem in \( O(|W| + |B|)^{1.5} \) time.

We also establish a connection between this special case of the independent set of rectangles problem and the problem of finding the jump number of a certain class of comparability graphs (known as two-directional orthogonal ray graphs). Using this connection, we can compute the jump number of convex graphs with \( n \) nodes in \( O(n \log n)^5 \) time, while previous algorithms for these instances ran in time at least \( O(n^6) \).

Extended formulations in discrete optimization III
Organizers/Chairs: Volker Kaibel, Otto-von-Guericke Universität Magdeburg; Samuel Fiorini, Université libre de Bruxelles (ULB) - Invited Session

Hans Raj Tiwary, Université Libre de Bruxelles [with Samuel Fiorini, Thomas Rothvoss]
Extended formulations for polygon

We consider the convex hull of a mixed-integer set \( S \) by expressing each continuous variable as the average of \( k \) integral variables. This allows us to model \( S \) as a pure integer set in an extended space. The integrality of the additional variables allows us to strengthen the inequalities that describe \( S \).

We concentrate on a mixed-integer set defined as follows: Given a bipartite graph \( G = (U \cup V, E) \), a set \( F \subseteq U \cup V \) and rational numbers \( b_{ij}, \; i \in F, \; j \in E, \) let \( S(G, F) = \{ x \in \mathbb{R}^{U \cup V} : x_{ij} \geq b_{ij}, \; i \in E, \; x_i \in \mathbb{Z}, \; i \in F \} \).

We show that the set \( S(G, F) \) is equivalent to the "network dual" set introduced and studied by Conforti, Di Summa, Eisenbrand and Wolsey. Conforti et al. give an extended formulation for the polyhedron \( \text{conv}(S(G, F)) \) and discuss cases in which the formulation is compact.

Our goal is to describe the polyhedron \( \text{conv}(S(G, F)) \) in the space of the \( x \) variables and we give properties of the facet-defining inequalities. Our principal result is a characterization of the structure of facet-defining inequalities when the graph \( G \) is a tree.

Giacomo Zambelli, London School of Economics and Political Science [with Michele Conforti, Bert Gerards, Laurence Wolsey]
Mixed-integer bipartite vertex cover and mixing sets

The mixed-integer bipartite vertex-covering problem consists in optimally assigning weights to the nodes of a bipartite graph so that the sum of the weights on the endnodes of each edge is at least some prescribed edge requirement, and that the weights on certain nodes are integer. Besides being the natural mixed-integer counterpart of the classical vertex-covering problem, this model arises as a relaxation of several lot-sizing problems. While no satisfactory polyhedral characterization is known, an extended formulation - albeit not polynomial in size - was given by Conforti, Di Summa, Eisenbrand and Wolsey. We give results on the projection of the extended formulation onto the original space, leading to full polyhedral characterizations for the case when the edge-requirements are half-integral and for certain classes of lot-sizing problems.
Geometric combinatorial optimization
Chair Maurice Queyranne, Sauder School of Business at UBC

Maurice Queyranne, Sauder School of Business at UBC

Modeling convex subsets of points

A subset $S$ of a given set $P$ of points in a vector space is convex relative to $P$ if every point of $S$ that is in the convex hull $S$ is also in $S$. We are interested in modelling such discrete convexity restrictions which arise, usually in a low-dimensional space and subject to additional constraints, in many applications (e.g., mining, forestry, location, data mining, political districting, police quadrant design). This question is well understood in one dimension, where optimization can be solved in time that is linear in the number $|P|$ of given points; a complete but exponential-size) piecewise linear description in the natural variables (that select the points in $S$), and a linear-time separation algorithm are known, as well as a linear-sized ideal extended formulation. On the other hand the optimization problem to find a maximum weight convex subset of given points with weights of arbitrary signs is NP-hard. In dimensions three and higher, and inapproximable when the dimension is part of the input. In the two-dimensional plane, the optimization problem is solved in polynomial (cubic) time by dynamic programming (Bautista-Santiago et al., 2011) and, thanks to Carathéodory’s theorem, in $O(n^2)$ time in dimensions $d$.

On the x-and-y axes travelling salesman problem

We consider a special case of the Euclidean Travelling Salesman Problem (TSP) known as x-and-y-axes TSP. In this case all cities lie on the x-axis and on the y-axis of an orthogonal coordinate system for the Euclidean plane. This is a special case of the so-called Constrained TSP (CTSP) investigated by Rubinstein, Thomas and Wormald (2001), where the cities lie on a given finite set $G$ of smooth, compact curves in the plane, such that each curve has a finite length and the number of (self) intersections is finite. Moreover at each intersection the branches of the curve approach in different directions. Rubinstein et al. have shown that the CTSP is polynomially solvable, where the degree of the polynomial is large and depends on $G$ and $n$. We show that for each circle around the origin the optimal tour of the x- and y-axes TSP contains at most eight edges passing through the circle. By considering one circle for each vertex we construct a dynamic programming scheme (DPS) which assembles the optimal tour by means of optimal sub-paths lying outside the circle and on one of the half-axes. A non-trivial analysis shows that this DPS leads to an $O(n^2)$ time algorithm.

Algorithms for the restricted strip cover problem

Broadly speaking, sensor cover problems comprise problems of the following nature. Given a region to be covered by a set of sensors previously positioned, each one powered with a battery of limited duration, assign to each sensor an initial time, so as to cover the given region for as long as possible.

We investigate the one-dimensional version of the problem, called restricted strip cover problem, in which the region to be covered is an interval of the real line and the duration of the batteries is non-uniform. We study both the preemptive and the non-preemptive case. In the first case, the sensors can be turned on and off more than once. For this case, we present a polynomial-time algorithm. For the non-preemptive case, known to be NP-hard, we develop a polynomial-time algorithm which we proved to be a 5-approximation. We proved that this algorithm has approximation ratio 4, being this ratio tight. We present integer linear formulations for the non-preemptive case, and report on the computational results obtained with this approach, and some relaxations.

Combinatorial optimization

Wed.2.H 3005

Combinatorial optimization

Organizer: Chair Friedrich Eisenbrand, TU Berlin - Invited Session

Bernd Gärtner, ETH Zürich (with Abel Camacho)

Abstract optimization problems revisited

Abstract Optimization Problems (AOP) generalize linear programs and have been invented with the goal of providing an abstract setting in which the subexponential randomized linear programming algorithms of Kalai and of Matousek, Sharir and Welzl still work. Linear programming abstractions have also been considered recently by Eisenbrand et al., and Kim, and others in the context of diameter bounds for polytopes. In this talk, I want to discuss whether and how AOP relate to these new abstractions.

Marco Di Summa, Università degli Studi di Padova (with Nicolas Bonifits, Friedrich Eisenbrand, Nicolai Rudehe, Martin Niemeyer)

A new bound on the diameter of polyhedra

We derive a new upper bound on the diameter of the graph of a polyhedron $\mathcal{P} = \{x \in \mathbb{R}^n : Ax \leq b\}$, where $A \in \mathbb{Z}^{m \times n}$, the bound is polynomial in $n$ and the largest absolute value of a sub-determinant of $A$, denoted by $\Delta$. More precisely, we show that the diameter of $\mathcal{P}$ is bounded by $O(\Delta^{n/4} \log(\Delta))$. If $\mathcal{P}$ is bounded, then we show that the diameter of $\mathcal{P}$ is at most $O(\Delta^{n/4} \log(\Delta))$. For the special case in which $\mathcal{P}$ is a totally unimodular matrix, the bounds are $O(n \log n)$ and $O(n^{3/2} \log n)$ respectively. This improves over the previous best bound of $O(n^{16} \log n)$ due to Dyer and Frieze.

Edward Kim, Pohang University of Science and Technology

Subset partition graphs and an approach to the linear Hirsch conjecture

Combinatorial abstractions of the graphs of polyhedra are receiving renewed interest as an approach to the linear Hirsch and polynomial Hirsch conjectures. Since Santos disproved the Hirsch conjecture, which was relevant in the theoretical worst-case running time of the simplex method for linear optimization. We will give a survey of several classical combinatorial abstractions for polyhedral graphs. Then we show how they fit into a more general framework, which leads to some variants of these earlier abstractions. This flexible framework is defined by combinatorial properties, with each collection of properties taken providing a variant for studying the diameters of polyhedral graphs. We present a variant which has superlinear diameter, which together with some combinatorial operations gives a concrete approach for disproving the linear Hirsch conjecture.

Wed.2.H 3012

Heuristics II

Chair Abderrazek Djadoun, ZAK Technology

Salim Bouamama, University of M’sila, Algeria (with Christian Blum, Abdallah Boukerram)

A population-based iterated greedy algorithm for the minimum weight vertex cover problem

Given an undirected, vertex-weighted graph, the goal of the minimum weight vertex cover problem is to find a subset of the vertices of the graph such that the subset is a vertex cover and the sum of the weights of its vertices is minimal. This problem is known to be NP-hard and no efficient algorithm is known to solve it optimally. Therefore, most existing techniques are based on heuristics for providing approximate solutions in a reasonable computation time. Population-based search approaches have shown to be effective for solving a multitude of combinatorial optimization problems. Their advantage can be identified as their ability to find areas of the space containing high quality solutions. This paper proposes a simple and efficient population-based iterated greedy algorithm for tackling the minimum weight vertex cover problem. At each iteration, a population of solutions is established and refined using a fast randomized iterated greedy heuristic based on successive phases of destruction and reconstruction. An extensive experimental evaluation on a commonly used set of benchmark instances shows that our algorithm outperforms current state-of-the-art approaches.

Abderrazek Djadoun, ZAK Technology (with Ibtih Bousaid)

Random synchronized prospecting: A new metaheuristic for combinatorial optimization

In this contribution, we introduce Random Synchronized Prospect-ing (RSP), a new metaheuristic for solving NP-Hard combinatorial optimization problems. This metaheuristic is presented as a successor of the Search Intellig-ence(SI) technique inspired by the way two groups of individuals would collaborate and exchange information while prospecting the solution’s search space. An example of the efficiency of this metaheuristic is presented by introducing the RSP-QAP algorithm, an adaptation of the RSP metaheuristic for the Quadratic Assignment Problem (QAP). Computational results of applying the RSP-QAP algorithm to over 60 instances from the QAPLIB are shown.
Our work on parallelization strategies. We finished the DIMACS Implementation Challenge. We reviewed successful internal and few external edges. The problem of finding clusters based on the objective function modularity was one category in the recently conducted challenge. Graph clustering aims at the identification of vertex subsets with many internal and few external edges. Current trends in graph clustering investigate how to approximate the following values for mathematical programs with quasi-variational inequality constraints

$$\omega = \inf_{x \in X} \sup_{u \in Q(x)} f(x,u)$$

via the values of appropriate regularized programs under or without perturbations. In particular, we consider the case where the constraint set $X$ and the constraint set-valued mapping $S$ are defined by inequalities

$$X = \{ x : g_i(x) \leq 0, i = 1, \ldots, m \}$$

$$S(x,u) = \{ w : f_i(x,u,w) \leq 0, j = 1, \ldots, n \}.$$ 

Using suitable regularizations for quasi-variational inequalities, we characterize the solutions which have the property that all players share the same Lagrange multipliers. Nash equilibria of this kind were introduced and investigated by Rosen in 1965, in finite dimensional spaces. In order to obtain the same property in infinite dimension we use very recent developments of a new duality theory. In view of its usefulness in the study of time-dependent or stochastic equilibrium problems an application in Lebesgue spaces is given.

**On generalized Nash equilibrium problems: The Lagrange multipliers approach**

We present a novel exact algorithm for the minimum graph bisection problem. Its goal is to partition a graph into two equally sized cells while minimizing the number of edges between them. Our algorithm is based on the branch-and-bound framework and, unlike most previous approaches, it is fully combinatorial. We present stronger lower bounds, improved branching rules, and a decomposition technique that contracts entire regions of the graph without losing optimality guarantees. In practice, our algorithm works particularly well on instances with relatively small minimum bisections, solving large real-world graphs (with tens of thousands to millions of vertices) optimally.

**High quality graph partitioning**

We present an overview over our graph partitioners KaFFPaE (Karlruhe Fast Flow Partitioner) and KaFFPaE (KaFFPa Evolutionary). KaFFPaE is a multilevel graph partitioning algorithm which on the one hand uses novel local improvement algorithms based on max-flow and min-cut computations and more localized FM searches and on the other hand uses more sophisticated global search strategies transferred from multi-grid linear solvers. KaFFPaE is a distributed evolutionary algorithm to solve the Graph Partitioning Problem. KaFFPaE uses KaFFPa which provides new effective crossover and mutation operators. By combining these with a scalable communication protocol we obtain a system that is able to improve the best known partitioning results for many inputs.

**Current trends in graph clustering**

Graph clustering has become very popular in recent years and is also known as community detection in networks. Generally speaking, graph clustering aims at the identification of vertex subsets with many internal and few external edges. The problem of finding clusters based on the objective function modularity was one category in the recently finished 10th DIMACS Implementation Challenge. We review successful techniques determined by the outcome of the challenge and describe our work on parallelization strategies.

**Combinatorial & variational inequalities**

**Advances in the theory of complementarity and related problems II**

Chair: Joachim Gwinner, Universität der Bundeswehr München

### Maria Lignola, University of Naples Federico II (with Jacqueline Morgan)

**Mathematical programs with quasi-variational inequality constraints**

We study a class of generalized Nash equilibrium problems and characterize the solutions which have the property that all players share the same Lagrange multipliers. Nash equilibria of this kind were introduced and investigated by Rosen in 1965, in finite dimensional spaces. In order to obtain the same property in infinite dimension we use very recent developments of a new duality theory. In view of its usefulness in the study of time-dependent or stochastic equilibrium problems an application in Lebesgue spaces is given.

**On linear differential variational inequalities**

Recently Pang and Stewart introduced and investigated a new class of differential variational inequalities in finite dimensional spaces as a new modeling paradigm of variational analysis. This new subclass of differential inclusions unifies ordinary differential equations with possibly discontinuous right-hand sides, differential algebraic systems with constraints, dynamic complementarity systems, and evolutionary variational systems. In this contribution we lift this class of nonsmooth dynamical systems to the level of a Hilbert space, but in contrast to recent work of the author we focus to linear input/output systems. This covers in particular linear complementarity systems studied by Heemels, Schumacher and Weiland. Firstly, we provide an existence result based on maximal monotone operator theory. Secondly we present a novel upper set convergence result with respect to perturbations in the data, including perturbations of the associated linear maps and the constraint set.

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**Semidefinite programming and geometric representations of graphs**

### Monique Laurent, CWI, Amsterdam and U Tilburg; Christoph Helmberg, TU Chemnitz - Invited Session

### Susanna Reiss, Chemnitz University of Technology (with Frank Görg, Christoph Helmberg)

**Optimizing extremal eigenvalues of the weighted Laplacian of a graph**

We study connections between the eigenspaces of the graph's Laplacian and graph properties. For this purpose, we analyze optimal solutions of

$$\min \{ \lambda_m (L_g (G)) - k_2 \lambda_2 (L_g (G)) \},$$

by semidefinite programming techniques, i.e., we optimize nonnegative edge weights $w$ of a graph, that sum up to one, so as to minimize the difference of the maximum and the second smallest eigenvalue of the corresponding weighted Laplacian $L_w (G)$. The dual program may be interpreted as a graph realization problem in Euclidean space, that reflects the optimized eigenspaces. We present connections between structural properties of the graph (especially its separator structure) and geometrical properties of optimal graph realizations, thereby shedding light on
relations between the graph’s properties and its eigenvectors. Furthermore we are able to prove the existence of optimal graph realizations whose dimensions are bounded by the tree-width of the graph plus one.

Marcel de Carli Silva, University of Waterloo (with Levent Tuncel)

**Optimization problems over unit-distance representations of graphs**

We start with a result of Lovász relating the theta number of a graph to its smallest radius hypersphere embedding where each edge has unit length. We use this identity and its generalizations to establish close relationships among many related graph parameters. We then study the more general problem of finding the smallest radius of an ellipsoid of a given shape that contains an embedding of a given graph where each edge has unit length.

This talk is based on joint work with Levent Tuncel.

Antonios Varvitsiotis, Centrum Wiskunde & Informatica (with Marianna Eisenberg-Nagy, Monique Laurent)

**Two new graph parameters related to semidefinite programming with a rank constraint**

We consider geometric representations of edge weighted graphs obtained by assigning unit vectors to the nodes, such that the weight of each edge is equal to the inner product of the vectors assigned to its endpoints. We introduce two new graph parameters related to the minimum dimension where such representations exist. Their study is motivated by their relevance to bounded rank positive semidefinite matrix completions and to the graphical Grothendieck problem with a rank constraint.

In this talk we analyze combinatorial and geometric properties of these parameters. In particular, we prove forbidden minor characterizations as well as structural and complexity results. Additionally, we discuss how our results imply some known characterizations of parameters related to Euclidean graph realizations and Colin de Verdiere-type graph invariants.

Stephen Wright, University of Wisconsin-Madison (with Caroline Uhler)

**Packing ellipsoids (and chromosomes)**

Problems of packing shapes with maximal density, possibly into a container of restricted size, are classical in mathematics. We describe here the problem of packing ellipsoids of given (and varying) dimensions into a finite container of given size, allowing overlap between adjacent ellipsoids but requiring some measure of total overlap to be minimized. A trust-region bilevel optimization algorithm is described for finding local solutions of this problem – both the general case and the more elementary special case in which the ellipsoids are in fact spheres. Tools from conic optimization, especially semidefinite programming and duality, are key to the algorithm. Theoretical and computational results will be summarized. Our work is motivated by a problem in structural biology – chromosome arrangement in cell nuclei – for which results are described.

James Saunderson, Massachusetts Institute of Technology (with Pablo Parrilo)

**Polynomial-sized semidefinite representations of derivative relaxations of spectrahedral cones**

The hyperbolicity cones associated with the elementary symmetric polynomials provide an intriguing family of non-polynomial relaxations of the non-negative orthant that preserve its low-dimensional faces and successively discard higher dimensional structure. A similar construction gives a family of outer approximations for any spectrahedral cone (i.e. slice of the psd cone), and more generally for any hyperbolicity cone. We show, by a simple and explicit construction, that these derivative relaxations of spectrahedral cones have polynomial-sized representations as projections of slices of the psd cone. This, for example, allows us to solve the associated linear cone program using semidefinite programming, and allows us to give corresponding explicit semidefinite representations for (the thus far poorly understood) duals of the derivative relaxations of spectrahedral cones.
Optimization methodologies in computational finance

In this talk, we present parallelization and extensions of algorithms for derivative-free optimization. In each iteration, we run several instances of an optimization algorithm with different trust region parameters, and each instance generates a point for evaluation. All points are kept in a common priority queue and the most promising points are evaluated in parallel when computers are available. We use models from several instances to prioritize the points and in case new information becomes available, we allow dynamic prioritization of points to ensure that computational resources are used efficiently. A database is used to avoid reevaluation of points. Together, these extensions make it easier to find several local optima and rank them against each other, which is very useful when performing robust optimization. Empirical testing reveals considerable decreases in the number of function evaluations as well as in the time required to solve problems.

Optimization methodologies in computational finance

Organizer/Chair Wei Xu, Tongji University - Invited Session

Cristina Falga, Institute of Mathematical Statistics and Applied Mathematics of Romanian Academy

Higher moments and conditional value at risk optimization

In order to control their exposure to risk, financial institutions are in charge of estimating risks caused by changes in asset prices and exchange and/or interest rates. Due to present regulations, the risk management of portfolios is intimately related to value at risk. For VaR calculation, there is the straightforward formula that can be used under the assumption that the log-returns of the portfolio are normally distributed and to which VaR can be expressed in terms of mean and variance. But empirical evidence shows that, generally, financial returns are not normally distributed. In this paper we find the expression of the VaR and conditional value at risk in terms of higher moments of the input loss distribution and compare the importance of different moments in VaR and CVaR. Using the maximum entropy principle, we find the best fit for the empirical probability distribution function in terms of its empirical moments. Their weights indicate which of them should be used in the Cornish-Fisher expansion. The VaR and CVaR approximation formulas are used to reduce the computational effort for large portfolio optimization problems.

Weizhong Xu, Tongji University (with Zhong Heng)

A new sampling strategy willow tree method with application to path-dependent option pricing

Willow tree algorithm, first developed by Curran in 1998, provides an efficient option pricing procedure. However, it leads to a big bias using in Curran’s sampling strategy when the number of points at each step is not large. Thus, in this paper, we propose a new sampling strategy with solving a small nonlinear least square problem. Compared with Curran’s sampling strategy, the new strategy gives a much better estimation of the standard normal distribution with small amount of sampling points. Then, we apply the willow tree algorithm with the new sampling strategy to price path-dependent options such as American and Asian moving-average options. The numerical results illustrate that the willow tree algorithm is much more efficient than the least square Monte Carlo method and binomial tree method.

Asaf Shugo, MNBa Canada TD Bank Group (with Dragoș Calițoiu, Hasan Mykolti)

Optimal promotion rate in a cash campaign

Taking care of customers and serving them better by building optimal strategies meeting their financial needs are the most important challenges to maintain existing customers and to remain profitable. In the scenario when a company lends money to its customers, the process of assigning to each offer the optimum interest rate becomes a complex task, considering many other offers from competitors and considering that, in many cases, the goal of lending is not only the profit while reducing risk but also satisfying real needs of customers.

This current research presents the results of implementing our previous reported network optimization approach that uses customer level scores produced by a suite of cash models. The implementation is a real-life application which helps building optimal promotion campaigns by offering the optimal interest rates to each customer. In summary, from the mathematical perspective, this application provides an integer optimal solution which optimizes a goal function subject to some budget and business constraints. The improvement of using this optimization process versus the classical approach was evident in all campaigns investigated in this research.

Per-Magnus Olsson, Linköping University (with Holmberg Kaj, Olsson Per-Magnus)

Parallelization of algorithms for derivate-free optimization

This talk presents parallelization and extensions of algorithms for derivative-free optimization. In each iteration, we run several instances of an optimization algorithm with different trust region parameters, and each instance generates a point for evaluation. All points are kept in a common priority queue and the most promising points are evaluated in parallel when computers are available. We use models from several instances to prioritize the points and in case new information becomes available, we allow dynamic prioritization of points to ensure that computational resources are used efficiently. A database is used to avoid reevaluation of points. Together, these extensions make it easier to find several local optima and rank them against each other, which is very useful when performing robust optimization. Empirical testing reveals considerable decreases in the number of function evaluations as well as in the time required to solve problems.

Wei Xu, Tongji University (with Zhiwu Hong)

Combination of algorithms for path-dependent option pricing

In order to control their exposure to risk, financial institutions are in charge of estimating risks caused by changes in asset prices and exchange and/or interest rates. Due to present regulations, the risk management of portfolios is intimately related to value at risk. For VaR calculation, there is the straightforward formula that can be used under the assumption that the log-returns of the portfolio are normally distributed and to which VaR can be expressed in terms of mean and variance. But empirical evidence shows that, generally, financial returns are not normally distributed. In this paper we find the expression of the VaR and conditional value at risk in terms of higher moments of the input loss distribution and compare the importance of different moments in VaR and CVaR. Using the maximum entropy principle, we find the best fit for the empirical probability distribution function in terms of its empirical moments. Their weights indicate which of them should be used in the Cornish-Fisher expansion. The VaR and CVaR approximation formulas are used to reduce the computational effort for large portfolio optimization problems.

Piotr Krysta, University of Liverpool (with Dimitris Fotakis, CarmineVentre)

Combinatorial auctions with verification

We study mechanism design for social welfare maximization in combinatorial auctions with general bidders. It is a major open problem in this setting to design a deterministic truthful auction which would provide the best possible approximation guarantee in polynomial time, even if bidders are double-minded i.e., they assign positive value to only two sets in their demand collection of sets. On the other hand, there are known such randomized truthful auctions in this setting. We introduce a general model of verification i.e., some kind of overbidding can be detected and we design in this model the first deterministic truthful auctions which indeed provide essentially the best possible approximation guarantees achievable by any polynomial-time algorithm. This shows that deterministic truthful auctions have the same power as randomized ones if the bidders withdraw from unrealistic lies.

Gergely Csupor, Maastricht University (with Rudolf Müller)

The private provision of a public good: Digging for gold

We study the problem of finding the profit-maximizing mechanism for the provision of a single, non-excludable public good. This problem has been well studied for the case when the valuations of the agents are independently distributed, but the literature is silent about the general case. We focus on general joint distributions, characterizing the deterministic mechanism implementable in dominant-strategies that yields the maximum revenue for the monopolistic provider of the public good. We investigate the problem from an automated mechanism design perspective and show that finding the optimal mechanism can be solved in time polynomial in the number of types by reducing it to a maximal closure problem with respect to sum of conditional virtual values. We also conclude that in case of independent type distributions the optimal mechanism is the same as under Bayesian implementation and interim individual rationality.

Angelina Vidali, University of Vienna (with George Christodoulou, Amos Fiat, Anna Karlin, Elias Koutsoupias)

Scheduling, auctions and truthfulness

I will give an introduction and present some of my recent results in one of the most fundamental problems in algorithmic game theory and mechanism design: the problem of scheduling unrelated machines to minimize the makespan. I will emphasize the connection between this problem and the problem of designing truthful auctions for selling multiple items.

Finally I will present a geometrical characterization of truthfulness and also some very recent work on strongly truthful mechanisms.

We assume that the machines behave like selfish players: they have to get paid in order to process the tasks, and would lie about their processing times if they could increase their utility in this way. The problem was proposed thirteen years ago in the seminal paper of Nisan and Ronen, where it was shown that the approximation ratio of mechanisms is between 2 and 1 + 1. We improve this to 1 + 3/2 for three or more machines and to 1 + 2ϕ many machines. I also characterize the class of truthful mechanisms for the case of two players (regardless of approximation ratio) and show how the result can be used as a black box to obtain characterizations for other domains.
ing to discuss our recent result regarding optimality conditions of locally Lipschitz functions.

Erk Moreno-Centeno, Texas A&M University (with Richard Karp)

Solving combinatorial optimization problems as implicit hitting set problems

The hitting set problem is: given a set \( U \) and a family \( S \) of subsets of \( U \), find a minimum-cardinality set that intersects each set in \( S \). In the implicit hitting set problem, \( S \) is given via an oracle which verifies that a given set is a hitting set or returns a non-intersected set from \( S \). Many NP-hard problems can be solved as implicit hitting set problems. We solve the implicit hitting set problem by combining efficient heuristics and exact methods. We present computational results for the minimum-\( k \)-feedback-vertex-set and the multiple-genome alignment problems.

Austin Buchanan, Texas A&M University (with Sergiy Butenko, Anurag Verma)

Maximum clique problem on very large scale sparse networks

We define a new clique relaxation called a \( k \)-community, and explore scale reduction techniques based on it to obtain the maximum clique on very large-scale real life networks. Analytically, the technique has been shown to be very effective on power-law random graphs. Experimental results on real life graph instances (collaboration networks, P2P networks, social networks, etc.) show our procedure to be much more effective than a regular \( k \)-core peeling approach.
Implementations & software

Software for PDE-constrained optimization

Organizer/Chair: Dennis Ridzal, Sandia National Labs - Invited Session

Joseph Young, Sandia National Laboratories (with Denis Ridzal)

Software abstractions for matrix-free PDE optimization with cone constraints

In this presentation, we describe algorithms and software abstractions for a matrix-free code for PDE constrained optimization problems that allow us to build an efficient code and how these abstractions change between different kinds of constraints. In addition to the theoretical and practical utility of this approach, we integrate these ideas into a new matrix-free code called ROL and present numerical examples.

Andreas Potschka, Heidelberg University (with Hans-Georg Bock)

MUSCOP: A multiple shooting code for time-periodic parabolic PDE constrained optimization

Time-periodic parabolic PDE constraints arise in important applications in chemical engineering, e.g., in periodic adsorption processes. We present the software package MUSCOP which was designed to solve such optimization problems. The GNU Octave/C++ code is based on a hybrid programming principle to allow for rapid development without sacrificing computational speed. Algorithmically, MUSCOP is based on the Multiple Shooting/Projected Multiple Shooting Sequential Quadratic Programming, and indefinite two-grid Newton-Picard preconditioning. For the generation of first and second order derivatives, MUSCOP relies heavily on Internal Numerical Differentiation and Algorithmic Differentiation within the adaptive C++ integrator suite SolvIND and the package ADOL-C. We explain the parallelization and mathematical exploitation of structures arising from the Direct Multiple Shooting and the two-grid approach. Grid-independent convergence can be observed in the numerical experiments and even be proved for a typical model problem. We conclude the talk with numerical results for problems ranging from academic models to a real world SMB process.

Union Building (US)

Gradient-based optimization using adjoint methods for optimization of compositional flow in porous media

Adjoint-based gradients form an important ingredient of fast optimization algorithms for computer-assisted history matching and life-cycle production optimization. Large-scale applications of adjoint-based reservoir optimization reported so far concern relatively simple physics, in particular two-phase (oil-water) or three-phase (oil-gas-water) applications. In contrast, compositional simulation has the added complexity of frequent flash calculations and high compressibilities which potentially complicate both the adjoint computation and gradient-based optimization, especially in the presence of complex constraints. These aspects are investigated using a new adjoint implementation in a research reservoir simulator designed on top of an automatic differentiation framework coupled to a standard large-scale nonlinear optimization package. Optimization of strongly compressible flow with constraints on well rates or pressures leads to slow convergence and potentially poor performance. We present a pragmatic but effective strategy to overcome this issue.

Polyhedral theory

Organizer/Chair: Quentin Louveaux, University of Liège - Invited Session

Carla Michini, Sapere University di Roma (with Gerardo Comaiulis, Giacomo Nannicini)

How tight is the corner relaxation? Insights gained from the stable set problem

The corner relaxation of a mixed-integer linear program is a central concept in cutting plane theory. In a recent paper Fischetti and Monaci provide an empirical assessment of the strength of the corner and other relaxed relaxations on benchmark problems. In this work we validate with theoretical arguments the empirical results obtained by Fischetti and Monaci: we give a precise characterization of the bounds given by the corner relaxation and three of its extensions, in the special case of the edge formulation of the stable set problem, for which a full description of the corner polyhedron is available. Our theoretical analysis shows that degeneracy plays a major role, as the difference in the bounds given by corner relaxations from two different optimal bases can be significantly large. Therefore, exploiting multiple degenerate bases for cut generation could give better bounds than working with just a single basis.

Laurent Poirier, University of Liège (with Quentin Louveaux, Domenico Salvagni)

The strength of multi-row models

We consider the question of how to generate cutting planes from arbitrary multi-row mixed-integer relaxations. In general, these cutting planes can be obtained by row generation, i.e., solving a ("master") LP whose constraint are iteratively constructed by solving ("slave") MIPs. We show how to reduce the size of both problems by adopting a two-phases approach exploiting the bounds on variables and performing sequential lifting whenever possible. We use these results to implement a separator for arbitrary multi-row mixed-integer relaxations and perform computational tests in order to evaluate and compare the strength of some important multi-row relaxations.

Mahdi Dostomohammadi, University of Aviero (with Agostinho Agr, Quentin Louveaux)

Valid inequalities for the single arc design problem with set-ups

We consider a variant of the classical single node fixed-charge net-
work set with constant capacities in which the capacity of the node is an integer multiple of some constant value. This set is a generalization of the single arc design set studied by Magnanti et al. (1993). It arises in lot-sizing and network design problems. We derive several families of facet-defining inequalities. In particular we generalize the residual capacity inequalities. Then we lift some of these valid inequalities through simultaneous lifting.

**Integer & mixed-integer programming**

Organizer/Chair Karen Aardal, Delft University of Technology Invited Session

Karen Aardal, Delft University of Technology (with Frederik von Heymann, Andrea Lodi, Laurence Weyers)

**The structure of LLL-reduced kernel lattice bases: background and outline of the main result**

The so-called lattice reformation of an integer program has been used to solve very hard instances. In this reformulation one expresses the vector of variables in terms of an integer linear combination of kernel lattice basis vectors. Most of the instances tackled so far have been extremely hard even in lower dimensions, so almost all of the computational experience so far is obtained for such instances. When solving larger instances one can observe a certain structure of the reduced kernel lattice bases. More specifically, a lattice basis will contain an identity matrix as a submatrix. This means that some of the variables will have a "rich" translation in terms of the lattice basis vectors, and that the other variables will be merely variable substitutions. In this presentation we address the theoretical reason for the structure to form. We give the necessary background and outline the main ingredients of the theoretical analysis.

Frederik von Heymann, TU Delft (with Karen Aardal, Andrea Lodi, Laurence Weyers)

**The structure of LLL-reduced kernel lattice bases: Theoretical details**

This presentation is continuation of the previous one. Here we go in more detail on how the various parts of the analysis are derived, and present several of the proofs. The key ingredient in our analysis is the result that, after a certain number of iterations, the LLL-algorithm, with high probability, only performs size reductions and no swaps. In our derivation we use an inequality derived by Azuma, as well as some Jensen-type inequalities. We illustrate our results computationally.

Andrea Lodi, University of Bologna (with Karen Aardal, Frederik von Heymann, Laurence Weyers)

**On cutting planes and lattice reformulations**

Lattice reformulations have been traditionally used to deal with Integer Programming problems that are difficult to solve by branch-and-bound on variables. We discuss full and/or partial lattice reformulations performed with the aim of generating cutting planes, which are then mapped back in the original space of variables.

**Logistics, traffic, and transportation**

TomTom routing and traffic research: Data, models and algorithms Chair Heiko Schilling, TomTom International B.V.

Heiko Schilling, TomTom International B.V.

**TomTom Navigation – How mathematics help getting through traffic faster**

TomTom is the leading global supplier of in-car location and navigation content and applications. We are focused on providing drivers with the best possible navigation experience to help them get through traffic faster from A to B. Our navigation applications can already significantly reduce the journey times for individual TomTom drivers but we believe we can help to reduce traffic congestion for all. In this talk we will give examples where we were able to successfully apply results of mathematical research in our navigation applications. Our applications are based on TomTom’s navigation software tool kit – called NavKit – which is built upon 20 years of routing and navigation know-how.

Felix König, TomTom International B.V.

**Crowd-sourcing in navigation – How selfish drivers help to reduce congestion for all**

In order to help users beat congestion, TomTom’s connected navigation systems receive traffic information in real time. Simultaneously, they function as traffic sensors, frequently and anonymously transmitting speed probes.

After a brief overview of some crowd-sourced traffic data, we will look at a scenario where routes are planned server-side and can hence be coordinated. We will sketch relevant models and results from algorithmic game theory. We will conclude with some research challenges and their practical relevance.

Arne Kersting, TomTom International B.V.

**The dynamics of traffic jams – How data and models help to understand the principles of traffic jam propagation**

Traffic jams are an undesirable result of our individual motor car traffic. From a scientific point of view, however, traffic congestions reveal rich collective dynamics in space and time. Based on empirical data, we will summarise qualitative and quantitative aspects of traffic jam propagation and show how to describe and simulate them with mathematical models. Recent findings suggest that traffic instabilities are of the convective type. Understanding the principles of traffic jams may help us to realize TomTom’s Manifesto – reducing traffic congestion for all.

Felix König, TomTom International B.V.
Math programming in supply chain applications
Organizer/Chair Panithra Harsha, IBM Research - Invited Session
Paat Rusmevichientong, University of Southern California (with Huyson Topaloglu)

Robust assortment optimization
We study robust formulations of assortment optimization problems under uncertainty. An assortment planning model, which determines the number of possible item types, is specified at the beginning of the season. The number of item types is fixed in advance, and the number of items within each type is chosen over time.

Organizer/Chair Hamid Nazerzadeh, Marshall School of Business. Invited Session

Optimal continuous pricing with strategic consumers
We derive the optimal pricing mechanism in this situation under reasonable conditions.

Ashish Goel, Stanford University (with Bahman Bahmani, Goel Dansker, Ramesh Govindan, Ian Post, Michael Weinman, Bryce Wiedenbeck)

Reputation and trust in social networks
Automated reputation and trust systems play an ever-increasing role in the emerging networked society. We first describe a model of networked trust that functions by exchange of IGS among nodes. Informed agents also act as a bank and print its own currency; this is then used to purchase services within the network. Such "trust networks" are robust to infiltration, since any node only accepts currency printed by other nodes that it directly trusts. We will analyze the liquidity of this model, i.e., the number of transactions that such a network can support. We will show that in many interesting cases, the liquidity of these trust networks is comparable to a system where currency is issued by a single centralized bank. We will then show that in simple networks, rational agents allocate trust in a socially optimal manner.

Avazkhor Malekian, Massachusetts Institute of Technology (with Saeed Alaei, hu fu, nima haghtanah, jason hartline)

Bayesian optimal auctions via multi- to single-agent reduction
We study an abstract optimal auction problem for a single good or service. This problem includes environments where agents have budgets, risk preferences, or multi-dimensional preferences over several possible configurations of the good (furthermore, it allows an agent's budget and risk preference to be known only privately to the agent). There are the main challenges for auction theory. A single-agent problem is to optimize a given objective subject to a constraint on the maximum probability with which each type is allocated, a.k.a., an allocation rule. Our approach is a reduction from multi-agent mechanism design problem to collection of single-agent problems. We focus on maximizing revenue, but our results can be applied to other objectives (e.g., welfare). An optimal multi-agent mechanism can be computed by a linear/convex program on interim allocation rules by simultaneously optimizing several single-agent mechanisms subject to joint feasibility of the allocation rules.

Mixed-integer nonlinear programming
Organizer/Chair Noam Goldberg, Mathematics and Computer Science Division, Argonne National Laboratory - Invited Session

Toni Lascusita, GAMS Software GmbH (with Michiel R. Bussieck, Stefan Emel)

Structured MINLP and applications
We study a new abstract optimal auction problem for a single good or service. This problem includes environments where agents have budgets, risk preferences, or multi-dimensional preferences over several possible configurations of the good (furthermore, it allows an agent's budget and risk preference to be known only privately to the agent). There are the main challenges for auction theory. A single-agent problem is to optimize a given objective subject to a constraint on the maximum probability with which each type is allocated, a.k.a., an allocation rule. Our approach is a reduction from multi-agent mechanism design problem to collection of single-agent problems. We focus on maximizing revenue, but our results can be applied to other objectives (e.g., welfare). An optimal multi-agent mechanism can be computed by a linear/convex program on interim allocation rules by simultaneously optimizing several single-agent mechanisms subject to joint feasibility of the allocation rules.

Chromatographic separation using GAMS extrinsic functions
In chemical and pharmaceutical industries, the process of separating products of a multicomponent mixture can arise. The objective is to efficiently separate the mixture within reasonable costs during a cyclic operation. To optimize the process a boundary value problem that includes differential equations needs to be solved. The presented Multi-Integer Non-linear Programming (MINLP) model solves an instance of the chromatographic separation process in GAMS by using extrinsic functions. The function library facility that was recently introduced in GAMS 23.7 provides a convenient way of modeling it. The problem has been earlier studied in "Comparisons of solving a chromatographic separation problem using MINLP methods" by Stefan Emet and Tapio Westerlund.

Noam Goldberg, Mathematics and Computer Science Division, Argonne National Laboratory (with Sven Leyffer, Ilya Sol0)

Cover inequalities for nearly monotone quadrilateral MINLPs
Cover Inequalities for nearly monotone quadrilateral MINLPs
We consider MINLPs arising from novel network optimization formulations with a quadratic objective and constraints that satisfy relaxed monotonicity conditions. We derive valid cover inequalities for these formulations and their linearized counterparts. We study heuristics for generating effective cuts in practice and also consider approximate separation in some cases.

Susan Margulies, Pennsylvania State University (with Shmuel Onn)

Hilbert’s Nullstellensatz and the partition problem: An infeasibility algorithm via the partition matrix and the partition polynomial
Given a set of integers W, the partition problem determines whether or not W can be partitioned into two disjoint sets with equal sums. In this talk, we model the partition problem as a system of polynomial equations, and then investigate the complexity of the Hilbert’s Nullstellensatz certification. We present an algorithm by finding lower bounds on the degree of Hilbert Nullstellensatz refutations, and survey a known result on the complexity of independent set Nullstellensatz certificates. We then describe a method for extracting a square
matrix from the combination of Hilbert’s Nullstellensatz and the partition problem, and demonstrate that the determinant of that matrix is a polynomial that factors into an iteration of all possible partitions of $W$.

On robustness for simulation-based multiobjective optimization

Many real-world engineering design problems are too complex to be modeled analytically and involve the use of computer simulations. In simulation-based applications, performance of a system is evaluated based on the output from a simulation model which is typically subject to various sources of uncertainty. In design optimization, the designer or the decision maker may prefer a robust solution which is as “good” as possible and at the same time leads to small performance variations that appear due to uncertainty. Robustness in this context is understood as an insensitivity of objective functions values to some uncertainty arising due to stochastic processes inside the simulation model. We survey the approaches for robust simulation-based multiobjective optimization proposed in the literature and discuss the multiobjective robustness measures that can be used to find robust solutions.

A modified subgradient algorithm for solving $K$-convex inequalities

Thirty years ago, Robinson proposed a subgradient method for solving $K$-convex inequalities in Hilbert spaces, and has two advantages: first, without additional hypotheses, it was possible to show that it converges strongly to a solution of the problem, and second, it has the desirable property that the limit point is the closest solution to the starting point. To prove that our algorithm is well defined it was necessary to show that the set of sub-gradients is non-empty at interior points of the domain. We demonstrate this fact when the cone $K$ is finitely generated. To our knowledge, this is the first time it is proved the existence of such sub-differentials of vectorial $K$-convex functions in infinite dimensional spaces.

Nonlinear programming

Regularization techniques in optimization II

Organizer: Chair: Jacopo Gardosi, University of Edinburgh - Invited Session

Stefania Bellavia, Università di Firenze (with Benedetta Morini)
Regularized Euclidean residual algorithm for nonlinear least-squares with strong local convergence properties

This talk deals with Regularized Euclidean Residual methods for solving nonlinear least-squares problems of the form:

$$\min_{x \in \mathbb{R}^n} \|F(x)\|^2$$

where $F : \mathbb{R}^n \to \mathbb{R}^m$. Any relationship between $n$ and $m$ is allowed. This approaches uses a model of the objective function consisting of the unsquared Euclidean residual regularized by a quadratic term. The role of the regularization term is to provide global convergence of these procedures without the need to wrap them into a globalization strategy. We will show that the introduction of the regularization term also allows to get fast local convergence to roots of the underlying system of nonlinear equations, even if the Jacobian is not full rank at the solution. In fact, they are locally fast convergent under the weaker condition that $\|F\|$ provides a local error bound around the solution. In particular, in case $m \geq n$, this condition allows the solution set to be locally nonunique. Some numerical results are also presented.

Benedetta Morini, Università di Firenze (with Stefania Bellavia, Valentina de Simone, Daniela di Serafini)
Preconditioning of sequences of linear systems in regularization techniques for optimization

We build preconditioners for sequences of linear systems

$$(A + \Delta_k)x_k = b_k, \quad k = 1, 2, \ldots$$

where $A \in \mathbb{R}^{m \times n}$ is symmetric positive semidefinite and sparse, $\Delta_k \in \mathbb{R}^{m \times n}$ is diagonal positive semidefinite and the systems are compatible. Such sequences arise in many optimization methods based on regularization techniques: trust-region and overestimation methods for nonlinear least-squares, regularized affine-scaling methods for convex bound-constrained quadratic programming and bound-constrained linear least-squares.

We propose a framework for updating any symmetric positive definite preconditioner for $A$, factorized by $LDL^T$. The resulting preconditioners are effective on slowly varying sequences and cluster eigenvalues of the preconditioned matrix when $\Delta_k$ has sufficiently large entries. We discuss two preconditioners in this framework and show their efficiency on sequences of linear systems arising in the solution of non-
linear least-squares problems and bound-constrained convex quadratic programming.

Serge Gratton, IRIT-CERFACS (with Selima Gued, Philippe Toint, Jean Tomihama)

Preconditioning inverse problems using duality

The problem considered in this talk is the data assimilation problem arising in weather forecasting and oceanography, which consists in estimating the initial condition of a dynamical system whose future behaviour is to be predicted. More specifically, new optimization techniques will be discussed for the iterative solution of the particular nonlinear least-squares formulation of this inverse problem known under the name of 4DVAR, for four-dimensional data assimilation. These new methods are designed to decrease the computational cost in applications where the number of variables involved is expected to exceed 10^6. They involve the exploitation of the problem’s underlying geometrical structure in reformulating standard trust-region techniques into significantly cheaper variants. Adapted preconditioning issues for the considered systems of equations will be discussed, which also depend on the problem’s geometrical structure and which exploit limited-memory techniques in a novel way.

Makoto Yamashita, Tokyo Institute of Technology (with Zh-Cin Lin, I-Lin Wang)

An approach based on shortest path and connectivity consistency for sensor network localization problems

Sensor network localization (SNL) problems are considered to be an important topic due to the variety of applications including a molecular conformation. In SNL problems, we have anchors (known locations) and sensors (unknown locations). The distance between a pair of them is available if the pair is closer than the radio range. From this partial distance information, we want to infer the sensor locations. SDP relaxation approaches often generate high quality solution, but their computation cost can easily grow up for large SNLs. To solve SNLs with a cheaper cost, we combine several heuristics. We first compute the shortest paths from anchors to sensors hopping some sensors. For each sensor, we use the path lengths to guess its location roughly. After applying a gradient method, we adjust the sensors based on connectivity consistency. When a pair should be closer than the radio range, but the computed distance is longer than it, we pull the sensor locations. We repeat the shortest path and the adjustment, until we fix all the sensors as reliable. Numerical results show that this approach obtains the sensor locations with relatively good accuracy using low computation cost.

Michael Patriksson, Chalmers University of Technology (with Christoffer Strömberg)

Nonlinear continuous resource allocation - A numerical study

We study the performance of the most important algorithms for solving the strictly convex and separable resource allocation problem. This convex optimization problem arises in many applications, particularly as a subproblem, whence the search for extremely efficient solution procedures for the problem continues. We compare the performance of algorithms belonging to the relaxation, breakpoint and quasi-Newton classes of methods, for sizes up to about 100 Million variables, establishing that a new implementation of a relaxation algorithm utilizing a blended evaluation of the relaxed problem performs the best in establishing that a new implementation of a relaxation algorithm utilizing a blended evaluation of the relaxed problem performs the best in a novel way.

Marc Steinbach, Leibniz Universität Hannover

Estimating material parameters by X-ray diffraction

X-ray diffraction is a standard method for quantitative material analysis in areas like crystallography, chemistry or biochemistry. X-Ray exposure yields intensity distributions that depend on the molecular structure and that can be measured with high precision over a certain range of diffraction angles. Material parameters are then obtained by suitable parameter estimation methods. The talk presents the resulting class of methods in the context of inverse problems and reports on the development and implementation of a real time solution algorithm. Main components of the algorithm include a Levenberg-Marquardt method, a truncated CG method featuring certain projection techniques, and sparse linear algebra exploiting the specific Jacobian structure. The post-optimality analysis includes a detection of modeling redundancy and a covariance computation based on an SVD or a QR decomposition with pivoting.

Optimization in energy systems

Wim van Ackooij, EDF R&D - Invited Session

Decomposition methods for unit-commitment with coupled joint chance constraints

An important optimization problem in energy management, known as the “Unit-Commitment Problem”, aims at computing the production schedule that satisfies the offer-demand equilibrium at minimal cost. Often such problems are considered in a deterministic framework. However uncertainty is present and non-negligible. Robustness of the production schedule is therefore a key question. In this talk, we investigate this robustness when hydro inflows are made robust against uncertainty on inflows, by using bilateral joint chance constraints. Moreover, we will make the global schedule robust, by using a bilateral joint chance constraint for the offer-demand equilibrium constraint. Since

Nonsmooth optimization

Applications of nonsmooth optimization

Chair Amirohssein Sadeghi, Frankfurt School of Finance & Management

Ann-Brith Strömberg, Chalmers University of Technology (with Emil Gustafsson, Torbjorn Larsson, Magnus Osthein, Michael Patriksson)

Lagrangian optimization for inconsistent linear programs

When a Lagrangian dual method is used to solve an infeasible optimization problem, the inconsistency is manifested through the divergence of the dual iterates. Will the primal sequence of subproblem solutions still yield relevant information about the primal solution? We answer this question in the affirmative for a linear program and an associated Lagrangian dual algorithm. We show that the primal-dual linear program can be associated with a saddle point problem in which - in the inconsistent case - the primal part amounts to finding a solution in the primal space such that the total amount of infeasibility in the relaxed constraints is minimized; the dual part aims to identify a steepest feasible ascent direction. We present convergence results for a subgradient optimization algorithm applied to the Lagrangian dual problem, and the construction of an ergodic sequence of primal subproblem solutions; this algorithm yields convergence to a saddle point. We establish that the primal sequence finally converges to a minimizer of the original objective over the primal solutions of the saddle-point problem, while the dual iterates diverge in the direction of steepest ascent.

Adilson Xavier, Federal University of Rio de Janeiro (with Claudia Gesteira, Vinicius Xavier)

The continuous multiple allocation $p$-hub median problem solving by the hyperbolic smoothing approach: Computational performance

Hub-and-spoke (HS) networks constitute an important approach for designing transportation and telecommunications systems. The continuous multiple allocation problem median problem consists in finding the least expensive HS network, locating a given number of Hubs in planar space and assigning traffic to them, given the demands between each origin-destination pair and the respective transportation costs, where each demand center can receive and send flow through more than one hub. The specification of the problem corresponds to a strongly non-differentiable min-sum-min formulation. The proposed method overcomes this difficulty with the hyperbolic smoothing strategy, which has been proven able to solve large instances of clustering problems quite efficiently. The solution is ultimately obtained by solving a sequence of differentiable unconstrained low dimension optimization subproblems. The consistency of the method is shown through a set of computational experiments with large hub-and-spoke problems in continuous space with up to 1000 cities. The quality of the method is shown by comparing the produced solutions with that published in the literature.

Amirohssein Sadeghi, Frankfurt School of Finance & Management (with Ole Burdakiv, Anders Granberg)

Piecewise monotonic regression algorithm for problems comprising seasonal and monotonic trends

We consider piecewise monotonic models for problems comprising seasonal cycles and monotonic trends. In contrast to the conventional piecewise monotonic regression algorithms, our algorithm can efficiently exploit a priori information about temporal patterns. Our approach is based on establishing monotonic relations between the observations that compose the data set. These relations make the data set partially ordered, and allows us to reduce the original data fitting problem to a monotonic regression problem under the established partial order. The latter is a large-scale convex quadratic programming problem. It is efficiently solved by the newly developed Generalized Pool-Adjacent-Violators (GPAV) algorithm.
this is a fairly big model, we will investigate several decomposition procedures and compare these on a typical numerical instance. We will show that an efficient decomposition schedule can be obtained.

Andris Müller, Weyerstrass Institute Berlin (WIAS) (with René Henrion, Wim Van Ackooij, Riahd Zorgati) Probabilistic programming in power production planning

Power production planning applications depend on stochastic quantities like uncertain demand, uncertain failure rates and stochastic inflow into water reservoirs, respectively. To deal with the stochastic behavior of these quantities we consider optimization problems with joint probabilistic constraints of the type

$$\min \{ \mathbb{E}[c(x)] | \mathbb{P}(A(x) \xi \leq b(x)) \geq \rho, x \in X \}$$

where $\rho \in (0,1)$ is the required probability level.

The treatment of this optimization problem requires the computation of function values and gradients of $g(x) := \mathbb{P}(A(x) \xi \leq b(x))$. We will present derivative formulae for special cases which extend a classical result (see Prekopa 1995). As in the classical result the derivative formulae reduces the computation of gradients to the computation of function values again. Thus the same existing codes may be used to compute $g(x)$ and $\nabla g(x)$.

Numerical results for selected power production applications will be reported.

Raimund Krämer, University of Vienna (with Alin Pichler) A process distance approach for scenario tree generation with applications to energy models

We develop algorithms to construct tree processes which are close to bigger trees or empirical or simulated scenarios and can e.g., be used for multistage stochastic programming. Our approach is based on a distance concept for stochastic processes, developed in Pflug and Pichler [2011]: The process-distance used is based on the process’ formula in the computation of the expected recourse function and in its approximation in the Benders-type algorithm. Standard integration techniques are employed that involve the calculation of lower and upper bounds.

Francisco Muñoz, Johns Hopkins University (with Benjamin Hobbs) Using decomposition methods for wide-area transmission planning to accommodate renewables: A multi-stage stochastic approach

Increasing environmental concerns have led authorities to promote the use of generation from renewable technologies. Although the type and location of future generation investments are still uncertain, transmission planners still need to make decisions "today", in order to have enough network infrastructure available for "tomorrow". Consequently, there is a need for tools to aid transmission planners to select robust transmission plans that will accommodate a broad range of generation configurations. We developed a two-stage stochastic programming formulation that considers transmission lumpsiness, generators' response, uncertainty and Kirchhoff Voltage Laws. We apply our methodology to a 17-bus representation of California, and a 240-bus representation of the Western Interconnection in the US. We discuss the implementation and performance of Benders decomposition as an alternative approach for large scale networks.

PDE-constrained opt. & multi-level/multi-grid meth.

Optimization in energy systems

Organizer/Chair Sara Lumbrares, Institute for Research in Technology (ITT), Universidad Pontificia Comillas - Invited Session

Sara Lumbrares, Institute for Research in Technology (ITT), Universidad Pontificia Comillas (with Santiago Cerisola, Andrius Ramos)

Efficient incorporation of contingency scenarios to stochastic optimization: Application to power systems

Many design problems include reliability as a sub-objective, which is evaluated through contingency scenarios. In particular, power system design problems usually incorporate reliability considerations of this kind in generation expansion or transport expansion problems. The incorporation of these scenarios to a stochastic optimization problem results in a special structure where each scenario is linked to the failure of a specific available component. We propose a Progressive Contingency Algorithm (PChi) to exploit this structure. This methodology is applied to the optimization of the electrical layout design of an offshore wind farm in a real case study. Time savings reached two orders of magnitude.

Santiago Cerisola, Universidad Pontificia Comillas (with Sara Lumbrares, Andrius Ramos)

Approximations of recourse functions in hydrothermal models. Numerical experiences.

In this exposition we present some results about the application of stochastic programming techniques to a multistage hydrothermal model. We give an overview of extensions to use binary variables at every stage and to use it for nonconvex models. Our current experiments of application of approximation techniques to the model are presented. We take advantage of the convexity and monotonicity of the recourse function in the computation of the expected recourse function and in its approximation in the Benders type algorithm. Standard integration techniques are employed that involve the calculation of lower and upper bounds.

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PDE-constrained opt. & multi-level/multi-grid meth.

Optimization applications in industry IV

Organizer/Chair Dietmar Hömberg, Weyerstrass Institute for Applied Analysis and Stochastics - Invited Session

Hans Josef Pesch, University of Bayreuth (with Kurt Chudej, Armin Rund, Kati Stemberg) Direct versus indirect solution methods in real-life applications: Load changes of fuel cells

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

We will particularly discuss the pros and cons of direct and indirect methods, resp. first discretize then optimize versus first optimize then discretize when applying these approaches on real-life problems of extremely high complexity.

Chantal Landry, Weyerstrass Institute, (with Matthias Gerdis, René Henrion, Dietmar Hömbeg) Modeling of the optimal trajectory of industrial robots in the presence of obstacles

In automotive industry robots work simultaneously on the same workpiece. They must accomplish their task as fast as possible and without colliding with surrounding obstacles. We model the search for the fastest collision-free trajectory of each robot as a time optimal control problem. The collision avoidance is based on linear programming and expressed as state constraints. The resulting optimal control problem is solved by a sequential quadratic programming method. In order to speed up the solution an active set strategy based on back-face culling is adopted. Numerical examples illustrate the efficiency of this strategy.

Jean-Antoine Désidéri, INRIA (with Adrian Zemati, Réjöis Davugpoue) Multiple gradient descent algorithm (MGDA) for multi-objective optimization with application to compressible aerodynamics

We focus on the development of numerical algorithms for multi-objective optimization, with application to physical systems governed by PDE’s. Indeed, concurrent engineering makes multi-objective optimization a particularly acute question in the design of complex systems. In several mature disciplines, modern simulation codes often provide alongside with the evaluation of the performance, or functional criteria, the calculation of the functional gradient. Assuming the gradients of different criteria are at hand, we propose and analyze systematic constructions of a descent direction common to all criteria. Based on this, MGDA generalizes to multi-objective optimization the classical steepest-descent method. We prove that it converges to Pareto stationary points, and demonstrate the efficiency of the method in several problems: aircraft wing design, shape optimization of an automobile cooling system duct.
tactical planning is carried out using an optimization model and then short term decisions are taken. It is expected that operational decisions be consistent with tactical plans, but that is not usually the case as the process is subject to various uncertainty, especially those originating in the natural variation of the forest. The "rolling horizon" approach is used in practice as an attempt to reduce inconsistencies, but we propose that a robust optimization tactical planning model should increase the chances of consistency with the short term. The question, however, is how much robustness do we need, as being robust is expensive, and whether structural characteristics of the problem can be used to anticipate these factors. We provide some specific estimates, like probabilities of consistency, and results on the relations as well as computational results based on an industrial case. We also show how to dynamically adjust the degree of robustness of the planning process in such a way to approach an "optimal" policy. These results should be relevant also in other problems where consistency is desirable.

Florian Bruns, Universität Darmstadt (with Marc Goerigk, Sajid Knust, Anita Schöbel)

Robust load planning of trains in intermodal transportation

In this paper the problem of robust load planning for trains in intermodal container terminals is studied. The objective is to assign load units (container, swap bodies and trailer) to wagons of a train such that the utilization of the train is maximized, and setup and transportation costs in the terminal are minimized. However, in real-world applications many uncertainties are needed for the characterization of the problem.

In our paper we enhance the load planning problem by taking the most important uncertainties into account. Based on a mixed-integer linear programming formulation developed in Bruns and Knust (2010) we are able to formulate robust counterparts and show how these may be solved within a reasonable runtime. Our results indicate that it might be worth to study the robust counterparts even of large and complicated mixed-integer programs.

Pierre-Louis Poirier, CEDRIC/ENSTA/CNAM (with Alain Billionnet, Marie-Christine Costa)

Robust optimal sizing of an hybrid energy stand-alone system

The development of renewable energy brought new complex combinatorial optimization problems as the one studied here: the conception of an autonomous hybrid energy system. The study is made considering a finite time horizon divided into periods where an energy demand has to be fulfilled. An auxiliary fuel generator guarantees to meet the demand in every case but its use induces important costs. The aim is to determine the optimal number of photovoltaic panels, wind turbines and batteries while minimizing the total cost of investment and use. We first propose a mixed integer linear model for the problem without uncertainty. However, the stochastic behavior of both solar and wind energy and of the demand needs to be taken into account for a robust solution: here, we only consider the variation of the demands. We focus on an approach where we assume that the total variation of the demands is bounded. The problem is modeled as a two stage optimization program where the decision variables are integer while the recourse problem is a quadratic continuous program. We show that it can be linearized, which allows us to solve the global robust problem with a constraint generation algorithm.

Efficient first-order methods for sparse optimization and its applications

Organizer/Chair: Shaqian Ma, University of Minnesota - Invited Session

Shiqian Ma, University of Minnesota

An alternating direction method for latent variable Gaussian graphical model selection

Latent variable Gaussian graphical model selection (LVGGMs) is an important topic in Statistics and Machine Learning. We propose an alternating direction method (ADM) that solves a convex formulation of LVGGMs proposed by Chandrasekaran, Parrilo and Willsky (2010). There are three sets of variables in this convex formulation. Our proposed ADM solves three subproblems that all have closed-form solutions in each iteration of which a major step is needed for the efficient and capable of solving very large problems. The global convergence result of the proposed algorithm is numerically validated. Numerical results on both synthetic data and gene expression data are shown to demonstrate the efficiency of the proposed method.

Zhaoqiang Lu, Simon Fraser University (with Yong Zhang)

Sparse approximation via penalty decomposition methods

In this talk we consider sparse approximation problems, that is, general $l_p$ minimization problems with the $l_p$- ‘norm’ of a vector being a part of constraints or objective function. In particular, we first study the first-order optimality conditions for these problems. We then propose penalty decomposition (PD) methods for solving them in which a sequence of penalty subproblems are solved by a block coordinate descent (BCD) method. Under some suitable assumptions, we establish that any accumulation point of the sequence generated by the PD methods satisfies the first-order optimality conditions of the problems. Furthermore, for the problems in which the $l_p$ part is the only nonconvex part, we show that such an accumulation point is a local minimizer of the problems. In addition, we show that any accumulation point of the sequence generated by the BCD method is a saddle point of the penalty subproblem. Moreover, for the problems in which the $l_p$ part is the only nonconvex part, we establish that such an accumulation point is a local minimizer of the penalty subproblem. Finally, we test the performance of our PD methods by applying them to sparse logistic regression.

Donald Goldfarb, Columbia University (with Bo Huang, Shiqian Ma)

An accelerated linearized Bregman method

We propose and analyze an accelerated linearized Bregman (ALB) method for solving the basis pursuit and related sparse optimization problems. Our algorithm is based on the fact that the linearized Bregman (LB) algorithm first proposed by Stanley Osher and his collaborators is equivalent to a gradient descent method applied to a certain dual formulation. We show that the LB method requires $(1/\varepsilon)$ iterations to obtain an $\varepsilon$-optimal solution and the ALB algorithm reduces this iteration complexity to $(1/\sqrt{\varepsilon})$ while requiring almost the same computational effort on each iteration. Numerical results on compressed sensing and matrix completion problems, are presented that demonstrate that the ALB method can be significantly faster than the LB method.

Pierre-Louis Poirier, CEDRIC/ENSTA/CNAM (with Alain Billionnet, Marie-Christine Costa)

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Organizer/Chair: Shaqian Ma, University of Minnesota - Invited Session

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Stochastic optimization

Large-scale stochastic programming
Organizer/Chair: Mihai Anitescu, Argonne National Laboratory - Invited Session
Andreas Grothey, University of Edinburgh
Multiple-tree interior point method for stochastic programming
We present an interior point based multi-step solution approach for stochastic programming problems, given by a sequence of scenario trees of increasing sizes. These trees can be seen as successively more accurate discretization of an underlying continuous probability distribution. Each problem in the sequence is warmstarted from the previous one. We analyse the resulting algorithm, argue that it yields improved complexity over either the coldstart or a naive two-step scheme, and give numerical results.
Miles Lubin, Massachusetts Institute of Technology (with Mihai Anitescu, J. A. Julian Hall, Kipp Martin, Cosmin Petra, Burhaneddin Sandikçi)
Parallel and distributed solution methods for two-stage stochastic MILPs
Large-scale linear and mixed-integer two-stage stochastic programming problems with recourse have a finite number of scenarios (typically arising from sample average approximation formulations) have been widely studied; however, many instances remain computationally challenging if not intractable on a modern desktop. For such instances, parallel computing holds great potential due to the decomposable nature of the problems. After reviewing the state of the art, we present our recent work on parallelizing the simplex algorithm for deterministic-equivalent form LP problems, thereby obtaining optimal bases for efficient hot starts for branch and bound or real-time control. We also present an acceleration of the Lagrangian relaxation of the problem that is akin to Caro and Schultz’s dual decomposition algorithm with a novel treatment of combining subproblems to decrease the Lagrangian duality gap. Both approaches look towards solving two-stage mixed-integer problems on a massively parallel scale, and we will compare their effectiveness on a stochastic power grid unit commitment problem as well as problems from the literature.
Werner Römisch, Humboldt-University Berlin (with Helge Heitsch, Herran Lorey)
Are quasi-Monte Carlo methods efficient for two-stage stochastic programs?
Quasi-Monte Carlo algorithms are studied for designing discrete approximations of two-stage linear stochastic programs. Their integrands are piecewise linear, but neither smooth nor of bounded variation in the sense of Hardy and Krause. We show that under some weak geometric condition on the two-stage model all terms of their ANOVA decomposition, except the one of highest order, are smooth if the densities are smooth. Hence, Quasi-Monte Carlo algorithms may achieve the optimal rate of convergence $O(n^{-1+\delta})$ for $\delta < (0, 1/2)$ and with a constant not depending on the dimension. The geometric condition is generically (i.e., almost everywhere) satisfied if the underlying distribution is normal. We also discuss sensitivity indices, efficient dimensions and suitable transformations to reduce the efficient dimension of two-stage integrands.

Variational analysis

Structural properties in variational analysis
Organizer/Chair: Stephen Robinson, University of Wisconsin-Madison - Invited Session
Boris Mordukhovich, Wayne State University (with Terry Rockafellar)
Second-Order variational analysis and stability in optimization
We present new results on the second-order generalized differentiation theory of variational analysis with new applications to tilt and full stability in parametric constrained optimization in finite-dimensional spaces. The calculus results concern second-order subdifferentials (or generalized Hessians) of extended-real-valued functions, which are dual-type constructions generated by coderivatives of first-order subdifferential mappings. We develop general second-order chain rules for amenable compositions and calculate second-order subdifferentials for some major classes of piecewise linear-quadratic functions. These results are applied to characterizing tilt and full stability of local minimizers for important classes of problems in constrained optimization that include, in particular, problems of nonlinear programming and certain classes of extended nonlinear programs described in composite terms.
Adrian Lewis, Cornell University (with J. Bolte, A. Daniilidis, D. Drusvyatskiy, and S. Wright)
Active sets and nonsmooth geometry
The active constraints of a nonlinear program typically define a surface central to understanding both theory and algorithms. The standard optimality conditions rely on this surface; they hold generically, and the surface consists of all solutions to nearby problems. Furthermore, standard algorithms “identify” the surface: iterates eventually remain there. A blend of variational and semi-algebraic analysis gives a more intrinsic and geometric view of these phenomena, attractive for less classical optimization models. A recent proximal algorithm for composite optimization gives an illustration.
Shu Lu, University of North Carolina at Chapel Hill
Confidence regions and confidence intervals for stochastic variational inequalities
The sample average approximation (SAA) method is a basic approach for solving stochastic variational inequalities (SVI). It is well known that under appropriate conditions the SAA solutions provide
asymptotically consistent point estimators for the true solution to an SSV. We propose a method to build asymptotically exact confidence regions for the true solution that are computable from the SAA solutions, by exploiting the precise geometric structure of the variational inequalities and by appealing to certain large deviations probability estimates. We justify this method theoretically by establishing a precise limit theorem, and apply this method in statistical learning problems.

We present a general time-dependent equilibrium model of financial flows and prices, obtaining the equilibrium conditions and the governing variational inequality formulation. Using delicate tools of Nonlinear Analysis and especially some properties of the dual model (the so-called shadow problem), the optimal composition of assets, liabilities and prices is determined and a qualitative analysis of the equilibrium is performed.

**Variational inequality theory facilitates the formulation of equilibrium problems in economic networks. Examples of successful applications include models of supply chains, financial networks, transportation networks, and electricity networks. Previous economic network equilibrium models that were formulated as variational inequalities only considered linear constraints. In this paper, we first highlight with an application of Nonlinear Analysis and especially some properties of the dual model that allow a characterization of the optimal solutions and the description of the costliest to cover.**

**The well-known Lovász Local Lemma (LLL) is a powerful probabilistic approach to prove the existence of certain combinatorial structures. While the original LLL was non-constructive – it was unclear how the existence proofs could be turned into polynomial-time algorithms – a series of works beginning with Beck and culminating with the breakthrough of Moser & Tardos (MT) have led to efficient algorithmic versions for most such proofs. However, there are several LLL applications to which these approaches inherently cannot apply. Our work makes progress toward bridging this gap.**

One of our main contributions is to show that when a LLL application provides a small amount of slack, the number of resamplings of the MT algorithm is nearly linear in the number of underlying independent variables (not events!), and can thus be used to give efficient constructions in cases where the underlying proof applies the LLL to super-polynomially many events, and even in cases where finding a bad event that holds is computationally hard. This leads to simple and efficient Monte-Carlo algorithms, in several cases resulting in the first efficient algorithms known.

**Given three permutations on the integers $1$ through $n$, the set system consisting of each interval in each of the three permutations is $O(1)$. In other words, Beck conjectured that for every three permutations, each integer from $1$ through $n$ can be colored either red or blue so that the number of red and blue integers in each interval of each permutation differs only by a constant. The discrepancy of a set system based on two permutations is two.**

In this talk, we give a counterexample to this conjecture: for any positive integer $n = 3^k$, we construct three permutations whose corresponding set system has discrepancy $\Omega(\log n)$. Our counterexample is based on a simple recursive construction, and our proof of the discrepancy lower bound is by induction.

We also present implications of this construction for the bin packing problem: There are instances of bin packing problem and corresponding set system has discrepancy $\Omega(\log n)$. Our counterexample is based on a simple recursive construction, and our proof of the discrepancy lower bound is by induction.

**We present an algorithmic template that achieves nearly tight approximation guarantees for $k$-robust and $k$-max-min versions of many covering problems. The analysis is based on establishing certain net-type properties, that rely on LP dual-rounding and primal-dual arguments.**

**We consider combinatorial covering problems [eg. Set cover, Steiner forest and Multicut] in the context of “robust” and “max-min” optimization. Given an instance of a covering problem $P$ with $n$ demands and parameter $k$:

(I) The $k$-max-min version of $P$ asks for $k$ (out of $n$) demands that are the costliest to cover.

(II) The $k$-robust version of $P$ is a two-stage optimization problem, where an arbitrary subset $D$ of $k$ demands materializes in the second stage. Elements (that cover demands) are more expensive in the second stage than the first. The objective is to anticipate purchase some elements in the first stage, so as to minimize the worst-case covering cost (sum of both stages) over all possible demands $D$.**

**The bounded Multiple Knapsack Problem (BMKP) is a generalization of the 0-1 multiple knapsack problem, where a bounded amount of each item type is available. In this work, a special case of BMKP is considered in which the sizes of the items are divisible.**

**We justify this method theoretically by establishing a precise limit theorem, and apply this method in statistical learning problems.**

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of the BSMKP polytope. Keywords: bounded sequential multiknapsack, optimal solutions, polytope description.

Joachim Schauer, University of Graz (with Ulrich Pferschy)

Knapasck problems with disjunctive constraints

We study the classical 0-1 knapsack problem subject to binary disjunctive constraints. Conflict constraints state that certain pairs of items cannot be simultaneously contained in a feasible solution. Forcing constraints enforces at least one of the items of each given pair to be included into the knapsack. A natural way for representing these constraints is the use of conflict (resp. forcing) graphs. We will derive FPTASs for the knapsack problem with chordal forcing graphs and with forcing graphs of bounded treewidth - complementing results for the conflict graph case given in Pferschy and Schauer (2009). The result for chordal forcing graphs is derived by a transformation of the problem into a minimization knapsack problem with chordal conflict graphs. We will furthermore give a PTAS for the knapsack problem with planar conflict graphs. In contrast the corresponding forcing graph problem is inapproximable. Similar complexity results are given for subclasses of perfect graphs as conflict (resp. forcing) graphs.

Jakub Marecek, IBM Research

Combinatorial optimization

Graph coloring

Chair Jakub Marecek, IBM Research

Noriyuki Sakasuga, Tokyo institute of Technology (with Yoshitsugu Yamamoto, Luyan Zhang)

Lagrangian relaxation and pegging test for clique partitioning problems

We develop a relaxation method to solve the clique partitioning problem (CPP), as it is done customarily by the Lagrangian relaxation, but in a new approach we have aimed at overcoming the burden imposed by the number of constraints. Since the binary integer linear programming formulation of CPP has a huge number of inequality constraints, we propose a modified Lagrangian relaxation which discards some of the multipliers and the modified subgradient method to solve the Lagrangian dual problem defined by the modified Lagrangian relaxation. This modification enables us to apply the Lagrangian relaxation to large instances. Computational results show that only a small fraction of all constraints are considered eventually. We also propose an improvement of the ordinary pegging test by using the structural property of CPP. The pegging test reduces the size of given instances, often significantly, and contributes to finding a very tight upper bound for several instances.

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Jakub Marecek, IBM Research (with Andrew Parker)

Semidefinite programming relaxations in timetabling and matrix-free implementations of augmented Lagrangian methods for solving them

Semidefinite programming provides the best known relaxations of graph colouring solvable in time polynomial in the dimensions of the graph. In order to derive strong bounds for timetabling and scheduling problems extending graph colouring, however, one cannot consider the graph colouring component alone.

We present semidefinite programming relaxations of graph colouring with an upper bound on the number of uses of each colour and numerous extensions encountered in timetabling. In timetabling terms, we consider the number of rooms available, room sizes, room features, room assignment stability, and pre-assigned room assignments.

We relax the structural constraints of the problem to make maximal profit. We state the problem as a bilevel integer programming problem. It includes the upper level (Leader’s) problem and the lower level (Follower’s) problem. We consider so-called optimal noncooperative solutions to the problem, where from all possible optimal solutions to Follower’s problem we choose the solution which yields the smallest value of the objective function of the Leader’s problem. We represent our problem as the problem of maximizing a pseudo-Boolean function. We propose a local search algorithm for constructing an approximate solution to the problem and a branch-and-bound algorithm for finding an optimal solution of the problem. An important ingredient of the algorithms is a method for calculating an upper bound for the values of the pseudo-Boolean function on subsets of solutions.

Yury Kochetov, Sobolev Institute of Mathematics

Algorithms for discrete competitive facility location problem

We consider a mathematical model generalizing the well-known facility location problem. In this model two rival sides (Leader and Follower) sequentially open their facilities and aim to capture clients in order to make maximal profit. We state the problem as a bilevel integer programming problem. It includes the upper level (Leader’s) problem and the lower level (Follower’s) problem. We consider so-called optimal noncooperative solutions to the problem, where from all possible optimal solutions to Follower’s problem we choose the solution which yields the smallest value of the objective function of the Leader’s problem. We represent our problem as the problem of maximizing a pseudo-Boolean function. We propose a local search algorithm for constructing an approximate solution to the problem and a branch-and-bound algorithm for finding an optimal solution of the problem. An important ingredient of the algorithms is a method for calculating an upper bound for the values of the pseudo-Boolean function on subsets of solutions.

Marta Pascoal, INESC-Coimbra and University of Coimbra (with Gilbert Laporte)

Path based methods for multicriteria metro location

We model the metro location problem considering the maximization of the population covered by the metro stations, the minimization of the construction cost and the minimization of the metro line lengths, under some constraints. Sets of efficient metro lines and corresponding efficient opened facilities to service clients. We assume that clients are on the Euclidean plane and facilities can be opened in arbitrary points on the plane. Leader opens p facilities. Later on, follower opens r facilities. Each client patronizes the closest facility. Our goal is to find p facilities for the leader to maximize his market share. We show that the problem is \( \text{NP} \)-hard. In other words, this Stackelberg game is more difficult than well-known \( \text{NP} \)-complete problems, unless \( \text{P}=\text{NP} \).

To find near optimal solutions we develop a local search heuristic, based on the exact approach for the follower problem. We apply discretization of the plane \( \mathbb{R}^2 \) -centroid problem. Computational experiments for the randomly generated test instances show that this local search algorithm dominates the previous heuristics.

Palina Konanova, Novosibirsk State University (with Yury Kochetov)

Local search heuristic for the buffer-constrained two-stage multimedia scheduling problem

We consider a two-machine flowshop scheduling problem originating in the multimedia industry. It is known that the problem is strongly \( \text{NP} \)-hard. We present some ILP-ref ormulations to get lower bounds and \( \text{VNS} \)-metaheuristic to find optimal or near optimal solutions. The Kernighan-Lin neighborhood and job-window neighborhoods are used in the VNS framework. For experiments we generate large scale instances with known global optima. Computational results and some open questions are discussed.

Beyzanur Cayir, Anadolu University (with Nil Aras)

A genetic algorithm for truck to door assignment in warehouses

Customer satisfaction is crucial for companies to survive. Right shipment planning is indispensable process of warehouse management
in supply chain and logistics management. This problem is similar to the problem of gate assignments in airports. We consider the over-constrained truck-to-door assignment problem with time window, operational time and customer priority constraints in warehouses where the number of vehicles exceed the number of doors available. The problem feasibility is affected by three factors: the arrival and departure time window of each type of vehicle, loading time for orders, total distance to customers. Objective of this study is to minimize total lead time and deviations from expected delivery time. Otherwise a penalty cost occurs for late or early delivery. Penalty cost depends on customer priorities. In this study, formulation of a mixed integer model for optimal solution of the vehicle scheduling problem is described and a genetic algorithm is proposed which can search for practical optimal solutions, on the basis of the theory of natural selection, without performing all searches. The computational experiment is carried out on real life instances.

Combinatorial optimization

Polyhedra in combinatorial optimization
Chair Shungo Koichi, Nanzan University
Shungo Koichi, Nanzan University
A note on ternary semimodular polyhedra
A ternary semimodular polyhedron associated with a submodular function on \(\{0, 1, \pm 1\}\) vectors was introduced by Fujishige in 1984, and it is not necessary integral even if the submodular function is integer-valued. However, it is known that the polyhedron has a nice property that corresponds to a laminarity property of the (standard) submodular polyhedra. In this paper, we give a slightly different type of polyhedron associated with a submodular function on \(\{0, 1, \pm 1\}\) vectors, and show that it also has the nice property as above and moreover, due to the nice property, it is quarter-integral if the submodular function is integer-valued. In addition, this paper proposes a variant of a submodular function on \(\{0, 1, \pm 1\}\) that preserves the quarter-integrality of the newly-defined associated polyhedron. The proof uses the result by Karzanov in 2007 concerning the integrality of the intersection of two integer bisubmodular polyhedra. Our results may be applicable to the multicommodity flow problem, which is our motivation.

Aleksandr Maksimenko, Yaroslavl State University
The common face of some 0/1 polytopes with NP-complete nonadjacency relations
We consider so-called double covering polytopes (DCP). In 1995, Matsu showed that the problem of checking nonadjacency on these polytopes is NP-complete. We show that double covering polytopes are faces of the following polytopes: knapsack polytopes, set covering polytopes, cubic graph polytopes, 3-SAT polytopes, partial order polytopes, traveling salesman polytopes, and some others. Thus, these families of polytopes inherit the property of NP-completeness of nonadjacency relations from DCP. We also show that the graph of a double covering polytope is superpolynomial clique number. The same is true for the mentioned families of polytopes.

Shaefer Li, Delft University of Technology (with Karen Aardal)
The polyhedral relationship between the capacitated facility location polytope and its knapsack and single-node flow relaxations
The knapsack and single node flow polytopes, \(X_K\) and \(X_{NSN}\) respectively, are well-known relaxations of the capacitated facility location polytope \(X_{CFL}\). In earlier studies specific classes of facets for \(X_K\) and \(X_{NSN}\) have been proved to be facets also for \(X_{CFL}\) and the computational effectiveness of these classes have also been demonstrated for \(X_{CFL}\). In this presentation we prove more general relationships between the polytopes \(X_K\), \(X_{NSN}\), and \(X_{CFL}\). We also prove results in the spirit of Goemans’ worst-case comparison of valid inequalities.

Peter Sanders, Karlsruhe Institute of Technology (with Yelt Batz, Robert Geisberger, Moritz Kobitzsch, Dennis Luken, Dennis Scheierdecker)
Advance route planning using contraction hierarchies
Contraction hierarchies are a simple and powerful way to grasp the hierarchical structure of road networks allowing very fast routing. The talk introduces the technique and gives applications focussing on advanced techniques like taking time-dependent travel times into account or using multiple objective functions. We also discuss applications like fast distance table precomputation for logistics or ride sharing.

Andrew Goldberg, Microsoft Research (with Ittai Abraham, Daniel Delling, Amos Fiat, and Renato Werneck)
The hub labeling algorithm
The labeling approach to distance oracle design is to precompute a label for every vertex so that distances can be computed from the corresponding labels. This approach has been introduced by [Gavoille et al. ’01], who also introduced the Hub Labeling algorithm (HL). HL has been further studied by [Cohen et al. ’02]. We study HL in the context of graphs with small highway dimension (e.g., road networks). We show that under this assumption HL labels are small and the queries are sublinear. We also give an approximation algorithm for computing small HL labels that uses the fact that shortest path set systems have small VC-dimension. Although polynomial-time, precomputation given by theory is too slow for continental-size road networks. However, heuristics guided by the theory are fast, and compute very small labels. This leads to the fastest currently known practical distance oracles for road networks. HL also has efficient (real-time) implementation inside of a relational database (e.g., in SQL).

Daniel Delling, Microsoft Research Silicon Valley (with Andrew Goldberg, Thomas Pajor, Ilya Razenshteyn, Renato Werneck)
Realistic route planning in road networks
I will present an extremely practical algorithm to compute shortest paths on continental road networks with arbitrary metrics, (cost functions). The approach has very low space usage per metric, supports real-time queries, and can incorporate a new metric in a few seconds. As a result, it can easily handle real-time traffic updates and personalized optimization functions. Unlike most previous methods, ours don’t rely on the strong hierarchy observed on road networks with travel times as the cost function, making it much more robust to metric changes. Our algorithm uses the fact that road networks can be partitioned into loosely connected regions. To find such partitions, we developed a new algorithm based on the notion of natural cuts, which are sparse regions separating much denser areas. This approach is currently used by Bing Maps.

Complementarity & variational inequalities

Applications of complementarity
Chair Wen Chen, The University of Western Australia
Jing-Shi Pang, University of Illinois at Urbana-Champaign (with Dane Schiro)
On differential linear-quadratic Nash games with mixed state-control constraints
This paper addresses the class of open-loop differential linear-quadratic Nash games with mixed state-control constraints. A sufficient condition is provided under which such a game is equivalent to a ctd南itetd linear-quadratic optimal control problem. This equivalent formulation facilitates the application of a time-stepping algorithm whose convergence to a continuous-time Nash equilibrium trajectory of the game can be established under certain conditions. Another instance of this game is also analyzed for which a convergent distributed algorithm can be applied to compute a continuous-time equilibrium solution.

Vadim Shmyrev, Sobolev Institute of Mathematics
A polyhedral complementarity algorithm for searching an equilibrium in the linear production-exchange model
A finite algorithm for searching an equilibrium in a linear production-exchange model will be presented. The algorithm is based on the consideration of two dual polyhedral complexes associated with the model. The intersection point of two corresponding each other polyhedrons of the complexes yields equilibrium prices. Thus, we deal with polyhedral complementarity. The mentioned approach made it possible to propose also finite algorithms for some other modifications of the exchange model. These algorithms can be considered as analogues of the simplex method of linear programming.

Wen Chen, The University of Western Australia (with Song Wang)
A power penalty method for fractional Black-Scholes equations governing American option pricing
In this talk, we present a power penalty approach to the linear fractional differential complementarity problem arising from pricing American options under a geometric Levy process. The process is first reformulated as a variational inequality, and the variational inequality is then approximated by a nonlinear fractional partial differential equation (FPDE) containing a power penalty term. We will show that the solution
to the penalty IPDE converges to that of the variational inequality prob-
lem with an exponential order. A finite difference method is proposed for
solving the penalty nonlinear IPDE. Numerical results will be presented to
illustrate the theoretical findings and to show the effectiveness and
usefulness of the methods.

Wed 3.JH 2336
First-derivative methods in convex optimization
Organizer/Chair Stephen Vavasis, University of Waterloo - Invited Session
Yoel Drori, Tel Aviv University (with Marc Teboulle)
Performance of first-order methods for smooth convex
minimization: A novel approach
We introduce a novel approach for analyzing the performance of
first-order black-box optimization methods. Following the seminal work
of Nemirovski and Yudin (1983) in the complexity analysis of convex opti-
mization methods, we measure the computational cost based on the or-
acle model of optimization. Building on this model, our approach relies
on the observation that by definition, the worst case behavior of a black-
box optimization method is by itself an optimization problem, which we
call the Performance Estimation Problem (PEP). We analyze the prop-
erties of the resulting convex formulation for the classical gradient method,
as well as to derive numerical bounds that can be ef-

ciency computed for a broad class of first order schemes. Moreover, we
dervive an efficient procedure for finding step sizes which produces a
first-order black-box method that achieves best performance.

Clovis Gonzaga, Federal University of Santa Catarina – Brazil
On the complexity of steepest descent algorithms for minimizing
quadratic functions
We discuss the question of how fast a steepest descent algorithm
can be for minimizing a convex quadratic function. We do not tackle the
general case of convex differentiable functions, which is more difficult. Steepest descent methods differ exclusively on the choice of step length at
each iteration. We examine patterns in the distribution of these step lengths for minimizing a convex quadratic function. We show how a large
number of short steps are needed, and how these relate to the much smaller number of large steps. We note that the order in which the step lengths are used is irrelevant, and show a worst case example with a
small number of variables. We also conceive a brute force algorithm which is in a certain way optimal, and compare it with known algorithms.

Sahar Karimi, University of Waterloo (with Stephen Vavasis)
CGSO for convex problems with polyhedral constraints
We have proposed CGSO (Conjugate Gradient with Subspace Opti-
mization) as an extension to Nemirovski–Yudin’s algorithm. CGSO is a
conjugate gradient type algorithm that benefits from the optimal com-
plexity bound Nemirovski–Yudin’s algorithm achieves for the class of un-
constrained convex problems. In this talk, we discuss CGSO for convex
problems with polyhedral constraints. We study the theoretical prop-
erties as well as the practical performance of CGSO for this class of problems.

Wed 3.JH 2338
Conic and convex programming in statistics and signal processing IV
Organizer/Chair Pushkar Shah, University of Wisconsin - Invited Session
Defeng Sun, National University of Singapore (with Weiwei Xiao)
Finding the nearest correlation matrix of exact low rank via convex
optimization
In this talk, we aim to find a nearest correlation matrix of exact low rank from a independent noisy observations of entries under a general
sampling scheme. Since the nuclear norm (trace) of a correlation matrix is a constant, the widely used nuclear norm regularization technique can no longer be applied to achieve this goal in the noisy setting. Here, we
propose a new convex optimization approach by using a linear regular-
ization term based on the observation matrix to represent the rank in-
formation. This convex optimization problem can be easily written as an
H-weighted least squares semidefinite programming problem, which
4
can be efficiently solved, even for large-scale cases. Under certain con-
ditions, we show that our approach possesses the rank consistency. We
also provide non-asymptotic bounds on the estimation error.

Sahand Negahban, MIT (with Alekh Agarwal, Martin Wainwright)
Fast global convergence of composite gradient methods for
high-dimensional statistical recovery
Many statistical M-estimators are based on convex optimization
problems formed by the combination of a data-dependent loss function with a norm-based regularizer. We analyze the convergence rates of
composite gradient methods for solving such problems, working within a
high-dimensional framework that allows the data dimension to grow with (and possibly exceed) the sample size n. This high-dimensional
structure precludes the usual global assumptions on the loss function, and smoothness conditions on the loss function become much of classical opti-
mization analysis. We define appropriately restricted versions of these conditions, and show that they are satisfied with high probability for vari-
ous statistical models. Under these conditions, our theory guarantees that composite gradient descent has a globally geometric rate of con-
vergence up to the statistical precision of the model, meaning the typical
distance between the true unknown parameter θ* and an optimal so-
lution ˆθ. This result is substantially sharper than previous convergence guarantees. These results extend existing ones based on constrained
M-estimators.

Maryam Fazel, University of Washington (with Ting Kei Pong, Defeng Sun, Paul Tseng)
Algorithms for Hankel matrix rank minimization for system
identification and realization
We introduce a flexible optimization framework for nuclear norm
minimization of matrices with linear structure, including Hankel, Toeplitz and Moment structures, and catalog applications from diverse
fields under this framework. We discuss first-order methods for solv-
ing the resulting optimization problem, including alternating direction
methods, proximal point algorithm and gradient projection methods. We perform computational experiments comparing these methods on system identification and system realization problems. For the sys-
tem identification problem, the gradient projection method (accelerated by Nemirovski’s extrapolation technique) outperforms other first-order
methods in terms of CPU time on both real and simulated data; while for the system realization problem, the alternating direction method, as applied to a certain primal reformulation, outperforms other first-order
methods.

Wed 3.JH 3003A
Computational sustainability
Organizer/Chair Alan Holland, University College Cork - Invited Session
Alan Holland, University College Cork (with Barry O’Sullivan)
Optimising the economic efficiency of monetary incentives for
renewable energy investment
Many governments have instituted policies to support the increased
generation of electricity using renewable energy devices, and there is
compelling need to ensure that publicly funded subsidy schemes are
operated in a manner that maximizes societal benefit. We consider the
mechanism design problem associated with the rollout of an auction for
monetary incentives to support the increased deployment of renew-
able energy devices. We assume a game-theoretic model with self-
interested agents that behave strategically in order to maximize their
expected utility. We seek to develop algorithms for the assignment of
investment subsidies and determination of payoff that are resilient to
the possibility that agents will lie in order to manipulate the outcome
for their own benefit. We seek to minimize the maximum cost imposed
on any single agent thus ensuring that a wide distribution of subsidies
can be expected. This problem is analogous to solving a makespan min-
imization problem and has associated algorithmic design challenges
when we require a mechanism that can support the elicitation of pref-

erences from potentially tens of thousands of agents in public auctions.

Rene Schinzel, German University of Technology in Luebeck (with Martin Loewer)
Stochastic routing for electric vehicles
The development of electric vehicles (EV) using regenerative energy
sources introduces various new algorithmic challenges. One aspect is to
find efficient driving directions in order to consume less energy in gen-
eral and to account for special properties of EVs in particular. Besides
the demand of the routes, one could be interested in other parameters into
the optimization, such as altitude maps, congestion probabilities, the weather forecast, multi-modality, the energy consumption of a fleet or of the overall traffic. We present some models to account for stochastic elements, such as
congestion, traffic lights or similar uncertainties. Two particular models
will be used to optimize either the success probability (i.e. the chance
to reach your destination with the current battery charge) or the condi-
tional expectation value of the energy use (given that a minimal success rate is satisfied). By adapting an algorithm from Uludag et al., we de-
volved an algorithm to approach the mentioned energy-optimal path
problems. Furthermore we provide a unified routing model to account for time-dependency and energy-constraints as well as stochasticity.

Marco Savarelli, University of Ferrara (with Michela Milano, Fabrizio Riguzzi)  
**Simulation and optimization for sustainable policy-making**

Policy-making for European regions is becoming more and more challenging. Good policies should take into account environmental sustainability, economic factors and social acceptance of the policy. Optimization promises to improve currently adopted, hand-made solutions and may generate a savings for the taxpayers and lower depletion of limited resources, given the scale of regional planning. On the other hand, the effectiveness of a policy depends strongly on the response of the population, which cannot be easily foreseen. In fact, it is the emerging behavior of a complex system, for which one can, at most, exploit a simulation. From this, one wishes to extract mathematical relationships to be modeled as constraints. In order to extract significant information from simulations, they should be run a statistically significant number of times, and the results aggregated through statistical analysis or machine learning. We show how optimization has been applied in the regional energy plan of the Emilia-Romagna region, in Italy. We propose an approach for the combination of simulation and combinatorial optimization that we evaluate experimentally.

W3.4.A 095  
**Network sharing and congestion**

Organizer/Chair Laurent Gouves, CNRS - Invited Session

Alexandre Błogowski, Orange Labs - LIP 6 (with Ousrou Adam, Pasqual Faney, Bouthou Mustapha, Chrétienne Philippe)  
**Access network sharing between two telecommunication operators**

We study the sharing of an existing radio access network (set of base stations antennas) between two telecommunication operators. For each base station, an operator has to decide whether it covers it, in which case it gains a profit, or not. This profit may be different if it is alone to cover the base station, or if both operators cover the base station (by the effectiveness of a policy depends strongly on the response of the population, which cannot be easily foreseen. In fact, it is the emerging behavior of a complex system, for which one can, at most, exploit a simulation. From this, one wishes to extract mathematical relationships to be modeled as constraints. In order to extract significant information from simulations, they should be run a statistically significant number of times, and the results aggregated through statistical analysis or machine learning. We show how optimization has been applied in the regional energy plan of the Emilia-Romagna region, in Italy. We propose an approach for the combination of simulation and combinatorial optimization that we evaluate experimentally.

Anne Auger, INRIA Scylac-It-ce de France (with Yoshik Akimoto, Nikolaus Hansen)  
**Convergence of adaptive evolution strategies on monotonic C^2-composite and scale-invariant functions**

Evolution Strategies (ES) are stochastic search algorithms for numerical black-box optimization where a family of probability distributions is iteratively adapted to ultimately converge to a distribution concentrated on optima of the function. They are derivative-free methods using the objective function value during the ranking of candidate solutions. Hence they are invariant when optimizing using the objective function through the ranking of candidates solutions.

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covering a same base station, both operators decrease their costs, but they may also cover less clients). We model this situation by a game, where each agent is an operator and the strategy set of each agent is the set of base stations it covers. We study the existence of Nash equilibria, the price of anarchy and the price of stability for various settings. We also study how the agents may cooperate so that both obtain larger profits than in a Nash equilibrium. Finally, we conduct experiments to measure the gain obtained.

Cheng Wan, Université Pierre et Marie Curie - Paris 6, Institut de Mathématiques de Jussieu

Coalitions in nonatomic network congestion games

The work studies coalitions in nonatomic network congestion games. Suppose that a finite number of coalitions are formed by nonatomic individuals. Having established the existence and the uniqueness of Nash equilibrium both in the nonatomic game without coalitions and in the composite game with coalitions and independent individuals, we show that the presence of coalitions benefits everyone: at the equilibrium of the composite game, the individual payoff as well as the average payoff of each coalition exceeds the equilibrium payoff in the nonatomic game. The individual payoff is higher than the average payoff of any coalition. The average payoff of a smaller coalition is higher than that of a larger one. In the case of unique coalition, both the average payoff of the coalition and the individual payoff increase with the size of the coalition. Asymptotic behaviors are studied for a sequence of composite games where some coalitions are fixed and the maximum size of the remaining coalitions tends to zero. It is shown that the sequence of equilibrium of these games converges to the equilibrium of a composite game played by those fixed coalitions and the remaining individuals.

Xavier Zeitoun, LIRIS

The complexity of approximate Nash equilibrium in congestion games with negative delays

The extended study of the complexity of computing an ε-approximate Nash equilibrium in symmetric congestion games from the case of positive delay functions to delays of arbitrary sign. Our results show that with this extension the complexity has a richer structure, and it depends on the exact nature of the signs allowed. We first prove that in symmetric games with increasing delay functions and with a bounded jump the ε-Nash dynamic converges in polynomial time when all delays are negative, similarly to the case of positive delays. We are able to extend this result to monotone delay functions. We then establish a hardness result for computing Nash equilibria of congestion games with increasing delay functions and with a bounded jump when the delays can be both positive and negative: in that case computing an ε-Nash equilibrium becomes PLS-complete, even if each delay function is of constant sign or of constant absolute value.

Solving cooperative games

Chair Kazutoshi Ando, Shizuoka University

Finding solutions of large cooperative games

The nucleolus is one of the most important solution concepts in cooperative game theory as a result of its attractive properties: it always exists, is unique, and is always in the core (if the core is non-empty). However, computing the nucleolus is very challenging because this involves lexicographical minimization of an exponentially large number of excess values. We present a method for computing the nucleolus of large games. We formulate the problem as nested LPs and solve them using a constraint generation algorithm. Although the nested LPs formulation has been documented in the literature, it has not been used for large games because of the large LPs involved. In addition, subtle issues such as how to deal with multiple optimal solutions and with large tight constraint sets have not been discussed in the literature. These issues are crucial and need to be resolved in each LP in order to formulate and solve the subsequent ones. We treat them rigorously and show that the nucleolus can be found efficiently as long as the worst coalition can be identified for a given imputation. We demonstrate our methodology with the case of the weighted voting games with up to 100 players.

Ping Zhao, City University of HongKong (with Chuanxin Ding)

A mixed-integer programming approach to the determination of a core element for an n-person cooperative game with nontransferable utility

A fundamental issue concerning n-person cooperative game with nontransferable utility is well the conditions about core existence and balancedness and necessary conditions for nonemptiness of the core have been given. From a complexity theoretic standpoint, the core existence problem has been proved to be NP-complete, which also indicates computation of core element intractable in general case. We transform a core computation problem into a mixed-integer programming problem such that core existence is equivalent to having an integer point in a polytope. The core of a game can be computed directly by this MIP in virtue of approximating characteristic function by a finite numbers of corners. This approach renders sufficient and necessary conditions dispensable and the information about core can be derived directly by solving the mixed-integer programming. Case in large scale can be computed in the MIP through CPLEX.

Kazutoshi Ando, Shizuoka University

Computation of the Shapley value of minimum cost spanning tree games: #P-hardness and polynomial cases

We show that computing the Shapley value of minimum cost spanning tree games is #P-hard even if the cost functions of underlying networks are restricted to be (0,1)-valued. The proof is by a reduction from counting the number of minimum 2-terminal vertex cuts of an undirected graph, which is #P-complete. We also investigate minimum cost spanning tree games whose Shapley values can be computed in polynomial time. We show that if the cost function of the given network is a subbtree distance, which is a generalization of a tree metric, then the Shapley value of the associated minimum cost spanning tree game can be computed in O(n^4) time, where n is the number of players.

Ervin Balikian, Wayne State University (with Hazrul Sherali)

RLT-POS: Reformulation-linearization technique-based optimization software for polynomial programming problems

We introduce a Reformulation-Linearization Technique (RLT)-based open-source optimization software for solving polynomial programming problems (RLT-POS). We present algorithms and mechanisms that form the backbone of RLT-POS, including grid-bound-factor constraints and semidefinite cuts, constraint filtering techniques, reduced RLT representations, and bound tightening procedures. When implemented individually, each model enhancement has been shown to significantly improve the performance of the standard RLT procedure. When implemented simultaneously, the coordination between model enhancement techniques becomes critical for an improved performance since special structures in the original formulation may be thus affected. More specifically, we discuss the coordination between (a) bound-grid-factor constraints and semidefinite cuts and (b) constraint filtering techniques and reduced RLT representations. We present computational results using instances from the literature as well as random generated problems to demonstrate the improvement over a standard RLT procedure, and we compare the performances of the software packages BARON, SparsePOP, and Couenne with RLT-POS.

Hong Ryoo, Korea University (with Ke Dong Yan)

0+1 multilinear programming & LAD patterns

In this paper, we present a new framework for generating LAD patterns based on 0-1 multilinear programming. The new framework is useful in that one can apply standard linearization techniques and obtain all optimization/MILP-based pattern generation models that have been developed in the literature. We demonstrate this and then apply the McCormick’s relaxation and logical implications to develop new pattern generation models that involve a small number of 0-1 decision variables and constraints. With experiments on benchmark machine learning datasets, we demonstrate the efficiency of the new MILP models over previously developed ones.

Spencer Schauer, Massachusetts Institute of Technology (with Paul Barton)

Convergence order of relaxations for global optimization of nonlinear dynamic systems

Deterministic methods for global optimization of nonlinear dynamic systems rely upon underestimating problems for rigorous bounds on the objective function on subsets of the search space. Convergence order of numerical methods is frequently highly indicative of their computational requirements, but has not yet been analyzed for these methods. We studied the convergence order of the underestimating problems to the original nonconvex problem for one method of nonlinear global dynamic optimization. We found that the convergence order of the underestimating problem is bounded below by the smallest of the convergence orders of the methods used to compute (i) the bounds for the state, (ii) the absolute deviations of the (ii) vector field, (iii) initial condition, and (iv) objective function in terms of the state variables. We compared the theoretical convergence order result to empirical results for several optimal-control and parameter-estimation problems and found that the bounds were valid for all problems and sharp for
some. We confirmed that empirical convergence order is highly corre-
lated with the CPU time for full global dynamic optimization.

Implementations & software

Wed.3.H 2013
Organizer/Chair Rudiger Stephan, TU Berlin / Zuse Institute Berlin
Nelson Hein, Universidade Regional de Blumenau (FURB) (with Adriana Kroenke, Volmir Wilhelm)
The use of hierarchical model is mostly related to some of the ad-
vantages it may provides this type of planning, like a lower requirement
for higher level of detailed information, a more simplified formulation
of the global model and the gradual introduction of the random effects.
Furthermore, beside the advantage of reducing the computational re-
sources, this approach allows a better establishment of parallelism be-
tween his formulation and the hierarchy of decisions in the organization.
Hierarchical models have been widely used to represent the processes
of planning operations in companies. So far, the practical implemen-
tation of these models has been made under a, somewhat, formal ap-
proach. In this case, a hierarchical model is presented, which takes into
consideration a great deal of the complexity that is commonly brought
up in production environments. A methodology based on goal program-
ning (applied to different disaggregation procedures to make room for
the hierarchical planning) is utilized to solve this matter. This study aims
at presenting a proposed methodology, the results obtained when ap-
plying it in a practical case, and the conclusions that derive from it.

Diego Recalde, Escuela Politécnica Nacional (with Ramiro Torres, Polo Vaca)

Scheduling the Ecuadorian professional football league by integer
programming

A sports schedule fixes the dates and venues of games between
teams in a sports league. Constructing a sports schedule is a highly restrict-
tive problem. The schedule must meet constraints due to regu-
lations of a particular sports league Federation and it must guaran-
tee the participation of all teams on equal terms. Moreover, economic
benefits of teams, and other agents involved in this activity are ex-
pected. Until 2011, the Ecuadorian Football Federation [FEF] has de-
veloped schedules for their professional football championship manu-
ally. In early 2011, the authors presented to the FEF authorities several
evidences that the use of mathematical programming to elaborate fea-
sible sports schedules could easily exceed the benefits obtained by the
empirical method. Under the last premises, this work presents an In-
teger Programming formulation for scheduling the professional foot-
ball league in Ecuador, which is solved to optimality, and also a three
phase decomposition approach for its solution. The schedules obtained
fulfilled the expectations of the FEF and one of them was adopted as
the official schedule for the 2012 edition of the Ecuadorian Professional
Football Championship.

Rudiger Stephan, TU Berlin / Zuse Institute Berlin

Smallier compact formulation for lot-sizing with constant batches

We consider a variant of the classical lot-sizing problem in which the
capacity in each period is an integer multiple of some basic batch size.
Pochet and Wolsey (MathOR 18, 1993) presented an \( O(n^2 \min\{n, C\}) \) al-
gorithm to solve this problem and a linear program with \( O(n^2) \) variables
and inequalities, where \( n \) is the number of periods and \( C \) the batch size.
We provide a linear program of size \( O(n^2 \min\{n, C\}) \), that is, in case that \( C < n \), our formulation is smaller.

Wed.3.H 2032
Organizer/Chair Marco Lübbecke, RWTH Aachen University - Invited Session
Marco Lübbecke, RWTH Aachen University (with Martin Bergner, Gerald Gamrath, Christian Puchert)
A generic branch-price-and-cut solver

We implemented GCG, a branch-price-and-cut solver based on the
branch-price-and-cut framework SCIP. Given a MIP, the solver
per-
forms a Dantzig-Wolfe reformulation (based on user input, or in some cases
the solver suggests a reformulation), does column generation
and full branch-price-and-cut. GCG inherits advanced MIP solving fea-
tures from SCIP, like presolving, propagation, (combinatorial) cutting
planes, pseudo-costs etc. A number of additional plugins are imple-
mented which are specific to exploiting the availability of having an orig-
inal compact and an extended column generation formulation, like pri-
mal heuristics or branching rules. We report on computational exper-
iments & software

Commercial mathematical programming solvers I
Organizer/Chair Hans Mittelmann, Arizona State University - Invited Session
Thorsten Koch, ZIB (with Gerald Gamrath, Hans Mittelmann)
Any progress one year after MIPLIB 2010?
It has been a little more than one year ago the release of MIPLIB
2010. How much progress has been in solving these instances and
how does this translate into real progress in the ability to solve mixed integer programs?
Michael Perregaard, FICO
Recent advances in the Xpress MIP solver
We will present some of the recent developments in the Xpress MIP
solver, with particular emphasis on heuristics. Modellers continually
push the boundaries on the size of problems that can be solved and is
often satisfied with a solution that is “good enough”. This talk will focus
on the developments in Xpress to address such problems.
Tobias Achterberg, IBM
Cover probing for mixed integer programs
This talk is about an extension of the probing procedure on binary variables
to set covering constraints. We will explain an algorithm to do
this efficiently. Computational results based on CPLEX 12.4 assess the
impact of the procedure in practice.

Implementations & software

Software for large-scale optimization
Organizer/Chair Dennis Ridzal, Sandia National Labs - Invited Session
Kevin Long, Texas Tech University (with Paul Boggs, Bart van Bloemen Waanders)
Sundance: High-level software for PDE-constrained optimization
Sundance is a package in the Trilinos suite designed to provide
high-level components for the development of high-performance PDE
solvers with built-in capabilities for PDE-constrained optimization.

We review the implications of PDE-constrained optimization on simula-
tor design requirements, then survey the architecture of the Sundance
problem specification components. These components allow immedi-
ate extension of a forward simulator for use in an optimization context.
We show examples of the use of these components to develop full-space
and reduced-space codes for linear and nonlinear PDE-constrained in-
verse problems.
Stefan Richter, ETH Zurich (with Jones Jones, Manfred Morari, Fabian Ullmann)
FiOrDo: A Matlab toolbox for C-code generation for first-order methods
FiOrDo is the first toolbox for automated C-code generation for
first-order methods. It considers the class of multi-parametric convex
problems with a quadratic cost and a feasible set given as the intersec-
tion of an affine set and a ‘simple’ convex set for which a projection can
be evaluated at low cost; this class comprises important embedded op-
timization problems, for example, model predictive control. The toolbox
implements both polyhedral and non-polyhedral simple sets, e.g. the
simplex and 1-norm ball and the 2-norm ball and second-order cone
correspondingly. Thus, solver code for problems beyond quadratic program-
ning can be generated. If required, the solution approach is based on
Lagrange relaxation which uses the gradient or the fast gradient method
at a lower level. Additional toolbox features include optimal precondition-
ing and the automatic certification of the iteration count for a re-
stricted set of problems. The generated C-code can be compiled for
an platform and can be made library-free. FiOrDo also provides a tai-
lored MEX-interface for calling the generated solvers inside Matlab and a
Simulink library for rapid prototyping.
Eric Phipps, Sandia National Laboratories (with Roger Pawlowski, Andy Salinger)
Support embedded algorithms through template-based generic programming
We describe a framework for incorporating embedded analysis al-
gorithms, such as derivative-based optimization and uncertainty quan-
tification, in large-scale simulation codes using template-based generic
programming. The framework is based on standard C++ language
constructs such as templating, operator overloading, expression tem-
plates, and template metaprogramming, and enables the incorporation
of advanced algorithms with a minimum of programmer effort. In this
talk we describe the overall approach, several software tools imple-
menting the approach in the Trilinos solver framework, and examples
demonstrating the usefulness of the approach applied to optimization
and uncertainty quantification of large-scale PDE-based simulations.

Implementations & software

Commercial mathematical programming solvers II
Organizer/Chair Hans Mittelmann, Arizona State University - Invited Session
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to set covering constraints. We will explain an algorithm to do
this efficiently. Computational results based on CPLEX 12.4 assess the
impact of the procedure in practice.
ments on a number of applications and discuss what can be learned from a generic solver.

Theodore Ralphs, Lehigh University (with Matthew Galati, Michael O’sullivan, Jiadong Wang)

Dip and DipPy: Towards a generic decomposition-based MIP solver
DIP is a software framework for simplifying the implementation of a range of decomposition-based algorithms for solving mixed integer linear optimization problems. It is based on an underlying theoretical framework that unifies a number of decomposition methods, such as Dantzig-Wolfe decomposition, Lagrangian relaxation, and cutting-plane methods. Recent efforts have focused on the development of a generic decomposition-based solver, capable of automatically detecting block structure and utilizing an appropriate decomposition method to solve the problem. DipPy is a modeling language front end to DIP, which allows block structure to be explicitly identified in cases where such block structure is known to the modeler. This is done in a very natural way, making it easy for unsophisticated users to experiment with powerful methods such as column generation. In this talk, we discuss the latest developments and present computational results.

Matthew Galati, SAS Institute

The new decomposition solver in SAS/OR
This talk demonstrates the new DECOMP feature in the SAS/OR suite of optimization solvers for solving decomposition-based techniques for solving linear and mixed-integer linear programs. Using the modeling language provided by the OMPMODEL procedure in SAS/OR software, a user can easily experiment with different decompositions simply by reusing the partition of constraints in the original compact problem. Algorithm details in the reformulated (Dantzig-Wolfe) space are automatically managed by DECOMP. We will discuss the overall software design motivated by the goal to minimize user burden and reduce the need for algorithmic expertise. We will then present results from several client-server applications. DECOMP was successfully used, including results in both shared and distributed memory parallel environments.

Organizer/Chair Justo Puerto, Universidad de Sevilla. Invited Session

Albin Fredriksson, Royal Institute of Technology

A characterization of robust radiation therapy optimization methods
A key aspect of external beam radiation therapy is the calculation of the patient anatomy and the treatment beams. Unless accounted for, systematic and random errors risk degrading the delivered treatment severely compared to the planned. We consider a minimax stochastic optimization framework that generalizes many previous methods used to account for systematic and random errors. The methods within this framework range from expected value to worst case optimization. We characterize how methods of this framework yield robust plans by studying the results of applying them to a two-dimensional phantom, and discuss how they differ from a conventional method that uses margins to account for uncertainties. For random errors, the importance of taking into account uncertainty in the probability distribution of the errors is highlighted.

Marina Epelman, University of Michigan (with Xiejun Gu, Xun Jia, Steve Jiang, Fei Peng, Edwin Romeijn)

A column generation-based algorithm for Volumetric Modulated Arc Therapy (VMAT) treatment planning
External beam radiation therapy is a common treatment for many types of cancer. During such treatment, radiation is delivered with a gantry, equipped with a radiation source, that is pointed at the patient from various angles. Optimization models are commonly used in individualized treatment planning, and formulation and solution methods for such models are an area of active research. VMAT is a particular technique for delivering radiation, in which the gantry continuously rotates around the patient while the leaves of a multi-leaf collimator (MLC) move in and out of the radiation field to shape it. This technique has the potential to produce treatments of high quality similar to, e.g., Intensity Modulated Radiation Therapy (IMRT), but requiring less time for delivery. Recently, commercial systems capable of delivering VMAT treatments became available, necessitating the development of relevant treatment planning methods. We propose one such method, which uses optimization models and column generation-based heuristics to produce high-quality VMAT treatment plans that allow for dynamically adjustable gantry speed and dose rate, and MLC leaf speed constraints.

Gary Fryland, University of New South Wales, Australia

Robust airline schedule planning, aircraft routing and crew pairing: An integrated scenario-based approach
For reasons of tractability, classical approaches to the airline scheduling problem have been to sequentially decompose the problem into various stages [e.g. schedule generation, fleet assignment, aircraft routing, and crew pairing], with the decisions from one stage imposed upon the decision making in subsequent stages. Such a sequential approach unfortunately fails to capture the many dependencies between the various stages, most notably between those of aircraft routing and crew pairing, and how these dependencies affect the propagation of delays through the flight network. As delays are commonly
Modeling and solving a toll enforcement problem

We present the Toll Enforcement Problem to optimize the tours of toll inspectors on German motorways. This is an integrated planning and scheduling model, consisting of a tour planning and a duty rostering part. The goal is to achieve a network-wide control proportional to the traffic distribution. We introduce a time-expanded planning graph, based on a given time discretization, where computing the tours corresponds to a Multi-Commodity flow problem. This is formulated as an IP using path variables. For the rostering problem we develop a graph model, where arcs model feasible sequences of duties. Finding feasible rosters again comes up to a Multi-Commodity flow problem in an IP formulation. By introducing coupling constraints, both problems were connected to an integrated model. We will show, that many important requirements and legal rules can be modeled by this approach. By our modeling issues the extreme complexity of our problem can be reduced to reasonable size problems instances. Computational experiments on several real-world instances indicate that we are able to solve them to a proven optimality with only a small gap.

Tactical and strategic crew planning problems in railways

We consider the tactical level planning problem in railways that determines the minimum sufficient crew resources level for one crew region at a time given the list of periodic train duties in a finite planning horizon. We formulate this problem once as a network flow problem and once as a set covering problem. The set covering version may only be attacked with a column-and-row generation algorithm, and the experimental results are not satisfactory from a computational point of view when compared to the network flow formulation. Even with complicating hard constraints that challenge the network flow formulation, the set covering problem is not easy to handle while the network flow formulation guarantees optimal solutions with no additional effort. We also extend the network flow formulation to consider multiple regions simultaneously while the allocation of train duties among the regions is partially unknown. The problem is to determine the allocation and the level of minimum sufficient crew resources level coherently. The network flow formulation still provides satisfactory results, but only for a limited number of regions under consideration.

An integer linear programming model for bus rapid transit network design

Public transportation plays an important role in most populated cities. In Iran, the majority of people use public bus transportation within the cities. Thus, the quality of bus network services is very important. Bus Rapid Transit (BRT) is a high capacity public transit solution that can improve urban mobility. For several decades, operations research (OR) has been successfully applied to solve a wide variety of optimization problems in public transit. This paper represents an integer linear programming (OR) has been successfully applied to solve a wide variety of optimization problems in public transit. This paper represents an integer linear programming model for bus rapid transit network design. BRT stations and the schedules.

A dial-a-ride problem for public transport using electric vehicles

With concern about environmental quality growing in the world, sustainable transportation systems, such as on-demand public transport and the use of electric vehicles (EV), are developing in many cities. An on-demand public transport system works similar to a taxi service, but combines the servicing of customers with similar routes in the same vehicle so as to reduce operational cost and impact to the environment. The usage of EV can further reduce pollution levels. We combine these two eco-friendly concepts to study a variant of the Dial-a-Ride problem (DARPEV), which aims to minimize the total distance travelled subject to meeting all customers’ requests, and constraints on vehicle capacity, pickup/ delivery time-window, customer ride-time and battery-charging restrictions. Using EV limits the travelling time between battery recharges. The restricted charging locations and the requirement that charging must be done with no customers in-service complicate the problem, as extra variables and constraints are added. Computational results and further research directions are discussed.

A new model for capacitated line planning

The planning of lines and frequencies is a well-known problem in public transportation planning. Passenger-oriented approaches to line planning often determine the lines to be established, the corresponding frequencies, and the passenger routing simultaneously. This integration of the planning steps yields better results than stepwise approaches which start with an estimation of the passengers’ paths by traffic-assignment procedures and then establish lines and frequencies accordingly. However, in presence of capacity constraints, integrated approaches aiming at a minimization of the overall travel time may find solutions which force some passengers to make long detours. When such a line concept is realized in practice, passengers will most likely not accept such a solution but choose a shortest route among the available routes, (leading to a violation of capacity constraints). For this reason, we develop a new line planning model that allows every passenger to choose a shortest route among all available ones. We provide complexity results and an integer programming formulation for this model.
Mixed-integer nonlinear programming

Topics in mixed-integer nonlinear programming III
Chair: Duan Li, The Chinese University of Hong Kong
Duan Li, The Chinese University of Hong Kong (with Xiaoling Sun, Xiaojun Zeng)
MIQP solvers for quadratic programs with cardinality and minimum threshold constraints: A semidefinite program approach
We consider in this research the cardinality constrained quadratic programming problem (IP) that arise naturally in various real-world applications such as portfolio selection and subset selection in regression. We first investigate how to construct tighter semidefinite program (SDP) relaxation of the problem by applying a special Lagrangian decomposition scheme to the diagonal decomposition of the problem. We show that for any fixed diagonal decomposition, the dual problem can be reduced to a second-order cone program (SOCP), which is the continuous relaxation of the perspective reformulation of (IP). This leads to an SDP formulation for computing the best diagonal decomposition in the perspective reformulation. Numerical results comparing the performance of different MIQP reformulations of the problem show that the proposed SDP approach can help to improve the performance of the standard MIQP solvers for cardinality constrained quadratic programs.

Vikas Sharma, Thapar University (with Kalpana Dahya, Vanita Verma)
A duality based approach for a class of bilevel programming problems
This paper proposes a globally convergent algorithm for a class of bilevel programming problem where the upper level objective function is linear fractional and lower level objective function is linear with an additional restriction on decision variables that are integers for upper level and continuous for lower level. The proposed algorithm makes use of duality theory, to transform the given bilevel problem into a nonlinear programming problem, which can be solved by solving a series of linear fractional programming problems with linear constraints, to obtain a global optimal solution of the original bilevel programming problem. A numerical example is also discussed which illustrates the feasibility and efficiency of the proposed algorithm.

Geeta Kumari, Thapar University, Patiala
Symmetric duality for multiobjective second-order fractional programs
In this paper, a pair of symmetric dual multiobjective second-order fractional programming problems is formulated and appropriate duality theorems are established. These results are then used to discuss the minimax mixed integer symmetric dual fractional programs.

Applications of vector and set optimization
Organizer/Chair: Andreas Löhrle, Martin-Luther-Universität Halle-Wittenberg - Invited Session
Sonia Radjef, Université USDL of Oran (with Mohand Ouamer Béja)
The direct support method to solve a linear multiobjective problem with bounded variables
We propose a new efficient method for defining the solution set of a multiobjective problem, where the objective functions involved are linear, the set of feasible points is a set of linear constraints and the decision variables are upper and lower bounded. The algorithm is a generalization of the direct support method, for solution a linear mono-objective program. Its particularity is that it avoids the preliminary transformation of the decision variables. It handles the bounds such as they are initially formulated. The method is really effective, simple to use and permits to speed-up the resolution process. We use the suboptimal criterion of the method in single-objective programming to find the subefficient extreme points and the subweakly efficient extreme points of the problem. This algorithm is applied to solve a problem of production planning in the Iffi Darty.

Andreas Löhrle, Martin-Luther-Universität Halle-Wittenberg
BENSOLVE – A solver for multi-objective linear programs
BENSOLVE is a MDLP solver based on Benson’s outer approxima-
tion algorithm and its dual variant. The algorithms are explained and the usage of the solver is demonstrated by different applications, among them applications from Mathematical Finance concerning markets with transaction costs.

Firejei Illuz, Princeton University (with Andreas Löhrle, Birgit Rudloff)
An approximation algorithm for convex vector optimization problems and its application in finance
Linear vector optimization problems (VOP) are well studied in the literature, and recently there are studies on approximation algorithms for convex VOP. We propose an approximation algorithm for convex VOP, which is an extension of Benson’s outer approximation and provides both inner and outer approximation for the convex optimal frontier. The algorithm requires solving only one optimization problem in each iteration, rather than two as in the literature. We also extend the algorithm to arbitrary solid polyhedral ordering cones. As a financial application, we consider a discrete time market model for d-asset, with proportional transaction costs, over a finite probability space. In this setting, we study the set valued approach for utility maximization, and show that this problem can be solved by reformulating it as a convex VOP and applying the proposed algorithm.

Nonlinear programming

Line-search strategies
Organizer/Chair: José María Martínez, University of Campinas - Invited Session
Emesto S. Birgin, University of São Paulo
Spectral projected gradients: Reviewing ten years of applications
The spectral Projected Gradient method (SPG) seeks the minimization of a smooth function over a convex set for which the projection operation can be inexpensively computed. The SPG is based on projected gradients and combines the spectral steepness with nonmonotone line searches. Since its introduction in 2000, many successful usages on a variety of fields have been reported, comprising Machine Learning, Medical Imaging, Meteorology, and Image Reconstruction, including Compressive Sensing, just to name a few. In this talk, some of those applications will be reviewed and analyzed.

Sandra Santos, State University of Campinas (with Marca Gomes-Ruggiero, Douglas Goncalves)
An adaptive spectral approximation-based algorithm for nonlinear least-squares problems
In this work we propose an adaptive algorithm for solving nonlinear least-squares problems, based on scalar spectral matrices employed in the approximation of the residual Hessians. Besides regularizing the Gauss–Newton step and providing an automatic updating for the so-called Levenberg–Marquardt parameter, the spectral approximation has a quasi-Newton flavour, including second-order information along the generated directions, obtained from the already computed first-order derivatives. A nonmonotone line search strategy is employed to ensure global convergence, and local convergence analysis is provided as well. Numerical experiments with the routines LMDER and NL2SOL put the approach into perspective, indicating its effectiveness in two collections of problems from the literature.

Natasa Kreic, University of Novi Sad (with Natasa Krklec)
Nonmonotone line search methods with variable sample sizes
Nonmonotone line search methods for minimization of unconstrained objective functions in the form of mathematical expectation are considered. Nonmonotone line searches can improve the computational efficiency of methods finding a global minimizer and convergence speed. Sample Average Approximation – SAA method transforms the expectation objective function into a real-valued deterministic function using a large sample in each iteration. The main drawback of this approach is its cost. We will analyze a couple of nonmonotone line search strategies with variable sample sizes. Two measures of progress – lack of precision and functional decrease are calculated at each iteration. Based on this two measures a new sample size is determined. Additional safe guard rule is imposed to ensure the consistency of the linear models obtained with different samples. The rule we will present allows us to increase or decrease the sample size in each iteration until we reach some neighborhood of the sample size in each iteration until we reach some neighborhood of the sample size in each iteration until we reach some neighborhood of the sample size in each iteration until we reach some neighborhood of the sample size in each iteration until we reach some neighborhood of the sample size in each iteration until we reach some neighborhood of the sample size in each iteration until we reach some neighborhood of the sample size in each iteration until we reach some neighborhood of the sample size. In this work we propose an adaptive algorithm for solving nonlinear least-squares problems, based on scalar spectral matrices employed in the approximation of the residual Hessians. Besides regularizing the Gauss–Newton step and providing an automatic updating for the so-called Levenberg–Marquardt parameter, the spectral approximation has a quasi-Newton flavour, including second-order information along the generated directions, obtained from the already computed first-order derivatives. A nonmonotone line search strategy is employed to ensure global convergence, and local convergence analysis is provided as well. Comparative numerical experiments with the routines LMDER and NL2SOL put the approach into perspective, indicating its effectiveness in two collections of problems from the literature.

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We conclude by presenting numerical results.

Aliya Fedotsova, Colombian National University

Modeling of transboundary pollutant displacement for groups of emission sources

Location of emission pollution sources, together with objects or areas that require compliance with environmental norms, often leads to their disruption. The task of reducing the excess pollution emissions to the optimum is complicated with the presence of wind shifts, which weaken or strengthen the general or local contamination. One part of the pollution can be controlled to leave the territory, and, on the contrary, it is possible the invasion of pollution plumes from neighboring areas. Transboundary displacements. Wind shifts incorporated directly into a stochastic semi-infinite optimization algorithm. Environmental objects are represented as a map of zones with arbitrary boundaries. This approach includes the replacement of the original pollution sources with a total virtual source having a total product equivalent to the initial emissions. Possible local directions of wind shifts are presented in the form of maps of the streamlines of wind area, accounted for in the numerical experiment. Objective function of semi-infinite program minimizes costs of pollution control with wind shifts.

Nonsmooth optimization

Variational methods in optimization

Organizers/Chairs Pando Georgiev, University of Florida; Julian Rewalicki, Bulgarian Academy of Sciences - Invited Session

Nina Ochroauer, Universität der Bundeswehr München

Second-order analysis of the Moreau-Yosida and the Lasry-Lions regularizations

In this work we drop the condition of convexity and consider both Moreau-Yosida and Lasry-Lions regularizations of locally Lipschitz quadratically minornized functions. Our aim is to investigate the second-order properties of both these regularizations and to relate them to the approximated function itself. For this purpose we consider functions that admit a second-order expansion (e.g., prox-regular functions). This function possess a generalized Hessian, but note that this property is weaker than the existence of a classical Hessian, since we suppose only the existence of the first partial derivatives. We give sufficient conditions for the regularizations to have a generalized Hessian as well. Emphasize that these results are useful for the convergence analysis of approximate numerical methods for solving nonsmooth optimization problems.

Pando Georgiev, University of Florida (with Paoos Pantazos)

Global optimality conditions of first order for non-smooth functions in a Banach space

We are going to discuss our recent result regarding global optimality conditions of non-smooth locally Lipschitz functions in a Banach space. We show that the first-order condition for a global minimum of a locally Lipschitz function under constraints can be obtained to attain a sufficient optimality condition of first order for a global minimum of a non-smooth function on a closed convex set in a Banach space. Namely, we use a theorem of F. Clarke and obtain a short proof and an extension to Banach spaces of a result of J.-B. Hiriart-Urruty and J.S. Ledyaev. This result generalizes also previous work of A. Strekalovsky and M. Dür, R. Horst, and M. Locatelli. Special cases are considered when minimizing concave and maximum of concave functions.

Applications of optimization II

Chair Aliya Fedotsova, Colombian National University

Thea Göllner, TU Darmstadt (with Wolfgang Hess, Stefan Ulbrich)

Geometry optimization of branched sheet metal products

We consider the geometry optimization of branched, and potentially curved, sheet metal products. Such metal parts can be produced continuously and in integral style by using the new technologies linear flow splitting and linear bend splitting, which are explored within the framework of the Collaborative Research Centre (CRC) 666. The geometry of such sheet metal parts can be parameterized by means of free form surfaces, more specifically, by tensor products of cubic B-splines. The mechanical behaviour is described by the three dimensional linear elasticity equations. We formulate the associated PDE-constrained problem for optimizing the stiffness of the considered structure. Then, an algorithm for solving this shape optimization problem with a globalization strategy based on cubic regularization terms is presented. Furthermore, the exact constraints of the problem are used. We conclude by presenting numerical results.

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tive contracts traded on Power Exchanges has been growing since the inception of the restructuring of the sector; the liquidity of electricity markets can drastically differ depending on the situation. We analyze the situation by formulating a spatial stochastic equilibrium model of the restructured power sector with a financial market consisting of futures and financial transmission rights. We prove the existence of an equilibrium in which the players optimize risk measures and show that the futures prices obey a risk neutral valuation property. Then we turn to illiquidity and use a definition based on the limitation of transaction volumes. This changes the model into a Generalized Nash equilibrium (GNE) implying that several equilibrium may exist. The non arbitrage property is lost in the illiquid case. Those two features are signs of a badly functioning market. The formalism also allows one to model a market applying bid/ask spreads. Eventually we illustrate these different ideas on a six node example.

Andreas Ehrenmann, GSF SDEZ (with Yves Smeers)

Risk adjusted discounting

Capacity expansion models in the power sector were among the first applications of operations research to the industry. We introduce stochastic equilibrium versions of these models that we believe provide a relevant context for looking at the current very risky market where the power industry invests and operates. We then look at the insertion of risk related investment practices that developed with the new environment and may not be easy to accommodate in an optimization context. Specifically, we consider the use of plant specific discount rates due to different risk exposure. In a first step we introduce an iterative approach that facilitates the use of exogenously given discount rates within an capacity expansion model. This corresponds to the industry practice of assigning specific hurdle rates. As a second step we allow for discount rates being set endogenously in the equilibrium model by including stochastic discount rates in the equilibrium model. This approach is compatible with the standard CAPM from finance as long as all agents use the same (market induced) stochastic discount rate. We close with a numerical illustration.

We present a second order approximation for the robust counterpart of general uncertain NLP with state equation given by a PDE. We show how the approximated worst-case functions, which are the essential part of the approximated robust counterpart, can be formulated as trust-region problems that can be solved efficiently. Also, the gradients of the approximated worst-case functions can be computed efficiently combining a sensitivity and an adjoint approach. However, there might be points where these functions are nondifferentiable. Hence, we introduce an eikonal formulation of the approximated robust counterpart (as MPEC), in which the objective and all constraints are differentiable. This formulation can further be extended to model the presence of actuators that are capable of applying forces to a structure in order to counteract the effects of uncertainty. The method is applied to shape optimization in structural mechanics to obtain optimal solutions that are robust with respect to uncertainty in acting forces and material parameters. Numerical results are presented.

Adrian Schich, TU Darmstadt (with Stefan Ulbrich)

Shape optimization under uncertainty employing a second order approximation for the robust counterpart

Andreas Ehrenmann, GSF SDEZ (with Yves Smeers)

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sparsity. Finally, examples taken from image/video processing and topic modeling illustrate the benefit of our method.

Minh Pham, Rutgers University [with Xiaodong Lin, Andrzej Ruszczyński]

**Alternating linearization for structured regularization problems**

We adapt the alternating linearization method for proximal decomposition to structured regularization problems, in particular, to the generalized lasso problems. The method is related to two well-known operator splitting methods, the Douglas–Rachford and the Peaceman–Rachford method, but it has descent properties with respect to the objective function. Its convergence mechanism is related to that of bundle methods of nonsmooth optimization. We also discuss implementation for very large problems, with the use of specialized algorithms and sparse data structures. Finally, we present numerical results for several synthetic and real-world examples, including a three-dimensional fused lasso problem, which illustrate the scalability, efficacy, and accuracy of the method.

John Duchì, University of California, Berkeley [with Elad Hazan, Yoram Singer]

**Adaptive subgradient methods for stochastic optimization and online learning**

We present a new family of subgradient methods that dynamically incorporate knowledge of the geometry of the data observed in earlier iterations to perform more informative gradient-based learning. Metaphorically, the adaptation allows us to find needles in haystacks in the form of very predictive but rarely seen features. Our paradigm stems from recent advances in stochastic optimization and online learning which employ proximal functions to control the gradient steps of the algorithm. We describe and analyze an apparatus for adaptively modifying the proximal function, which significantly simplifies setting a learning rate and results in regret guarantees that are provably as good as the best proximal function that can be chosen in hindsight. We give several efficient algorithms for empirical risk minimization problems with common and important regularization functions and domain constraints. We experimentally study our theoretical analysis and show that adaptive subgradient methods significantly outperform state-of-the-art, yet non-adaptive, subgradient algorithms.

Zhili Zhou, IBM Research

A network based model for traffic sensor placement with implications on congestion observation

In this paper, we define and solve the traffic sensor placement problem for congestion observation, which targets to place the minimum number and location of traffic sensors in order to infer all traffic flow information in a dynamic changing congestion area. To handle uncertain traffic flow, we formulate this problem as a stochastic mixed-integer programming problem. We first study the combinatorial structure for traffic arc sensor placement to achieve full network coverage without historical data in a given traffic network. Then, we present the relationship between the traffic sensor placement for full network coverage in the deterministic setting and for dynamic congestion area observation. A sampling approximation algorithm is developed to solve the problem with budget constraints. The paper also provides a number of illustrative examples to demonstrate the effectiveness of the proposed methodology.

Ruwei Jiang, University of Florida [with Yongpei Guan]

**Optimization under data-driven chance constraints**

The traffic sensor placement problem is formulated as a chance-constrained optimization problem with budget constraints. The paper also provides a number of illustrative examples to demonstrate the effectiveness of the proposed methodology.

Zuzana Šabartová, Chalmers University of Technology [with Pavel Popela]

**Spatial decomposition for differential equation constrained stochastic programs**

When optimization models are constrained by ordinary or partial differential equations (ODE or PDE), numerical method based on discretising domain are required to obtain non-differential numerical description of the differential parts; we chose the finite element method. The real problems are often very large and exceed computational capacity. Hence, we employ the progressive hedging algorithm (PHA) – an efficient decomposition method for solving scenario-based stochastic programs – which can be implemented in parallel to reduce the computing time. A modified PHA was used for an original concept of spatial composition formed by an outer algorithm providing us with both lower and upper bounds for the optimum in each iteration. Numerical example is presented. The network design method is applicable to find optimal capacity expansion problems in interconnected power systems, water supply, transportation, evacuation and other networks.

Rasool Tahmasbi, Amirkabir University of Technology [with S. Mehdi Hashemi]

**Network flow problems with random arc failures**

Network flow problems with random arc failures

Networks have been widely used for modeling real-world problems such as communication, transportation, power, and water networks, which are subject to component failures. We consider stochastic network flow problems, in which the arcs fail with some known probabilities. In contrast to previous research that focuses on the evaluation of the expected maximum flow value in such networks, we consider the situation in which a flow has to be implemented before the realization of the uncertainty. We present the concept of expected value of a given flow and seek for a flow with maximum expected value. We show the problem of computing the expected value of a flow is NP-hard. We examine the “value of information”, as the relative increase in the expected flow value that we allow implementing a maximum flow before the uncertainty is revealed. We show that the value of information can be around 61% on some instances. While it is significantly hard to compute the expected maximum flow value and to determine a flow with maximum expected value, we apply a simple simulation-based method to approximate these
two values. We give computational results to demonstrate the ability of
this method.

Capacitated network design with facility location
We consider a network design problem that arises in the design of
last mile telecommunication networks. It combines the capacitated net-
work design problem (CNDP) with the single-source capacitated facility
location problem (SSCFLP). We will refer to it as the Capacitated con-
ected facility location problem (CapConFL). We develop a basic integer
programming model based on multi-commodity flows. Based on valid
inequalities for the subproblems, CNDP and SSCFLP, we derive sev-
eral (new) classes of valid inequalities for the CapConFL. We use them
in a branch-and-cut framework and show their applicability on a set of
benchmark instances.

Approximation algorithms for connected facility location with
buy-at-bulk edge costs
We consider a generalization of the Connected Facility Location
problem (ConFL), where we need to design a capacitated network with
a tree configuration to route client demands to open facilities. In addi-
tion to choosing facilities to open and connecting them by a Steiner tree,
where each edge of the Steiner tree has infinite capacity, we need to buy
cables from an available set of cables with different costs and capacities
to route all demands of clients to open facilities via individual trees.
We assume that the cable costs obey economies of scale. The objective is to
minimize the sum of facility opening, connecting the open facilities and
cable installation costs. In this presentation, we give the first approxi-
mation algorithm for the problem with K different types of cables. We
also consider the simplified version of the problem where capacity of
an edge is provided in multiples of only one cable type and give a better
constant factor approximation algorithm for this case.

An incremental algorithm for the facility location problem
We are given an instance of a facility location problem. We provide an
incremental algorithm to obtain a sequence of customers and facilities
along with their assignments. The algorithm guarantees that the cost of
serving the first k customers in the sequence with their assigned fa-
cilities in the sequence is within a constant factor from the optimal cost
of serving any k customers. The problem finds applications in facility
location problems equipped with planning periods, where facilities are
opened and customers are served in an incremental fashion.

Non-smooth analysis with applications in engineering
We study the application of implicit and inverse function theorems
in nonsmooth analysis to the study of dynamical systems described
by differential inclusions. We establish results for both well posed
and stability problems that can be achieved by a proper analysis of the correspond-
ing feasible set mapping, i.e. \( S : P \to 2^P \)

\[
S(p) = \{ x \in X : f(p, x) \in C \}.
\]

In this vein, whenever \( P \) and \( X \) have a metric space structure, a property
of \( S \) playing a crucial role, both from the theoretical and the com-
putational viewpoint, is calmness. Mapping \( S \) is said to be calm at \( (p_0, x_0) \) if
\( x_0 \in S(p_0) \) and there exist \( r, \zeta > 0 \) and \( t \geq 0 \) such that

\[
S(p) \cap B(x_0, r) \subseteq S(B(p_0, t\|d(p_0, p_0)\|)). \forall p \in B(p_0, \zeta),
\]

where \( B(A, r) = \{ x \in X : \inf_{a \in A} d(x, a) \leq r \} \). This talk is devoted to the
analysis of conditions for the calmness of \( S \). Such task is carried out by
referring to recent developments of variational analysis. Emphasis is
given to the case in which mapping \( f \) defining \( S \) is nonsmooth.

On convex relaxation of optimization problems
We relate a given optimization problem \( \inf_{x} f \) to its lsc convex re-
laxation \( \inf_{x} (c(x) - co(f)) \), here \( (c(x) - co(f)) \) is the lsc convex hull of \( f \).
We establish a complete characterization of the solutions set of the re-
laxed problem by means exclusively of “some kind” of the solution of the
initial problem. Consequently, under some natural conditions, of coer-
civity type, this analysis yields both existence and characterization of the
solution of the initial problem. Our main tools rely on the subdifferential
analysis of the so-called Legendre-Fenchel function.

First order analysis of set-valued maps and differential inclusions
The framework of differential inclusions encompasses modern op-
timal control and the calculus of variations. Its analysis requires the
use of set-valued maps. For a set-valued map, the tangential deriva-
tive and coderivatives separately characterize a first order sensitiv-
ity analysis property, or more precisely, a pseudo strict differentiabil-
ity property. The characterization using tangential derivatives requires
fewer assumptions. In finite dimensions, the coderivative characteriza-
tion establishes a bijective relationship between the convexified limi-
ting coderivatives and the pseudo strict derivatives. This result can be used
to estimate the convexified limiting coderivatives of limits of set-valued
maps. We apply these results to the study of differential inclusions by
calculating the tangential derivatives and coderivatives of the reachable
map, which leads to the subdifferential and subderivative dependence of
the value function in terms of the initial conditions. These results in
turn furs our understanding of the Euler-Lagrange and transver-
sal conditions in differential inclusions.

Implicit vs. inverse function theorem in nonsmooth analysis
We study the application of implicit and inverse function theorems
to systems of complementarity equations. The goal is to characterize the
so-called topological stability of those systems. Here, stability refers to
homeomorphic invariance of the solution set under small perturba-
tions of the defining functions. We discuss the gap between the non-
smooth versions of implicit and inverse function theorems in the com-
plementarity setting. Namely, for successfully applying the nonsmooth
implicit function theorem one needs to perform first a linear coordinate
transformation. We illustrate how this fact becomes crucial for the non-
smooth analysis.
In a recent paper, Coulououx gives a beautiful \( \frac{1}{2} \)-approximation algorithm to the problem of finding a minimum-cost set of edges such that each connected component has at least \( k \) vertices in it. The algorithm improved on previous \( 2 \)-approximation algorithms for the problem. In this paper, we show how to reinterpret Coulououx’s analysis as dual-fitting and also show how to generalize the algorithm to a broader class of graph problems previously considered in the literature.

Stasinos Kollipousis, University of Athens (with Ioide Adler, Dimitrios Thilikos)

**Planar disjoint-paths completion**

Take any graph property represented by a collection \( P \) of graphs. The corresponding completion problem asks typically for the minimum number of edges to add to a graph so that it belongs to \( P \). Several such problems have been studied in the literature.

We introduce the completion version of Disjoint Paths on planar graphs. Given a plane graph \( G \), \( k \) pairs of terminals, and a face \( F \) of \( G \), find the minimum set of edges, if one exists, to be added inside \( F \) so that: the embedding remains planar and the pairs become connected by \( k \) disjoint paths in the augmented network.

We give an explicit upper bound on the number of additional edges needed if a solution exists. This bound is a function of \( k \), independent of the size \( n \) of \( G \). Second, we show that the problem is fixed-parameter tractable, i.e., it can be solved in time \( f(k)\text{poly}(n) \).

Naonori Kakimura, University of Tokyo (with Kazuhisa Makino, Kento Seimi)

**Computing knapsack solutions with cardinality robustness**

In this paper, we study the robustness over the cardinality variation for the knapsack problem. For the knapsack problem and a positive number \( p \leq 1 \), we say that a feasible solution is \( p \)-robust if, for any positive integer \( k \), it includes an \( \alpha \)-approximation of the maximum \( k \)-knapsack solution, where a \( k \)-knapsack solution is a feasible solution that consists of at most \( k \) items. In this talk, we show that, for any \( \epsilon > 0 \), the problem of deciding whether the knapsack problem admits a \( (1+\epsilon) \)-robust solution is weakly \( NP \)-hard, where \( \nu \) denotes the rank quotient of the corresponding knapsack system. Since the knapsack problem always admits a \( \nu \)-robust knapsack solution, this result provides a sharp border for the complexity of the robust knapsack problem. On the positive side, we show that a \( k \)-robust knapsack solution can be computed in pseudo-polynomial time, and present a fully polynomial-time approximation scheme (FPTAS) for computing a max-robust knapsack solution.

David Williamson, Cornell University (with James Davis)

**A dual-fitting \( \frac{1}{2} \)-approximation algorithm for some minimum-cost graph problems**

In this talk, we present an enhanced second moment method that allows us to narrow the gap to an additive \( 2^{\Omega(1)} \) in the random \( k \)-NAESAT problem, one of the standard benchmarks in the theory or random CSPs. This is joint work with Konstantinos Panagiotou.

Amin Coja-Oghlan, University of Warwick (with Konstantinos Panagiotou)

**Catching the \( k \)-NAESAT threshold**

The best current estimates of the thresholds for the existence of solutions in random CSPs mostly derive from the first and the second moment method. Yet apart from a very few exceptional cases these methods do not quite yield matching upper and lower bounds. Here we present an enhanced second moment method that allows us to narrow the gap to an additive \( 2^{\Omega(1)} \) in the random \( k \)-NAESAT problem, one of the standard benchmarks in the theory or random CSPs. This is joint work with Konstantinos Panagiotou.
that no shortest path from \( c \) to \( f \) shares any vertex other than \( c \) with any shortest path from \( c \) to \( P \) (a restriction required when routing is done by the OSPF protocol with path-splitting). This “cover by pairs” problem has potential applications to network monitoring and to the distribution of time-critical streaming content. Theoretical results suggest that no algorithm can be expected to get even a polylogarithmic factor of optimal for our problem, and MIP-based optimization approaches become infeasible for graphs with more than about 100 vertices. However, a collection of heuristics we devised succeed in finding optimal solutions to all the instances in our testbed of synthetic and real-world instances with up to 1000 vertices, as verified by computing a [much easier] MIP-based lower bound. We describe the algorithms, theory, algorithms, bounds, and experimental results.

David Applegate, AT&T Labs – Research (with Aaron Archer, Vijay Gopalakrishnan, Seungjun Lee, K.K. Ramakrishnan)

Using an exponential potential function method to optimize video-on-demand content placement

For a large-scale Video-On-Demand service, as the library size grows, it becomes important to balance the disk space necessary to store content locally at the requesting node with the bandwidth required to serve requests from remote nodes. This gives rise to the problem of deciding which content to place at which serving nodes, taking into account the resource constraints (disk and bandwidth) and content attributes (request patterns, size, and bandwidth).

We model this optimization problem as a mixed-integer program. However, even for moderately large instances \((20,000,000, 50\text{ serving nodes})\), the linear relaxation becomes intractable for off-the-shelf linear programming solvers, both in terms of time and memory use. Instead, we approximately solve the linear relaxation by using a Le-grangian decomposition approach based on exponential potential functions, and then round that solution to an integer solution.

Computational experiments on a testbed of synthetic and real-world instances show that this decomposition approach typically reduces the running time by orders of magnitude, while achieving solutions within \(2\%\) of optimal with no constraint violated by more than \(1\%\).

Réal Carbonneau, GÉRAD and HEC Montréal (Université de Montréal) (with Gilles Caporossi, Pierre Hansen)

Global optimally clustered regression by branch and bound optimization with heuristics, sequencing and ending subset

Clusterwise regression is a clustering technique which fits multiple lines or hyperplanes to mutually exclusive subsets of observations. It is a cubic problem, but can be re-formulated as a mixed logical-quadratic programming problem. An extension and generalization of Brusco’s repetitive branch and bound algorithm (RBBBA) is proposed for global optimization of the clusterwise regression problem. Branch and bound optimization is enhanced by heuristics, observation sequencing and ending subset optimization. Heuristics can improve the upper bound, observation sequencing can improve the search path and can increase fathoming, while the ending subsets can recursively strengthen the lower bounds of the search. Additionally, symmetry breaking and incremental regression calculations are employed to further speed up the optimization. Experiments demonstrate that the proposed optimization strategy is significantly faster than CPLEX and that the combination of all the components is significantly faster than each one individually. The proposed approach can optimize much larger datasets than what is possible using CPLEX.

Marzena Fügenschuh, Boeth University of Applied Sciences (with Michael Armbuster, Christoph Helmbung, Alexander Martin)

LP and SDP branch-and-cut algorithms for the minimum graph bisection problem: A computational comparison

While semidefinite relaxations are known to deliver good approximations for semidefinite optimization problems like graph bisection, their practical scope is mostly associated with small dense instances. For large sparse instances, cutting plane techniques are considered the method of choice. These are also applicable for semidefinite relaxations via the spectral bundle method, which allows to exploit structural properties of sparsity. In order to evaluate the relative strengths of linear and semidefinite approaches for large sparse instances, we set up a common branch-and-cut framework for linear and semidefinite relaxations of the minimum graph bisection problem. Extensive numerical experiments show that our semidefinite branch-and-cut approach is a superior choice to the classical simplex approach for large sparse test instances from VLSI design and numerical optimization.

Adelaide Cerveira, UTAD (with Agostinho Agra, Fernando Bastos, Joaquim Sorm Monteiro)

A two-stage branch and bound algorithm to solve truss topology design problems

Our paper considers a classic problem in the field of Truss topology design, the goal of which is to determine the stiffest truss, under a given load, with a bound on the total volume and discrete requirements in the cross-sectional areas of the bars. To solve this problem we propose a new two-stage branch and bound algorithm. In the first stage we perform a branch and bound algorithm on the nodes of the structure. This is based on the following dichotomy study: either a node is in the final structure or not. In the second stage, a branch and bound on the bar areas is conducted. The existence or otherwise of a node in this structure is ensured by adding constraints on the cross-sectional areas of its incident bars. For stability reasons, when a free node exists in the structure, we impose that at least two incident bars on it. These constraints are added during the first stage and lead to a tight model. We report the computational experiments conducted to test the effectiveness of this two-stage approach, enhanced by the rule to ensure stability, as compared to a classical branch and bound algorithm, where branching is only performed on the bar areas.

Kenny Rammann, TU Braunschweig (with Uwe Zimmermann)

Minimal shunting operations for freight train composition

In planning freight train schedules in dense rail networks provides an enormous challenge. Resulting optimization models include a tremendous number of eligible train routes and departure times restricted by sparse infrastructure capacities. From our ongoing cooperation with the Deutsche Bahn (DB) within a three-year project, we outline first results focusing on the composition of rail cars in freight trains. According to requests of the customers of the DB, rail cars are routed from origin to destination through Germany by assigning them to a suitable sequence of previously scheduled freight trains. Additionally, the sequence of the rail cars within a freight train may be chosen. The real challenge consists in assigning rail cars to freight trains with choice of their sequence within the train minimizing the total number of time-consuming shunting operations in the visited rail yards. To our knowledge, the resulting NP-hard problem was previously not studied in the literature. We present new mixed integer programming formulations, some heuristics as well as computational experience for practical data from the DB. We conclude the talk with some remarks on future research.

Andreas Bärmann, FAU Erlangen-Nürnberg (with Andreas Heidt, Alexander Martin, Sebastian Pokutta, Christoph Thurner)

Approximate robust optimization and applications in railway network expansion

This talk is concerned with the application of robust optimization to railway network expansion planning. We introduce a methodology that linearizes the elliptic uncertainty sets describing the demand uncertainty to maintain the linearity of the problem. Dealing with data uncertainty is of great importance in infrastructure development which can be affected by inaccurate information in demand forecast. The robust optimization framework immunizes the model against all data scenarios in a given uncertainty set. In this talk we introduce a methodology that linearizes elliptic uncertainty sets. For this purpose we apply the approach of Ben-Tal and Nemirovski for the linearization of the second order cone. In the case of a linear optimization model this allows for solving the robustified model as a linear program again. The benefits especially arise in discrete optimization, as we can maintain the warm start capabilities of the simplex method.

We present computational results for an implementation of the method in the context of a railway network expansion application in cooperation with Deutsche Bahn AG. We also outline applications in air traffic management and energy systems optimization.

Torten Klug, Zuse Institute Berlin (with Ralf Borndörfer, Amin Fügenschuh, Thomas Schlechte)

An approach for solving the freight train routing problem

We consider the following freight train routing problem. Given is a transportation network with fixed routes for passenger trains and a set of freight train requests, each defined by an origin and destination station pair. The objective is to calculate a feasible route for each freight train such that a sum of expected delays and running times is minimal. Previous research concentrated on microscopic train routing for junctions or major stations. Only recently approaches were developed.
to tackle larger corridors or even networks. We investigate the routing problem from a strategic perspective, calculating the routes in a macroscopic transportation network. In this terms macroscopic means complex structures are aggregated into smaller elements and the departure and arrival times of freight trains are approximated. The problem has a strategic character since it asks only for a rough routing through the network without the precise timings. We propose a best insertion heuristic and a mixed integer programming model for the freight train routing problem, compare them, and present some computational results using different state of the art MIP-solvers.

Samedrao Zangeneh, Maastricht University (with Tobias Brunsch, Heiko Röglin, Cyriel Rutten)

Smoothed analysis of local search

In this talk, we consider the concept of smoothed performance guarantees and apply it to the performance guarantees of local optima. Smoothed analysis was introduced by Spielman and Teng (JACM 2004) as a hybrid between worst case and average case analysis, to get a better understanding of local search algorithms that have a bad worst case performance. Up to now, smoothed analysis has been mainly applied to the running time of algorithms. We will use smoothed analysis to investigate the approximation ratio of an algorithm, that is, the rate between the value of an approximate solution and the optimal solution value. In the last decade, there has been a strong interest in understanding the worst case behavior of local optimal solutions. We extend this research by investigating whether or not this worst case behavior is robust. We will apply the concept of smoothed performance guarantees to several local optima for some scheduling problems. As a by-product, we also get a smoothed price of anarchy for some scheduling games.

Kai Plociennik, Fraunhofer ITWM

A probabilistic PTAS for shortest common superstring

We consider approximation algorithms for the shortest common superstring problem (SCS). It is well-known that there is a constant $\varepsilon > 1$ such that there is no efficient approximation algorithm for SCS achieving a factor of at most $1 + \varepsilon$ in the worst case, unless $P = NP$. We study SCS on random inputs and present an approximation scheme that achieves, for every $\varepsilon > 0$, a $1 + \varepsilon$-approximation in expected polynomial time. This result applies directly to the letters are chosen independently at random, but also to the more realistic mixing model, which allows for dependencies among the letters of the random strings. Our result is based on a sharp tail bound on the optimal compression, which improves a previous result by Friese and Szpankowski.

Tobias Brunsch, University of Bonn (with Heiko Röglin)

Improved smoothed analysis of multiobjective optimization

We present several new results about smoothed analysis of multiobjective optimization problems. Particularly, we consider problems in which $d$ linear and one arbitrary objective function are to be optimized over a set $S \subseteq \{0, 1\}^d$ of feasible solutions. The coefficients of the linear objectives are subject to random perturbations specified by an adversary whose power is limited by a perturbation parameter $\delta$. We improve the previously best known bound for the smoothed number of Pareto-optimal solutions to $O(n^{2d}\delta^d)$ for natural perturbation models. Additionally, we show that for any constant $c > 0$, the $c$-th moment of the smoothed number of Pareto-optimal solutions is bounded by $O((n^{2d}\delta^d)^c)$. This improves the previously best known bounds significantly. Furthermore, we address the criticism that the perturbations in smoothed analysis destroy the zero-structure of problems by giving a polynomial bound for the smoothed number of Pareto-optimal solutions for zero-preserving perturbations. One consequence of this result is that the smoothed number of Pareto-optimal solutions is polynomially bounded for polynomial objective functions.
Conic programming

Thu. 1.H 3083A

Instance-specific tuning, selection, and scheduling of solvers
Organizer/Chair Meinolf Sellmann, IBM Research - Invited Session
Meinolf Sellmann, IBM Research (with Yuni Malitsky, Ashish Sabharwal, Harst Samuelsen)

Solvers portfolios

We discuss the idea of selecting and scheduling solvers based on the features of a given input instance. In particular, we review the recently propose SAT Solver Selector (SJS) and its parallel counterpart, pS5.

Yuni Malitsky, University College Cork (with Meinolf Sellmann)

Instance-specific algorithm configuration

The presentation focuses on a method for instance-specific algo-

rithm configuration (ISAC). ISAC is a general configurator that focuses on tuning different categories of parameterized solvers according to the instances they will be applied to. Specifically, this presentation will show that the instances of many problems can be decomposed into a rep-

resentative vector of features. It will further show that instances with similar features often cause similar behavior in the applied algorithm. ISAC exploits this observation by automatically detecting the different sub-types of a problem and then training a solver for each variety. This technique is employed on a number of problem domains, including set covering, mixed integer, satisfiability, and set partitioning. ISAC is then further expanded to demonstrate its application to traditional algorithm portfolios and adaptive search methodologies. In all cases, marked impro-

vements are shown over the existing state-of-the-art solvers.

Lin Xu, University of British Columbia (with Holger Hoos, Frank Hutter, Kevin Leyton-Brown)

Evaluating component solver contributions to portfolio-based algorithm selectors

Portfolio-based algorithm selection can exploit complementary strengths of different solvers and often represent the state of the art for solving many computationally challenging problems. In this work, we argue that a state-of-the-art method for constructing such algorithm selectors for the propositional satisfiability problem (SAT), SATzilla, also gives rise to an automated method for quantifying the importance of each of a set of available solvers. We entered the latest version of SATzilla into the analysis track of the 2011 SAT competition and drew two main conclusions from the results that we obtained. First, automatically-constructed portfolios of sequential, non-portfolio com-

petition entries perform substantially better than the winners of all three sequential categories. Second, and more importantly, a detailed analysis of these portfolios yields valuable insights into the nature of successful solver designs in the different categories. For example, we show that the solvers contributing most to SATzilla were often not the overall best-performing solvers, but instead solvers that exploit novel solution strategies to solve instances that would remain unsolved with- out them.

Thu. 1.H 3027

Risk management in financial markets
Organizers/Cheirs Nikos Trichakis, Harvard Business School; Dan Iancu, Stanford University - Invited Session
Gerry Tsoukalas, Stanford University (with Kay Giesecke, Jiang Wang)

Dynamic portfolio execution

We analyze the problem of dynamic portfolio execution for a port-

folio manager facing adverse market impact and correlated assets. We focus on the market microstructure and show that supply/demand in-

formation, contained in the assets’ limit order books, can be utilized to improve execution efficiency. Adopting a partial-equilibrium framework, we show that the multivariate problem requires an extended liquidity model which cannot be efficiently solved via the usual dynamic pro-

gramming methods. We provide an equivalent static reformulation of the problem that is solvable in polynomial time. We find that a strat-

gic manager can take advantage of asset cross-elasticities to mitigate adverse market impact and significantly reduce risk-adjusted execution costs. We also introduce and analyze an important trade-off that arises in heterogeneous portfolios, between the manager’s need to minimize costs, and his desire to remain well-diversified throughout the horizon. We develop a simple risk management tool which gives managers dy-

namic control over this trade-off.

Zachary Feinstein, Princeton University (with Birgit Rudloff)

Set-valued dynamic risk measures

Set-valued risk measures appear naturally when markets with transac-

tion costs are considered and capital requirements can be made in a basket of currencies or assets. We discuss the definition for such functions and the financial interpretation. Results for primal and dual representations of set-valued dynamic risk measures are deduced. Def-

initions of different time consistency properties in the set-valued frame-

work are given. It is shown that in the set-valued case the recursive form for multivariate risk measures as well as an additive property for the acceptance sets is equivalent to a stronger time consistency property called multi-portfolio time consistency. As an example we consider the superhedging problem in markets with proportional transaction costs.

Vishal Gupta, Massachusetts Institute of Technology (with Dimitri Bertsimas)

A data-driven approach to risk preferences

Accurately specifying risk preferences is critical to financial appli-

cations; yet, risk preferences are not directly observable. Typical indus-

try practice asks investors to self-describe as “conservative” or “risky”. In this work we take a data-driven perspective. Using ideas from in-

verse optimization, we construct risk measures that are consistent with an investor’s historical portfolio holdings. When applied to a single in-

vestor’s portfolio, our technique recovers a coherent risk measure ap-

proximately describing her behavior. This risk measure can then be used to inform subsequent reallocation or to cluster similar investors. When applied to the market portfolio, our approach provides an alter-

native derivation of the popular Black-Litterman estimator. Unlike the

original Bayesian derivation, our approach requires no probabilistic as-

sumptions, and generalizes beyond the mean-variance paradigm. In-

deed, we propose “BL”-type estimators in environments characterized by volatility uncertainty. Computational experience suggests portfolios built from these estimators offer a better risk-reward tradeoff than their traditional counterparts.
Mechanisms for resource allocation problems

Carmine Vorent, University of Teeside (with Paul Goldberg)

Using lotteries to approximate the optimal revenue

There has been much recent work on the revenue-raising properties of truthful mechanisms for selling goods. Typically, the revenue of a mechanism is compared against a benchmark (such as, the maximum revenue obtainable by an omniscient seller selling at a fixed price to at least two customers), with a view to understanding how much lower the mechanism’s revenue is than the benchmark, in the worst case. Here we study this issue in the context of lotteries, where the seller may sell a probability of winning an item. We are interested in two general issues. Firstly, we aim at using the true optimum revenue as benchmark for our auctions. Secondly, we study the extent to which the additional expressive power resulting from lotteries, helps to improve the worst-case ratio.

We study this in the well-known context of digital goods, where the production cost is zero. We show that in this scenario, collusion-resistant lotteries (these are lotteries for which no coalition of bidders exchanging side payments has an advantage in lying) are as powerful as truthful ones.

Vangelis Markakis, Athens University of Economics and Business (with Christos-Alexandros Psomas)

On worst-case allocations in the presence of indivisible goods

We study a fair division problem with indivisible goods. In such settings, proportional allocations do not always exist, i.e., allocations where every agent receives a bundle of goods worth to him at least \( 1/n \), with \( n \) being the number of agents. Hence one would like to find worst case guarantees when it comes to the value that every agent can have. We focus on such an algorithmic and mechanism design aspects of this problem. In the work of [Hill 1987], an explicit function was identified, such that for any instance, there exists an allocation that provides at least this guarantee to everybody. The proof however did not imply an efficient algorithm for finding such allocations. Following upon the work of Hill, we first provide a slight strengthening of the guarantee we can make for every agent, as well as a polynomial time algorithm for computing such allocations. We then move to the design of truthful mechanisms. For deterministic mechanisms, we obtain a negative result showing that a truthful 2/3-approximation of this guarantee is impossible. We complement this with a constant approximation for a constant number of goods. Finally we also establish some negative results for randomized algorithms.

Annamaria Kovacs, Goethe University, Frankfurt/M. (with Giorgos Christodoulou)

Characterizing anonymous scheduling mechanisms for two tasks

We study truthful mechanisms for domains with additive valuations, like scheduling mechanisms on unrelated machines, or additive combinatorial auctions. Providing a global, Roberts-like characterization of such mechanisms is a classic, long open problem. Among others, such a characterization could yield a definitive bound on the makespan approximation ratio of truthful scheduling.

We investigate special classes of allocation functions, and show that any allocation that is either locally efficient (enjoy-free) or anonymous (‘player-symmetric’) must be an special affine minimizer, i.e. a weighted version of the VCG allocation. This is the first characterization result for truthful unrelated scheduling on more than two machines.

Interestingly, for the ‘mirrored’ problem of additive combinatorial auctions our characterization admits mechanisms different from affine minimizers. Thus our result demonstrates the inherent difference between the scheduling and the auctions domain, and inspires new questions related to truthfulness in additive domains.

Thuy.1 MA 063

Mean-field approaches to large scale dynamic auctions and mechanisms

Kishnathmurthy Iyer, Stanford University (with Ramesh Johari, Mukund Sundararajan)

Mean field equilibria of dynamic auctions with learning

We study learning in a dynamic setting where identical copies of a good are sold over time through a sequence of second price auctions. Each agent in the market has an unknown independent private valuation which determines the distribution of the reward she obtains from the good; for example, in sponsored search settings, advertisers may initially be unsure of the value of a click. Though the induced dynamic game is complex, we simplify analysis of the market using an approximation methodology known as mean field equilibrium (MFE). The methodology assumes that agents optimize only with respect to long run average estimates of the distribution of other players’ bids. We show a remarkable fact: in a mean field equilibrium, the agent has an optimal strategy where she bids truthfully according to a conjoint valuation. The conjoint valuation is the sum of her current expected valuation, together with an additional amount that is exactly the expected utility that she obtains from an additional observation about her true private valuation. We conclude by establishing a dynamic version of the revenue equivalence theorem.

Santiago Balseiro, Columbia University (with Omar Besbes, Gabriel Weintraub)

Auctions for online display advertising exchanges: Approximations and design

We study the competitive landscape that arises in Ad Exchanges and implications for publishers’ decisions. Advertisers join these markets with a pre-specified budget and participate in multiple auctions over the length of a campaign. They bid on online ad placements based on specific viewer information. We introduce the notion of a Fluid Mean Field Equilibrium (FMFE) to study the advertisers’ dynamic bidding strategies. This concept is based on a mean field approximation to relax the informational requirements of advertisers, together with a fluid approximation to approximate the complex dynamics of the advertisers’ stochastic control problems. We derive a closed-form characterization of the bidding strategies under a FMFE, and of the resulting landscape. Choosing this characterization as our starting point, we first study the advertisers from the publisher’s perspective, and analyze the impact of three design levers: [1] the reserve price; [2] the supply of impressions to the Exchange versus an alternative channel; and [3] the disclosure of viewers’ information. Our results provide novel insights with regard to the description and design of such markets.

Alexandre Provost, KTH (with Rantik Ouromlhi, Peter Key)

Optimal bidding strategies and equilibria in repeated auctions with budget constraints

How should agents bid in repeated sequential auctions when they are budget constrained? A motivating example is that of sponsored search auctions, where advertisers bid in a sequence of generalized second price (GSP) auctions. These auctions have many idiosyncratic features that distinguish them from other models of sequential auctions. [1] Each bidder competes in a large number of auctions, where each auction is worth very little. [2] The total bidder population is large, which means it is unrealistic to assume that the bidders could possibly optimize their strategy by modeling specific opponents. [3] The presence of a virtually unlimited supply of these auctions means bidders are necessarily expense constrained. Motivated by these three factors, we first frame the generic problem as a discounted Markov Decision Process and provide a structural characterization of the associated value function and the optimal bidding strategy, which specifies the extent to which agents underbid from their true valuation due to budget constraints. We then show the existence of Mean Field Equilibria for both the repeated second price and GSP auctions with a large number of bidders.

Advances in global optimization I

Chair: Pål Buri; TU Berlin and University of Debrecen

Dmytro Leshchenko, Odessa State Academy of Civil Engineering and Architecture (with Leonid Akulinson, Alla Rachinskaya, Yaroslav Zhenich)

Optimal deceleration of an asymmetric gyrostat in a resistive medium

We investigate the problem of time–optimal deceleration of rotations of a dynamically asymmetric body with a spherical cavity filled with highly viscous fluid (for small Reynolds numbers). In addition, the rigid body is subjected to the action of a small retarding torque of linear resistance of the medium. The rotations are controlled by a bounded torque, which can be exerted by vernier jet engines. The functional Schwartz inequality turns out very useful in synthesizing control laws for deceleration of quasi-rigid bodies. Approximate solutions of perturbed minimum-time problems on rotation deceleration of rigid bodies relative to the center of mass, including objects with internal degrees of freedom, which have applications in dynamics of space- and aircrafts, are obtained. A number of mechanical models are invariant with respect to the angular momentum. In our problem the asymptotic approach made is possible to determine the control, time (Bellman’s function), evolutions of the magnitude of the elliptic functions modulus, and dimensionless kinetic energy and kinetic moment. The qualitative properties of the optimal motion were found.

Emilio Carrióza, Universidad de Sevilla (with Rafael Blanquero, Amaya Nogales)

Location on networks, Global optimization problems

We address some low-dimensional location problems on networks.
Contrary to classical location models such as the $p$-median or $p$-center, for which finite dominating sets exist, we consider models [e.g., the Huff problem, the $p$-median problem with continuously distributed demand] which can be written as (piecewise) d.c. optimization problems.

Structural properties are analyzed, and a branch-and-bound algorithm which exploits the d.c. structure of the objective to obtain bounds is described. Computational results are given, showing that problems on large networks are solvable in reasonable time as soon as the number of facilities is small.

Pål B ur, T U Berlin and University of Debrecen

Necessary and sufficient condition on global optimality without convexity and second order differentiability

The main goal of this talk is to give a necessary and sufficient condition of global optimality for unconstrained optimization problems, when the objective function is not necessarily convex. We use Gâteaux differenti- ability of the objective function and its bidual [the latter is known from convex analysis].

Implementations & software

Thu.1.H 0110

Commercial mathematical programming solvers II

Organizer/Chair Hans Mittelmann, Arizona State University - Invited Session

Robert Bixby, Gurobi Optimization, Inc. (with Zonghao Gu, Ed Rothberg)

Presolve for linear and mixed-integer programming

From our benchmarks at http://plato.asu.edu/bench.html we will quote the discrete and some of the continuous benchmarks. The dis- crete benchmarks are partly based on MIPLIB 2010. The continuous benchmarks include LP/GP, QCQP, SOCP, and SDP.

Joachim Dahl, MOSEK ApS

Extending the conic optimizer in MOSEK with semidefinite cones

We discuss the conic optimizer in MOSEK with a special emphasis on the recent semidefinite capabilities in the solver.

Robert Bixby, Gurobi Optimization, Inc. (with Zonghao Gu, Ed Rothberg)

Presolve for linear and mixed-integer programming

For linear programming, presolve typically amounts to reducing the size of the model; however, for mixed-integer programming the changes can be much more fundamental, producing a model “strengthening”, where this strengthening doesn’t simply speed the solution pro-

Thu.1.H 1058

Modeling languages and software I

Organizer/Chair Robert Fourer, AMPL Optimization - Invited Session

John Simola, Sandia National Laboratories (with William Hart, Jean-Paul Watson)

Modeling and optimizing block-composable mathematical programs in Pyomo

Computational tools for modeling mathematical programs are in wide-spread use within both academia and industry. However, avail-
able commercial and open-source software packages broadly lack ca-

Thu.1.R 1013

Polyhedral combinatorics

Chair Vinicius Forte, Universidade Federal do Rio de Janeiro

Diego Delle Donne, Universidad Nacional de General Sarmiento (with Javier Mareche)

Vertex coloring polytopes over trees and block graphs

Many variants of the vertex coloring problem have been defined, such as precoloring extension, $\gamma$-coloring, $\mu$-coloring, and list coloring. These problems are NP-hard, so they generalize the classical vertex coloring problem. On the other side, there exist several families of graphs for which some of these problems can be solved in polynomial time. The standard integer programming model for coloring problems uses a binary variable $x_{vc}$ for each vertex $v$ and each color $c$ to indicate whether $v$ is assigned $c$ or not. An extension of this model considers binary variables $w_{v}$ for each color $c$ to indicate whether color $c$ was used or not. In this work we study this formulation for the polyhedral cases of the coloring problems mentioned above. In particular, we prove that if the classical vertex coloring problem yields an integer polytope for a family of graphs, then the same holds for $\gamma$-coloring, $\mu$-coloring, and list coloring over the same family. We prove that the polytope asso-
ciated to these problems over trees is integer, and we provide empirical evidence suggesting that the same holds for block graphs.

Vinicius Forte, Universidade Federal do Rio de Janeiro (with Abilio Lucena, Nelson Maculan)

Formulations and exact solution algorithms for the minimum two-connected dominating set problem

Given an undirected graph $G = (V, E)$ a dominating set is a subset $D$ of $V$ such that any vertex of $V$ is in $D$ or has a neighbor vertex in $D$. The dominating set is 2-connected if the subgraph $G(D)$ it induces in $G$ is 2-connected and the Minimum 2-Connected Dominating Set Problem (M2CDS) asks for a least cardinality 2-connected $D$. The problem has applications in the design of ad-hoc wireless telecommunication networks. However no exact solution algorithm or heuristic appears to exist for it in the literature. In this presentation we discuss a number of different formulations for the M2CDS as well as some valid inequalities to strengthen them. The formulations address the two variants of the problem, namely the 2-edge connected and the 2-node connected ones and are based on either cut-set inequalities or multi-commodity flows. Preliminary computational results are discussed for branch and cut algorithms based on these formulations.

Mónica Braga, Universidad Nacional de General Sarmiento (with Javier Mareche)

The acyclic coloring polytope

A coloring of a graph $G$ is an assignment of colors to the vertices of $G$ such that any two vertices receive distinct colors whenever they are adjacent. An acyclic coloring of $G$ is a coloring such that no cycle of $G$
receives exactly two colors, and the acyclic chromatic number \(\chi_a(G)\) of a graph \(G\) is the minimum number of colors in any such coloring of \(G\).

Given a graph \(G\) and an integer \(k\), determining whether \(\chi_a(G) \leq k\) or not is NP-complete even for \(k = 3\). The acyclic coloring problem arises in the context of efficient computations of sparse and symmetric Hessian matrices via graph coloring methods. In this work we present an integer programming approach for this problem by introducing a natural integer programming formulation and presenting six facet-inducing families of valid inequalities. We study the disjunctive rank of these families of valid inequalities for the polytope associated to this formulation. We also introduce the concept of disjunctive anti-rank and study the anti-rank of these families.

**Integrating & mixed-integer programming**

**Thu. 1.R 2032**

**Branch-and-price II: Column and row generation**

Organizer/Chair Marco Lübbecke, RWTH Aachen University - Invited Session

Pedro Murani, University of Sao Paulo (with Jacek Gondzio)

Using interior point methods in branch-price-and-cut framework

- Branch-price-and-cut framework has proven to be a very powerful method for solving integer programming problems. It combines decomposition techniques with the generation of both columns and valid inequalities and relies on strong bounds to guide the search in the branch-and-bound tree.

- In this talk, we present how the performance of branch-price-and-cut framework can be improved by using the primal-dual interior point method. We discuss in detail how the challenges involved in combining the primal dual interior point method with the integer programming techniques are addressed. The effort to overcome the difficulties pays off in a number of advantageous features offered by the new approach. We present the computational results of solving the well-known instances of the Vehicle Routing Problem with Time Windows, a challenging integer programming problem. The results confirm that the proposed approach delivers the best overall performance when compared with other branch-price-and-cut frameworks available in the literature.

Kenem Butkul, Sabanci University (with S. Ikic Bribir, Ibrahim Muler)

Simultaneous column-and-row generation for large-scale linear programs with column-dependent-rows

- We develop a simultaneous column-and-row generation algorithm that could be applied to a general class of large-scale linear programming (LP) problems. These problems typically arise in the context of LP formulations with exponentially many variables. The defining property for these formulations is a set of linking constraints, which are either too many to be included in the formulation directly, or the full set of linking constraints can only be identified, if all variables are generated explicitly.

- Due to this dependence between columns and rows, we refer to this class of LPs as problems with column-dependent-rows. To solve these problems efficiently, we need to be able to generate both columns and rows on-the-fly. We emphasize that the generated rows are structural constraints and distinguish our work from the branch-and-cut and price framework. We first characterize the underlying assumptions for the proposed column-and-row generation algorithm. We then introduce in detail a set of pricing subproblems, and prove the optimality of the algorithm. We conclude by applying the proposed framework to the multi-stage cutting stock and the quadratic set covering problems.

Ruslan Sadykov, INRIA Bordeaux - Sud-Ouest (with François Vrandebbeck)

Column generation for extended formulations

- Working in an extended variable space allows one to develop refined formulations for mixed integer programs. However, a direct treatment by a MIP solver is not possible because of the size of the reformulation.

- If the extended formulation stems from a decomposition principle: a sub-problem admits an extended formulation from which is derived the extended formulation for the original problem, then, one can implement column generation for this extended formulation by transposing the equivalent procedure for the Dantzig-Wolfe reformulation.

- Pricing sub-problem solutions are expressed in the variables of the extended formulation and added to the current restricted version of the extended formulation along with the active sub-problem constraints. This so-called “column-and-row generation” procedure is revisited here in an unifying presentation and extended to the case of working with an approximate extended formulations. Numerical comparison of column-and-row generation with standard column generation shows that lifting pricing problem solutions in the space of the extended formulation permits their recombination into new sub-problem solutions and results in faster convergence.

**Thu.1.2033**

**New developments in integer programming**

Organizer/Chair Andreas Schöbel, MIT - Invited Session

Daniel Dadush, Georgia Institute of Technology

Convex minimization over the integers

- In the seminal works of Lenstra [MOR ’83] and Kannan [MOR ’87], it was shown that any\(\ P\) - and \(\ AP\) -valued Integer Linear Program (ILP) can be solved in time \(2^{O(n^2 \cdot \text{poly}(n))}\) (with polynomial dependence on the remaining parameters). In this work, we give a \(2^{O(n^a \cdot \text{poly}(n))}\) time algorithm to minimize a convex function over the integer points in any \(n\) dimensional convex body, thereby improving the computational complexity of the In- terger Programming Problem. The algorithm yields the first exact algorithmic convex IP and the current fastest algorithm for ILP. For our techniques, we rely on new insights in the geometry of numbers as well as new algorithms for lattice problems.

Gauss Regts, CWI (with Dion Gijbels)

Polyhedra with the integer Carathéodory property

- A polyhedron \(P\) has the Integer Carathéodory Property if the following holds. For any positive integer \(k\) and any integer vector \(w \in kP\), there exist affinely independent integer vectors \(x_1, \ldots, x_n \in P\) and positive integers \(n_1, \ldots, n_k\) such that \(n_1 x_1 + \cdots + n_k x_k = w\) and \(x_i \in \mathbb{Z}^n\).

- It was shown by Bruns et. al (W. Bruns, J. Gubeladze, M. Henk, A. Martin, R. Weismantel, A counter example to an integer analogue of Carathéodory’s theorem, J. Reine Angew. Math., 510 [1999], pp. 179-185) that the Integer Carathéodory Property is strictly stronger than the integer decomposition property.

- In this talk I will show that if \(P\) is a polyhedral base polytope or if \(P\) is a polytope defined by a totally unimodular matrix, then \(P\) has the Integer Carathéodory Property. For the matroid base polytope this answers a question by Cunningham from 1986.

Juliane Dinkel, IBM Research (with Andreas Schöbel)

A refined Gomory-Chvátal closure for polytopes in the unit cube

- We introduce a natural strengthening of Gomory-Chvátal cutting planes for the important class of \(0/1\)-integer programming problems and study the properties of the elementary closure that arises from the newieve cuts. Most notably we prove that the new closure is polyhe- dral, we characterize the family of all facet-defining inequalities, and we compare it to elementary closures associated with other cutting-plane procedures.

Vincent Barra, Clermont University, Blaise Pascal University, LIMOS - UMR 6159 (with Clément de Ribe, Rute Ekkeland, Erik Rason, Erlend Hodeland, Arnd Lundervold, Tessa Welte)

Assessing functional brain connectivity changes in cognitive aging using RS-fMRI and graph theory

- The observation that spontaneous BOLD-fMRI activity is not random noise, but is organized in the resting human brain as functionally relevant resting state networks has generated a new avenue in neuroimag- ing and cognitive research, where brain connectivity and graph theory are increasingly important concepts for understanding and for com- putation. We investigate functional brain connectivity and graph analy- sis methodology applied to the aging brain at two quite different time scales. The study involves whole brain BOLD fMRI measurements, con- ducted at time \(t_1\) and \(t_2\) 3 years later, designing binary functional connec- tivity graphs \(G_1\) and \(G_2\) for subjects \(i = 1, N\). We computed lo- cal and global nodal network metrics to assess functional connectiv- ity changes between these graph collections. We found individual and group-wise reduction from \(t_1\) to \(t_2\) in all local and global graph indices. These findings were uniform across different threshold values used for thresholding the Pearson’s correlations (edge weights) and included the binary graphs. Several perspectives are proposed by these pre- liminary results, eg in the context of test-retest reliability and reproducibility of graph metric.

Engelbert Meghu Nguido, LIMOS, Clermont University, UBP, CNRS (with Sabeur Abidi, Mondher Maddouri, Rabie Saidi)

Stability measurement of motif extraction methods from protein sequences in classification tasks

- Feature extraction is an unavoidable task, especially in the critical step of pre-processing of biological sequences. This step consists for example in transforming the biological sequences into vectors of motifs where each motif is a subsequence that can be seen as a property
(or attribute) characterizing the sequence. Hence, we obtain an object-property table where objects are sequences and properties are motifs extracted from sequences. This table can be used to apply standard machine learning tools to perform data mining tasks such as classification. Previous works described motif extraction methods for sequences classification, but none of the discussed algorithms are robustness of these methods when perturbing the input data. In this work, we introduce the notion of stability of the generated motifs in order to study the robustness of motif extraction methods. We express this robustness in terms of the ability of the method to reveal any change occurring in the input data and also its ability to target the interesting motifs. We use these criteria to evaluate and experimentally compare four existing methods.

### Clique separator decomposition and applications to biological data

The study of gene interactions is an important research area in biology. Nowadays, high-throughput techniques are available to obtain gene expression data, and clustering is a first mandatory step towards a better understanding of the functional relationships between genes. We propose a new approach using graphs to model this data, and decompose the graphs by means of clique minimal separators. A clique separator is a clique whose removal increases the number of connected components of the graph; the decomposition is obtained by repeatedly copying a clique separator into the components it defines, until only sub-graphs with no clique separators are left; these subgraphs will be our clusters. The advantage of our approach is that this decomposition can be computed efficiently, is unique, and yields overlapping clusters. The latter enables us to visualize the data by a meta-graph where two clusters are adjacent if they intersect. In addition, clique separators help to identify special genes, called fusion genes, in sequence similarity networks, in the context of evolutionary history. Our first results applying this approach to transcriptomic data are promising.

### The competitive facility location game: Equilibria and relations to the 1-median problem

We consider a competitive facility location problem on a network in which consumers are located on the vertices and wish to connect to the nearest facility. Knowing this, competitive players locate their facilities on vertices that capture the largest possible market share. The competitive facility location problem was first proposed by Hotelling in 1929, where two ice-cream sellers compete on a mile of beach with demand uniformly distributed among the shore. It is well-known that a generator of that game on a tree always admits an equilibrium. Furthermore, a location profile is an equilibrium if and only if both players locate their facilities in a 1-median of the tree. In this work, we further explore the relationship between the 1-median problem and the equilibria in competitive facility location games with two players. We generalize the previous result to the class of strongly chordal graphs, which strictly contains trees. In addition, we show that for certain classes of graphs in which an equilibrium does not always exist (such as cycles), if there is an equilibrium, it must satisfy that both players select vertices that solve the 1-median problem.

Douglas Fearing, Harvard Business School (with Ian Kast)

### Managing air traffic disruption through strategic prioritization

In the U.S., air traffic congestion places a tremendous financial burden on airlines, passengers, and the economy as a whole. Outside of capacity increases, there are, broadly, two approaches to address congestion. The first is to manage existing capacity more effectively, while the second is to incentivize airlines to schedule fewer flights. In our work, we show how to accomplish both through strategic prioritization, a competitive scheme that allows airlines to make flight priority decisions in advance of operations. When there is a disruption, the specified priorities allow the regulator to ration capacity more effectively. Additionally, many of these trade-offs can be further rationalized, e.g., by internalizing some of the congestion-related costs to be internalized by each airline, thus reducing over-scheduling. Specifically, our approach requires airlines to bid for a proportional allocation of a fixed pool of prioritization minutes at each airport. We then modify the existing capacity rationing scheme by treating prioritized flights as if they had been scheduled earlier than their actual time. We demonstrate the benefits of this approach through both simulation and theoretical results.

### Mixed-integer nonlinear programming

Techniques for convex MINLPs
Organizers/Organizers, Jeff Linderoth, University of Wisconsin-Madison - Invited Session
Pierre Bonami, CNRS - Aix Marseille Université

On disjunctive cuts for mixed integer convex programs

We study the separation of disjunctive cuts for mixed integer nonlinear programs where the objective is linear and the relations between the decision variables are defined by an interval. We call convex feasible region. Our method can be seen as a practical implementation of the classical lift-and-project technique to the nonlinear case. To derive each cut we use a combination of a nonlinear programming subproblem and a linear outer approximation. One of the main features of the approach is that the nonlinear programming subproblems solved to generate cuts are typically not more complicated than the original continuous relaxation. In particular they do not require the introduction of additional variables and maintain the properties of the nonlinear functions describing the feasible region. We propose several strategies for using the technique and present computational evidence of its practical interest. In particular, the cuts allow us to improve the state-of-the-art branch-and-bound of the solver Bonmin, solving more problems in faster computing times on average.
Mixed-integer nonlinear programming

Thu.1 MA 042

MINLP theory and algorithms
Organizer/Chair Giacomo Nannicini, Singapore University of Technology and Design - Invited Session

Emilioano Traversi, TU Dortmund (with Christoph Buchheim)

Separable underestimators for quadratic combinatorial optimization

We propose a method to obtain separable underestimators for quadratic combinatorial optimization problems. By exploiting separability, we can provide lower bounds by solving an integer linear program and use them in a branch and bound scheme. This is useful in practice when the underlying linear counterpart is easy to solve. We investigate the tightness of the bounds and their effect on the running time of the algorithm. Computational results are provided concerning the quadratic binary unconstrained problem and the quadratic spanning tree problem.

Stefano Coniglio, Politecnico di Milano (with Francesca Margot)

Spatial branch-and-bound for nonconvex Euclidean norm constrained mathematical programs

We are interested in mathematical programs involving Euclidean point-to-hyperplane distances. In particular, we focus on the Euclidean Linear Classification problem (ELC) of finding a hyperplane which best separates two sets of points by minimizing the sum of its Euclidean distance to the points on the wrong side. Given a point \( w \in \mathbb{R}^n \) and hyperplane with parameters \((w, y) \in \mathbb{R}^{n+1}\), their distance is \( |w^T w - y| \) subject to \( w^T w \geq 1 \), which feasible region is the nonconvex complement of the unit ball.

First, we observe that standard spatial branch-and-bound \( \{BB \} \) methods employ not tight relaxations which yield nontrivial bounds only after many iterations. Then, we propose a novel \( \{BB \} \) method where the complement of the unit ball is approximated with the complement \( P^c \) of a polyhedron \( P \). We represent \( P^c \) as a disjunction with a subproblem for each facet of \( P \) and, at each \( \{BB \} \) iteration, we refine it by adding a new vertex to \( P \) which corresponds to the new infeasible solution. Compared to a standard \( \{BB \} \) on random ELC instances, our method reduces, on average, the computing time by 36%, the number of tree nodes by 63%, and the tree depth by 55%.

Thu.1 IH 1029

Multi-objective optimization
Organizer/Chairs César Gutiérrez, Universidad de Valladolid; Vicente Novo, UNED - Invited Session

Maria Beatriz Hernández-Jiménez, Universidad Pablo de Olavide (with Manuel Arana-Jiménez, Rafaela Duara-Gómez, Gabriel Ruiz-García)

Characterization of efficient solutions for non-regular multijobjective problems with inequality-type constraints

For multijobjective problems with inequality-type constraints the necessary conditions for efficient solutions are presented. These conditions are applied when the constraints do not necessarily satisfy any regularity assumptions, and they are based on the concept of \( 2 \)-regularity introduced by Izmailov. In general, the necessary optimality conditions are not sufficient and the efficient solution set is not the same as the Karush-Kuhn-Tucker points set. So it is necessary to introduce generalized convexity notions. In the multijobjective nonregular case we give the notion of \( 2 \)-KKT-pseudoconvex-II problems. This new concept of generalized convexity is both necessary and sufficient to guarantee the characterization of all efficient solutions based on the optimality conditions.

César Gutiérrez, Universidad de Valladolid (with Bienvenido Jiménez, Vicente Novo)

Approximation of efficient sets via \( \varepsilon \)-efficient sets

When a vector optimization problem is solved, usually an approximated solution set is attained. In order to this surrogate optimization process works, the obtained \( \varepsilon \)-efficiency sets should satisfy certain continuity properties with respect to the solution set. In this talk we show several results from which one can analyze this problem, which are based on a generic \( \varepsilon \)-efficient concept. Finally, some of these results are applied to a vector optimization problem where the objective mapping is set-valued.

Fabián Flores-Bazán, Universidad de Concepción

Efficiency and ordering variational principles

It is shown that several results on ordering principles (among them the Brezis-Browder and the Ekeland variational ones on partially or quasi-ordered spaces that appear in the literature and have been proved in an independent way, have a common root: efficiency. Existence results of maximal elements for non constant binary relations are also discussed.

Thu.1 IH 0107

Linear algebra for optimization
Organizer/Chair Dominique Orban, GERAD and École Polytechnique de Montréal - Invited Session

Martin Stoll, MPI Magdeburg (with John Pearson, Tyrone Rees, Andrew Wathen)

Preconditioning for time-dependent PDE-constrained optimization problems

In this talk, we motivate and test effective preconditioners to be used within a Krylov subspace algorithm for solving a number of saddle point systems, which arise in PDE-constrained optimization problems. We consider a variety of setups for different time-dependent PDEs such as the distributed control problem involving the heat equation, the Neumann boundary control problem subject to the heat equation and a distributed control problem with Stokes equations as the PDE-constraint. Crucial to the performance of our preconditioners in each case is an effective approximation of the Schur complement of the matrix system. In each case, we propose the preconditioning approach and provide numerical results, which demonstrate that our solvers are effective for a range of regularization parameter values, as well as mesh sizes and time-steps.

Santiago Akle, ICMC Stanford University (with Michael Saunders)

Preconditioning for iterative computation of search directions within interior methods for constrained optimization

Our primal-dual interior-point optimizer PDCCO has found many applications for optimization problems of the form

\[
\min \{ f(x) \mid Ax = b, \quad 1 \leq x \leq u, \}
\]

in which \( f(x) \) is convex and \( A \) is a sparse matrix or a linear operator. We focus on the latter case and the need for iterative methods to compute dual search directions from linear systems of the form

\[
ADx = r,
\]

diagonal and positive definite.

Although the systems are positive definite, they do not need to be solved accurately and there is reason to use MINRES rather than CG (see PhD thesis of David Fong (2011)). When the original problem is regularized, the systems can be converted to least-squares problems and there is similar reason to use LSQR rather than LSRQR.

Since \( D \) becomes increasingly ill-conditioned as the interior method proceeds, there is need for some kind of preconditioning. We examine the partial Cholesky approach of Bellavia, Gondzio and Morini (2011) and explore some alternatives that are better suited to applications in which \( A \) is a linear operator.

Dominique Orban, GERAD and École Polytechnique de Montréal (with Chen Greif, Eric Moulding)

Spectral analysis of matrices arising in regularized interior-point methods

Interior-point methods feature prominently in the solution of inequality-constrained optimization problems, and involve the need to solve a sequence of \( 3 \times 3 \) block indefinite systems that become increasingly ill-conditioned with the iterations. To solve these systems, it is common practice to perform a block Gaussian elimination, and either solve the resulting reduced \( 2 \times 2 \) block indefinite system that has a typical saddle-point form, or further reduce the system to the normal equations and apply a symmetric positive definite solver. In this paper we explore whether the step of reducing the system from a \( 3 \times 3 \) block matrix to a \( 2 \times 2 \) block matrix necessarily pays off. We use energy estimates to obtain bounds on the eigenvalues of the coefficient matrices, and conclude that, at least in terms of spectral structure, it may be better to keep the matrix in its original unreduced form rather than perform a partial elimination before solving it.

Thu.1 II 0112

Nonlinear programming

Convex nonlinear optimization I
Chair Ganesh Perumal, Infosys Limited / International Institute of Information Technology, Bangalore

Stefan Stefanov, Neofit Rilski South-Western University

Convex separable minimization with box constraints

Scalar minimization problems with a convex separable objective function subject to a convex separable inequality constraint of the form less than or equal to / linear equality constraint / linear inequality constraint of the form the greater than or equal to, respectively, and bounds on the variables (box constraints). Such problems arise in both theoretical considerations and in practical problems. For the first and the second problem, a necessary and sufficient condition is proved for a feasible solution to be an optimal solution to the respective problem, and a sufficient condition is proved for a feasible solution to be an optimal solution to the third problem. Algorithms of polynomial computational complexity are presented.
A decomposition technique for convex optimization problems

In this presentation, we give a decomposition technique that is applicable to general convex optimization problems. The feasible space is divided into small sub-spaces and information about a particular sub-space containing the optimal solution is estimated from the cost function and the constraint set. The properties of such sub-spaces and their existential proof are explained. The complexity of applying this decomposition technique is also discussed.

Optimization problems with value function objectives

The family of optimization problems with value function objectives includes the minmax programming problem and the (pessimistic and original optimistic) bilevel optimization problem. In this talk, we would like to discuss necessary optimality conditions for this class of problems while assuming that the functions involved are nonsmooth and the constraints are the very general operator constraints.

Minimizing functions containing absolute values of variables

We propose an algorithm for the minimization of the function $f(Ax - b, |x|)$ on a box $\mathbb{R}^n \subseteq \mathbb{R}^n$ with nonempty interior, where $|x|$ denotes the componentwise absolute value, $f$ is a $C^2$ function, $b \in \mathbb{R}^m$ and $A \in \mathbb{R}^{m \times n}$. Moreover, we assume that gradients and Hessian matrices are available and that the Hessian matrices of $f$ can be represented in the form $G = D + RE$, where $D$ and $E$ are diagonal matrices.

The algorithm MINABS proceeds from a starting point by making coordinate searches, minimizing local quadratic models and checking the optimality conditions. For the minimization of the quadratic models, an algorithm for minimizing a quadratic function of the form $q(x) = y^T x + \frac{1}{2}(Bx - c)^T D (Bx - c)$, $F$ a diagonal matrix, is developed.

Finally, MINABS is applied to problems of the above kind in order to demonstrate the applicability of the algorithm.

Capacity of gas transport networks

Due to regulations gas network operators face the new challenge of allocating free capacity at all entry and exit points. Customers may then book within the reported capacity intervals separately at the entry and exit points. Operators have to guarantee that all expected requests within these intervals (called nominations) can be transported through the network. Where no historical withdrawal data is applicable, the worst-case request situation has to be considered. However, due to gas physics and active elements like compressors, the underlying question whether a nomination can be transported through the network, called nomination validation, already is far from being trivial and is modeled as a non-convex MINLP. Thus, it is not obvious what the operating limits of the network are. We discuss the hardness of the capacity allocation problem and propose an algorithm for solving a relaxed variant. Therein a nomination validation tool is used as black box. The potential of our implementation is demonstrated on real-life instances from gas network optimization.

Optimization in energy systems

### Thu.1 MA 550

**Gas and electricity networks**

Organizer/Chair Alexander Martin, FAU Erlangen-Nürnberg - Invited Session

Robert Schwarz, Zuse Institute Berlin

**Gas network design with integrated optimization of topology and dimensioning**

Natural gas is transported through networks of pipelines from sources to sinks. Given the geographical locations of these points together with nominated amounts of flow, we solve the problem of building the cost-optimal network able to satisfy all demands within the feasible pressure bounds. The decisions include both the selection of arcs where pipelines are built, as well as the choice of suitable diameters out of a set of discrete values with associated cost factors. Because of the nonconvex, nonlinear relationship between the flow rate and the pressure loss along the pipes, the diameters do not correspond directly to flow capacities. This leads to a MINLP formulation of the problem, which is solved using outer approximation and spatial branching. The discrete diameter choice is exploited to reformulate certain subproblems as MILPs after variable fixations during the branch and bound process. We present some preliminary computational results and discuss some possible extensions of the model.

**MILP-based islanding of large electricity networks using an aggregated model of power flows**

Wide-area blackouts of an electricity network can be prevented by splitting the system into islands. To achieve balanced, feasible islands, nonlinear AC power flow equations should be included, resulting in an MINLP problem. However, for large networks, it is not always necessary to model in detail power flows in areas far from the splitting boundaries. In this talk, we present a MILP-based formulation for islanding that uses an aggregated model of power flows, modelling power flows close to splitting boundaries by a piecewise linear approximated AC model, beyond that a linear DC model, and neglecting individual line flows in areas.
far from the boundaries. The effectiveness of the approach is demonstrated by examples of islanding large, real networks.

Ken McKinnon, Edinburgh University [with Waqas Bukhsh, Andreas Grothey, Paul Todbro]
**An MINLP approach to islanding electricity networks**

Intentional islanding is attracting an increasing amount of attention as a means of preventing large-scale blackouts in electricity transmission networks. In this talk, a mathematical formulation for islanding is presented, in which suspected unhealthy components of the network are identified while the island load shed is minimised. To achieve balanced, feasible islands, nonlinear AC power flow equations should be included, resulting in an MINLP problem. In the proposed MILP formulation, these terms are approximated by piecewise linear functions. The approach is demonstrated by results on test networks.

Thu.1.H.011

PDE optimization in medicine I
Organizer/Chair Anton Schiela, TU Berlin - Invited Session

Luis A. Fernandez, University of Cantabria
**Optimizing a chemotherapy model for brain tumors by using PDE**

We study some optimal control problems concerning a reaction-diffusion PDE that describes the growth of some brain tumors called gliomas, taking into account the pharmacokinetics of the chemotherapy treatment through its corresponding PDE in different frameworks.

Thu.1.H.011

PDE-constrained opt. & multi-level/multi-grid meth.

Lars Ole Sween, Fraunhofer MEVIS [with Preussor Tobolas]
**Modeling flow through realistic, algorithmically generated vascular structures in the liver**

The liver is a highly perfused and central metabolic organ. Its main connection to the rest of the organism is the blood flow through two supplying and one draining vascular system. For modeling blood flow through these, a proper geometric model of the vascular systems in the liver is an important building block.

In vivo imaging or imaging of corrosion casts does not provide sufficient details to obtain a geometric representation of the vascular structures down to the sinusoidal scale. The method of Constrained Constructive Optimization [Buxbaum, Schreiner; Karch et al.] is used for this purpose, determining a structure of minimal intravascular volume that provides homogeneous supply/drainage for the perfused volume. We quantify the similarity of algorithmically generated vascular structures to real human and murine ones, comparing different geometric features, and use these findings to improve the algorithm. For simulating flow in the whole organ as well as for jointly generating supply- and draining vascular systems, the tissue in between is taken into account as a porous medium in a 3D simulation coupled to the vascular flow.

Thu.1.MA.004

Robust optimization, estimation and machine learning
Organizer/Chair Aharon Ben-Tal, Technion - Israel Institute of Technology - Invited Session

Shimrit Shtem, Technion – Israel Institute of Technology [with Aharon Ben-Tal]
**A robust optimization approach for tracking under bounded uncertainty**

Classical dynamic control theory assumes that the system is inflicted with white noise and minimizes estimation mean square estimation error, usually by applying the Kalman filter (KF). In some applications, such as tracking, the assumption of white, unbounded noise is unrealistic. In these cases a worst case analysis, specifically the maximal error norm, might be a better measure of performance. In tracking applications ignoring worst case occurrences might have grave implications since large errors decrease the probability of successfully tracking an object, especially in presence of clutter or when tracking multiple objects. In order to analyze the worst case scenario for a general dynamic control problem, given the filter, we need to solve a non-convex Quadratic Constrained Quadratic Problem. Since this problem is generally NP-hard we try to utilize the problem’s block characteristics in order to find upper and lower bounds. We find these bounds through Semidefinite Programming and Block-wise Optimal Ascent. We compared the KF results to a greedy worst case filter (UBF) and found that, in most cases, UBF indeed performs better in regard to worst case analysis.

Thu.1.MA.004

Optimization in medicine I
Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics - Invited Session

Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics (with Klaus Krumbiegel, Nataliya Togobytska)
**Optimal control of multiphase steel production**

In this talk I will discuss an optimal control problem related to the production of multiphase steels. The state system consists of a partial differential equation for the evolution of temperature and a system of rate laws to describe occurring phase transitions, while a coefficient in the Robin boundary condition acts as the control. I will discuss necessary and sufficient optimality conditions, and we will discuss theoretical aspects of the problem. We will then develop and apply optimization strategies combined with model reduction methods such as Proper Orthogonal Decomposition, $H_2$-norm model reduction and Balanced Truncation to solve the problem efficiently.

Thu.1.MA.015

Optimization applications in industry VI
Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics - Invited Session

Ekaterina Kostina, University of Marburg [with H.-G. Bock, G. Kriwet, J.P. Schloder]
**Optimization methods for nonlinear model predictive control of non-stationary partial differential equations**

Many spatio-temporal processes in the natural and life sciences, and engineering are described by the mathematical model of non-stationary PDE. It would be of high practical relevance as well as a mathematical challenge to use such models for a process optimization subject to numerous important inequality restrictions. However in the presence of disturbances and modeling errors the real process will never follow the off-line computed optimal solution. Thus the challenge is to compute feedback controls that take these perturbations into account. We present a new optimization method for the NMPC. The NMPC principle is to solve a complete optimal control problem whenever new information about perturbations is available and to apply the first instant of the optimal control as a feedback law. However the frequency of perturbation information is orders of magnitude higher than even a single optimization iteration. Therefore we discuss multi-level iterations strategy to make NMPC computations real-time feasible for PDE optimal control problems.

Thu.1.MA.015

Optimization methods for nonlinear model predictive control of non-stationary partial differential equations

Eugenia Vosen, Niederer Universität of Applied Sciences [with Axel Haack, Andreas Pitter]
**Optimization and model reduction methods for heat source determination in welding**

The physical phenomena in welding can yet not completely be described by mathematical models. In industrial applications, it is therefore common to describe the effects of the heat energy by means of a parametrized volume source. Its parameters are obtained in several steps by a calibration of computed and experimental temperature data extracted out of transverse sections and thermo-elements. In each step, a time-dependent partial differential equation [PDE] on a three-dimensional domain has to be solved. The industrial standard practice is to use standard Finite Element methods for simulation of the PDE and to apply the calibration manually leading to overall times of up to several weeks for the procedure.

In this talk, we will formulate the procedure as an optimization problem with a finite-dimensional optimization variable and infinite-dimensional equality constraints, and we will discuss theoretical aspects of the problem. We will then develop and apply optimization strategies combined with model reduction methods such as Proper Orthogonal Decomposition, $H_2$-norm model reduction and Balanced Truncation to solve the problem efficiently.

Thu.1.MA.015

Optimization and model reduction methods for heat source determination in welding

Nataliya Togobytska)

Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics (with Klaus Krumbiegel, Nataliya Togobytska)
**Optimal control of multiphase steel production**

In this talk I will discuss an optimal control problem related to the production of multiphase steels. The state system consists of a partial differential equation for the evolution of temperature and a system of rate laws to describe occurring phase transitions, while a coefficient in the Robin boundary condition acts as the control. I will discuss necessary and sufficient optimality conditions, and we will discuss theoretical aspects of the problem. We will then develop and apply optimization strategies combined with model reduction methods such as Proper Orthogonal Decomposition, $H_2$-norm model reduction and Balanced Truncation to solve the problem efficiently.

Thu.1.MA.015

Optimization methods for nonlinear model predictive control of non-stationary partial differential equations

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sublinear-time algorithms for linear classification, support vector machine training, and other related optimization problems, including general semi-definite programming and robust linear programming. These new algorithms are based on a primal–dual approach, and use a combination of novel sampling techniques and the randomized implementation of online learning algorithms. We give lower bounds which show our running times to be nearly best possible.

Chiranjib Bhattacharyya, Indian Institute of Science (with Aaditya Ben-Tal, Sahely Bhadra, Arkadi Nemirovski)

Making SVM Classifiers robust to uncertainty in kernel matrices

We consider the problem of uncertainty in the entries of the Kernel matrix, arising in Support Vector Machine (SVM) formulation. Using Chance Constraint Programming and a novel large deviation inequality we derive a robust formulation which requires only second order statistical information. The formulation in general is non-convex, but in several cases of interest it reduces to a convex program. To address the non-convex nature of the problem we propose a robust optimization based procedure. Specifically the uncertainty is modeled as a possible affine combination of given positive definite kernels, with the coefficients ranging in a norm bounded uncertainty set. Subsequently using the Robust Optimization methodology, the SVM can be posed as a convex constrained saddle point problem. We show that the problem admits an efficient first order algorithm for this problem, which achieves $\mathcal{O}(1/\epsilon^4)$ reduction of the initial error after $T$ iterations. A comprehensive empirical study on both synthetic data and real-world protein structure datasets show that the proposed formulations achieve desired robustness.

Verifiable sufficient conditions for $\ell_1$-recovery of sparse signals

In this talk we will cover some of the recent developments in large-scale optimization motivated by the compressed sensing paradigm. The majority of results in compressed sensing theory rely on the ability to design use sensing matrices with good recoverability properties, yet there is not much known in terms of how to verify them efficiently. This will be the focus of this talk. We will analyze the usual sparse recovery framework as well as the case when a priori information is given in the form of sign restrictions on the signal. We will propose necessary and sufficient conditions for a sensing matrix to allow for exact $\ell_1$-recovery of sparse signals and utilize them. These conditions, although difficult to evaluate, lead to sufficient conditions that can be efficiently verified via linear or semidefinite programming. We will analyze the properties of these conditions while making connections to disjoint linear programming and introducing a new and efficient bounding schema for such programs. We will finish by presenting limits of performance of these conditions and numerical results.

Fatma Kilinc-Karzan, Carnegie Mellon University (with Anatoli Juditsky, Arkadi Nemirovski)

Verifiable sufficient conditions for $\ell_1$-recovery of sparse signals

We will finish by presenting limits of performance of these conditions while making connections to disjoint bilinear programming and semidefinite programming. We will analyze the properties of these conditions while making connections to disjoint linear programming and introducing a new and efficient bounding schema for such programs. We will finish by presenting limits of performance of these conditions and numerical results.

Anatoli Juditsky, LKCN, Université J. Fourier (with Fatma Kilinc-Karzan, Arkadi Nemirovski)

Accuracy guaranties and optimal $\ell_1$-recovery of sparse signals

In this talk we will discuss new methods for recovery of sparse signals which are based on $\ell_1$ minimization. Our emphasis is on verifiable conditions on the problem parameters (sensing matrix and sparsity structure) for accurate signal recovery from noisy observations. In particular, we show how the certificates underlying sufficient conditions of exact recovery in the case without noise are used to provide efficiently computable bounds for the recovery error in different models of imperfect observation. These bounds are then optimized with respect to the parameters of the recovery procedures to construct the estimators with improved statistical properties. To justify the proposed approach we provide oracle inequalities which link the properties of the recovery algorithms to the best estimation performance in the Gaussian observation model.

High-dimensional statistics: Techniques from stochastic and robust optimization

Organizers: Chair Constantine Caramanis, The University of Texas at Austin - Invited Session
Philippe Rigollet, Princeton University

Deviating optimal model selection using greedy algorithms

A statistical problem of model selection for regression can be simply described as a stochastic optimization problem where the objective is quadratic and the domain finite or countable. To solve this problem it is now known that, contrary to the principle of empirical risk minimization, one should seek a solution in the convex hull of the domain. This idea is implemented by exponential weights that are known to solve the problem in expectation, but they are, surprisingly, sub-optimal in deviation. We propose a new formulation called Q-aggregation that consists in minimizing a penalized version of the original criterion but for which the penalty vanishes at the points of interest. This approach leads to efficient greedy algorithms in the spirit of Frank-Wolfe but for which stronger bounds can be derived.

Sheer Manon, Technion - Israel Institute of Technology (with Constantine Caramanis, Yudong Chen)
Robust sparse regression and orthogonal matching pursuit

In this talk we consider simple, greedy methods for high dimensional regression with noise and erasures. We consider the setting of such corruptions not only in the output variable, but also in the covariates. We show our algorithms achieve more simple and efficient settings with excellent empirical performance. We prove bounds on their performance that substantiate our computational results, and in particular show that the guaranteed performance is at least as good as all existing algorithms, including those of greater complexity.

Sujay Sanghavi, UT Austin (with Praneeth Netrapalli)

Learning the graph of network cascades

Cascades, or epidemic processes, are widely used models for phenomena in social networks (for viral marketing, spread of ideas), genetic networks (spread of activation of genes) and epidemiological networks (communicable diseases in populations). We consider the natural inverse problem in this setting: learning the graph of a network, given only node states as the cascade spreads. In this talk we show that for most popular cascade models, this can be posed as a sparse recovery problem in high dimensions, but from non-linear measurements. a) Show that simple maximum likelihood, without regularization but with thresholding, achieves consistent graph recovery with sample complexity close to the corresponding lower bound b) Establish a connection between the network graph, and the Markov graph of the cascade process. We finish with two open problems: the performance of simple greedy algorithms, and the role of correlation decay.

Vincent Guigues, UFRJ (with Werner Römisch)

Decomposition methods for multistage stochastic programs

Organizers: Chair Vincent Guigues, UFRJ - Invited Session

Vincent Guigues, UFRJ (with Werner Römisch)

Sampling-based decomposition methods for multistage stochastic programs based on extended polyhedral risk measures

We define a risk-averse nonanticipative feasible policy for multistage stochastic programs and propose a methodology to implement it. The approach is based on dynamic programming equations written for a risk-averse formulation of the problem. This formulation relies on a novel class of multiperiod risk functionals called extended polyhedral risk measures. Dual representations of such risk functionals are given and used to derive conditions of coherence. In the one-period case, conditions for convexity and consistency with second order stochastic dominance are also provided. The risk-averse dynamic programming equations are specialized considering convex combinations of one-period extended polyhedral risk measures such as spectral risk measures. To implement the proposed policy, the approximation of the risk-averse recourse functions for stochastic linear programs is discussed. In this context, we detail a stochastic dual dynamic programming algorithm which converges to the optimal value of the risk-averse problem.

WeiJi Tang, Georgia Institute of Technology (with Jian Du, Costa, Alexander Shapiro, Manio Soares)

Risk neutral and risk averse stochastic dual dynamic programming method

In this talk, we discuss risk neutral and risk averse approaches to multistage linear stochastic programming problems based on the Stochastic Dual Dynamic Programming (SDDP) method. We give a gen-
eral description of the algorithm and present computational studies related to planning of the Brazilian interconnected power system.

Surejjeet Sen, University of Southern California (with Zhihong Zhou) Multi-stage stochastic decomposition

In this paper, we propose a statistically motivated sequential sampling method that is applicable to multi-stage stochastic linear programs, and we refer to it as the Multi-stage Stochastic Decomposition (MSD) algorithm. As with earlier SD methods for two-stage stochastic linear programs, this approach preserves the good features of SD: asymptotic convergence of the solutions can be proven (with probability one) without any iteration requiring more than a small sample-size. Our asymptotic analysis shows the power of regularization in overcoming some of the assumptions (e.g., independence between stages) associated with other sample-based algorithms for multi-stage stochastic programming.

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We consider variants of online network optimization problems concerning graph exploration. In the pro-客流-collecting travelling salesman problem, we are given a weighted graph $G = (V, E)$ with edge weights $\ell : E \to \mathbb{R}_+$, a special vertex $r \in V$, penalties $p : V \to \mathbb{R}_+$, and the goal is to find a closed tour $T$ such that $r \in V(T)$ and such that the cost $\ell(T) + p(T)$ is minimized. In an online variant, which we call the Canadian Tour Operator Problem (CTOP), the task is to route a tourist bus through a given network $G = (V, E)$ in which some edges are blocked by avalanches. An online algorithm learns from a blocked edge only when reaching one of its endpoints. The bus operator has the option to avoid visiting each node $v \in V$ by paying a refund of $p(v)$ to the tourists. The goal is to minimize the sum of the travel costs and the refunds. We show that no deterministic or randomized algorithm can achieve a bounded competitive ratio for the CTOP on general graphs and give $O(1)$-competitive algorithms for special networks. We also relate the problem to other (classical) online network and routing problems.

We consider the Online Delay Management Problem on a network with path-topology that is served by one railroad. In this model, the number of delayed passengers is not known beforehand but revealed in an online fashion. The goal is to decide at which station a train should wait in order to minimize the total delay of all passengers.

We introduce the concept of a lookahead which yields information about delays at succeeding stations. The concept does not lead to better competitive ratios, we can justify the intuition that it is a feature that does help an algorithm. To this end, we make use of comparative analysis that allows to compare different classes of lookahead algorithms with each other. Furthermore, we show how knowledge about the distributions of delayed passengers can be used in order to set up a stochastic programming framework.

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corresponding stationary indices) of the original problem and those with the feasible set \( F \).

Helmut Gfrerer, Johannes Kepler University Linz

Second-order conditions for a class of nonsmooth programs

We study infinite dimensional optimization problems with constraints given in form of an inclusion \( 0 \in F(x) - S(x) \), where \( F \) denotes a smooth mapping and \( S \) is a generalized polynomial multifunction, e.g., the normal cone mapping of a convex polyhedral set. By using advanced techniques of variational analysis we obtain second-order characterizations, both necessary and sufficient, for directional metric subregularity of the constraint mapping. These results can be used to obtain second-order optimality conditions for the optimization problem.

Peter Fusiok, Comenius University Bratislava

On metric regularity of the Kojima function in nonlinear semidefinite programming

The one-to-one relation between the points fulfilling the KKT conditions of the optimization problem and the zeros of the corresponding Kojima function is well-known. In the present paper we study the interplay between metric regularity and strong regularity of this a priori nonsmooth function in the context of semidefinite programming. Having in mind the topological structure of the positive semidefinite cone we identify a class of Lipschitz metrically regular functions which turn out to have a globally oriented \( B \)-subdifferentials. This class is broad enough to include the Kojima function corresponding to the nonlinear semidefinite programming problem.

THU 1.2 2051

Optimization methods for nonsmooth inverse problems in PDEs

Organizers/Chair: Akhtar Khan, Rochester Institute of Technology; Christian Clason, Karl-Franzens-Universitéit Graz - Invited Session

Barbara Kaltenbacher, Alpen-Adria University Klagenfurt (with Bernd Hofmann, Frank Schöpfer, Thomas Schuster)

Iterative regularization of parameter identification in PDEs in a Banach space framework

Natural formulations of inverse problems for PDEs often lead to a Banach space setting, so that the well-established Hilbert space theory of regularization methods does not apply. The talk will start with an illustration of this fact by some parameter identification problems in partial differential equations. Then, after a short detour to variational regularization, we will mainly focus on iterative regularization methods in Banach spaces. We will dwell on gradient and Newton type methods as well as on their extension from the original Hilbert space setting to smooth and convex Banach spaces. Thereafter, convexity of the Newton step subproblems is preserved while often nondifferentiability might be introduced, which results in the requirement of solving a PDE with nonsmooth nonlinearly for evaluating the duality mapping. Convergence results for iterative methods in a Banach space framework will be discussed and illustrated by numerical experiments for one of the above mentioned parameter identification problems.

Bernd Hofmann, TU Chemnitz

On smoothness concepts in regularization

A couple of new results on the role of smoothness and source conditions in Tikhonov type regularization in Hilbert and Banach spaces are presented. Some aspect refers to the role of appropriate choice rules for the regularization parameter. The study is motivated by examples of nonlinear inverse problems from inverse option pricing and laser optics.

Christian Clason, Karl-Franzens-Universität Graz

Inverse problems for PDEs with uniform noise

For inverse problems where the data is corrupted by uniform noise, it is well-known that the \( L^\infty \) norm is a more robust data fitting term than the standard \( L^2 \) norm. Such noise can be used as a statistical model of quantization errors appearing in digital data acquisition and processing. Although there has been considerable progress in the regularization theory in Banach spaces, the numerical solution of inverse problems in \( L^\infty \) has received rather little attention in the mathematical literature so far, possibly due to the nondifferentiability of the Tikhonov functional. However, using an equivalent formulation, it is possible to derive optimality conditions that are amenable to numerical solution by a superlinearly convergent semi-smooth Newton method. The automatic choice of the regularization parameter \( \nu \) using a simple fixed-point iteration is also addressed. Numerical examples illustrate the performance of the proposed approach as well as the qualitative behavior of \( L^\infty \) fitting.

THU 2.3 3018

Scheduling, packing and covering

Organizer/Chair: Nicole Mogw, Technische Universität Berlin - Invited Session

Wiebe Höhn, TU Berlin (with Tobias Jacobs)

On the performance of Smith’s rule in single-machine scheduling with nonlinear cost

We consider the problem of scheduling jobs on a single machine. Given some continuous cost function, we aim to compute a schedule minimizing the weighted total cost, where the cost of each individual job is determined by the cost function value at the job’s completion time. This problem is closely related to scheduling a single machine with nonuniform processing speed. We show that for piecewise linear cost functions it is strongly NP-hard.

The main contribution of this article is a tight analysis of the approximation factor of Smith’s rule under any particular convex or concave cost function. More specifically, for these wide classes of cost functions we reduce the task of determining a worst case program instance to a continuous optimization problem, which can be solved by standard algebraic or numerical methods. For polynomial cost functions with positive coefficients it turns out that the tight approximation ratio can be calculated as the root of a univariate polynomial. To overcome unrealistic worst case instances, we also give tight bounds that are parameterized by the minimum, maximum, and total processing time.

Christoph Dürr, CNRS, UniX Pierre et Marie Curie

Packing and covering problems on the line as shortest path problems

A popular approach to understand a new problem is to model it as an integer linear program, and to analyze properties of the relaxed linear program. Sometimes one might discover that the variable/constraint matrix is totally unimodular (TUM), which implies that the problem has a polynomial time solution, most likely with a flow structure. In some cases however the linear program is not TUM, but nevertheless has the property, that whenever it has a solution, all optimal extrem point solutions are integral. Again this leads to a polynomial time solution, just by solving the relaxed linear program. D. and Mathilde Hurand in 2006 found that some of these linear programs could be simplified as shortest path formulations. In 2011 Alejandro López-Ortiz and Claude-Guy Quimper showed how the special structure of these shortest path instances could be used to solve the problem within improved running time. In this talk the outline of these analyses and simplification techniques are presented, illustrated on packing and covering problems on the line.

Alexander Souza, Apixxo AG (with Matthias Heilwig)

Approximation algorithms for generalized and variable-sized bin covering

We consider the NP-hard Generalized Bin Covering problem: We are given \( m \) bin types, where each bin of type \( i \) has profit \( p_i \) and demand \( d_i \). There are \( n \) items, where item \( j \) has size \( s_j \). A bin of type \( i \) is covered if the set of items assigned to it has total size at least the demand \( d_i \). The profit of \( p_i \) is earned and the objective is to maximize the total profit. To the best of our knowledge, only the cases \( m = 1, \) \( m = 1 \) (Bin Covering) and \( m = 1 \) (Variable-Sized Bin Covering) have been treated before. We study two models of bin supply: In the unit supply model, we have exactly one bin of each type and in the infinite supply model, we have arbitrarily many bins of each type.

We prove that there is a combinatorial \( \frac{3}{2} \)-approximation algorithm for Generalized Bin Covering with unit supply, which has running time \( O(nm \sqrt{m} + n) \). For Variable-Sized Bin Covering, we show that the Next Fit Decreasing (NFD) algorithm is a \( \frac{9}{4} \)-approximation in the unit supply model. We also show that there is an APTAS for Variable-Sized Bin Covering in the infinite supply model.

Thu. 2.3 3004

Cycles in graphs

Chair Peter Recht, TU Dortmund

Eva-Maria Sprengel, TU Dortmund, Germany (with Peter Recht)

An optimal cycle packing for generalized Petersen graphs \( P(n, k) \) with \( k \) even

For an undirected graph \( G = (V, E) \) a maximum cycle packing is a collection of pairwise edge-disjoint cycles. The maximum cardinality of such a packing is denoted as the cycle packing number \( \nu(G) \).

In general the determination of a maximum cycle packing and the cycle packing number, respectively, is NP-hard.

In this lecture we consider the family of generalized Petersen graphs \( P(n, k) \) with \( k \) even. We give a lower and an upper bound on

Thu. 1.2 2051

Variational analysis

Approximation & online algorithms

Thu. 2.3 3018

Combinatorial optimization

Thu. 2.3 3004

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In this lecture we consider the family of generalized Petersen graphs \( P(n, k) \) with \( k \) even. We give a lower and an upper bound on
the cycle packing number and outline the structure of one optimal cycle packing of such graphs.

Peter Recht, TU Dortmund (with Eva-Maria Sprengel)

"A min-max-theorem" for the cycle packing problem in Eulerian graphs

This lecture deals with the problem to determine a set $Z^* = (C_1, C_2, \ldots, C_{|C|})$ of edge-disjoint cycles of maximum cardinality $v(G)$ in a graph $G = (V, E)$. The problem is tackled by considering special subgraphs: for a vertex $v \in V$, let $T(v)$ be a local trace at $v$, i.e. $T(v)$ is an Eulerian subgraph of $G$ such that every walk $W(v)$, with start vertex $v$ can be extended to an Eulerian tour in $T(v)$.

In general, maximal local traces are not uniquely defined but their packing numbers $v(T(v))$ are.

We prove that if $T$ is an Eulerian every maximum edge-disjoint cycle packing $Z^*$ of $G$ induces maximum local traces $T(v)$ at $v$ for every $v \in V$. In the opposite, if the total size $\sum_{v \in V} E(T(v))$ is minimal then the set of induced edge-disjoint cycles in $G$ must be maximum.

The determination of such a maximal trace leads to a multi-commodity flow-problem with quadratic objective function.

Lamia Aoudia, University of Sciences and Technologies Houari Boumediene (U.S.T.H.B) (with Mezzane Ader)

4-cycle polytope on a graph

The aim of this work is to give a convex hull of 4-cycle on a wider class of complete bipartite graphs. Given a bipartite graph $K_{m,n}$, where $|V_1| = n$ and $|V_2| = m$, $E = V_1 \times V_2$ and a weight function $w : E \rightarrow \mathbb{R}$. The minimum weighted 4-cycle problem consist on finding a 4-cycle $C \subseteq E$ such that $\sum_{e \in C} w_e$ is minimum. This problem can easily be solved in polynomial time by complete enumeration of the the 4-cycles of $G$. For each 4-cycle $C$, let $X^C$ denote the incidence vectors $C$ defined by $X^C(e) = 1$ and $X^C(e) = 0$ if $e \notin C$. The 4-cycle polytope $PC_{4,n,m}$ is the convex hull of the incidence vectors of the 4-cycles of $K_{m,n}$, i.e. $PC_{4,n,m} = \text{convex hull} \left\{ X^C : C = 4$-cycle of $G \right\}$. The minimum weighted 4-cycle problem is clearly equivalent to the linear program

$$\min \{ w_x : x \in PC_{4,n,m} \}.$$ 

We are mainly interested by the facial structure of $PC_{4,n,m}$. Thus, we enumerate some inequalities defining facets of $PC_{4,n,m}$.

Thu.2.H.3012

Nonlinear combinatorial optimization

Chair Laura Klein, TU Dortmund

Lauru Klein, TU Dortmund (with Christoph Buchheim)

Separation algorithms for quadratic combinatorial optimization problems

Binary quadratic optimization problems (BQP) are known to be NP-hard even in the unconstrained case. The standard linearization, where
auxiliary variables replace the quadratic monomials, yields an exact LP-formulation, but the resulting LP-bounds are weak in general. For BQP whose underlying linear problem is efficiently solvable, we propose an improved approach. We consider the corresponding problem with only one monomial in the objective function and observe that valid inequalities of the single monomial problem remain valid for the general case. With the aid of an extended formulation and a polynomial time separation algorithm for the single monomial problem is presented, which exploits the simple structure of the linear case and is extendable to BQP with a constant number of monomials. The idea of separating valid inequalities for the single monomial case is applied to the quadratic minimum spanning tree problem (QMST). We present a new class of facets for QMST with one monomial and, similarly to the linear case, exploit its combinatorial structure for obtaining an efficient separation algorithm. Computational results show the advantages of the resulting inequalities for QMST.

Agniesz Garge, University Paris-Sud, LRi (with Abdel Lisser, Kristh Zorgati) Quadratic cuts for semidefinite relaxation of combinatorial problems Semidefinite Programming is well known for providing tight relaxations of combinatorial problems. In practice, only few real-world applications of this approach have been reported, especially on 0/1 Linear Programming, which is yet a large part of practical combinatorial problems. The reasons for this are twofold. First, some powerful MILP software are already available. Furthermore, for such problems, it is necessary to tighten the basic semidefinite relaxation with cuts, since as it is, it is equivalent to the linear relaxation. Then, we face the difficulty of picking the right cuts to tighten the relaxation in the most relevant fashion. There might be quadratic cuts in order to outperform the linear relaxation. We present here a systematic approach to compute such cuts. This method extends naturally to binary programs with non convex quadratic constraints, for which no dedicated software are currently available. Finally, we apply this technique to a well-known problem of energy management i.e., the scheduling of the nuclear outages, a combinatorial problem with quadratic objective and non-convex quadratic constraints. Numerical results on real life instances are given.

Marta Vidal, Universidad Nacional del Sur, Universidad Tecnológica Nacional FRBB (with María Maciel) A new proposal for a lower bound in a generalized quadratic assignment problem applied to the zoning problem Zoning is a key prescriptive tool for administration and management of protected areas. However, the lack of zoning is common for most protected areas in developing countries and, as a consequence, many protected areas are not effective in achieving the goals for which they were created. In this work we introduce a quantitative method to expeditiously zone protected areas. Zoning problem was mathematically modeled as a generalized quadratic assignment problem (GQAP), this problem generalizes the well known quadratic assignment problem, one of the most difficult problems in the combinatorial optimization field, it belongs to the NP-hard class. To solve it we applied a simulated annealing heuristic, obtaining satisfactory results in both academic problems of different dimensions as a real large scale problem. In this work we propose a lower bound for the GQAP based on a new Lagrangean relaxation, which will be applied to the simulated annealing algorithm.

Organizer/Chair Bo Chen, University of Warwick - Invited Session Xiuli Chao, University of Michigan (with Beryl Chen) Dynamic pricing decision for a monopoly with strategic customers and price adjustment We consider a monopoly firm selling a product over a finite planning horizon to a finite customer base. Each customer requires at most one product and decides whether and when to purchase the product. The customers are strategic and forward looking in making their purchasing decisions. The firm’s objective is to set the selling price in each period to maximize its total discounted revenue. We analyze the effect and benefit for the firm’s strategy to offer a price adjustment. Our research questions are the following: How does the price adjustment strategy affect the optimal selling price in each period and the consumer behavior, who benefits and who is hurt by this price adjustment strategy? The problem is modeled as a dynamic game and we obtain Markov subgame perfect equilibrium. We show that, depending on the system parameters, the optimal pricing strategy has several interesting patterns. These results are then applied to answer the research questions raised above. We also offer the managerial insights yielded from this model.

Mahdi Noorizadegan, Warwick Business School, Warwick University (with Bo Chen, Laura Galli) A branch and cut approach for some heterogeneous routing problems under demand uncertainty The Capacitated Vehicle Routing Problem (CVRP), with its many variants, is one of the most widely studied NP-hard problems in combinatorial optimisation due to its wide practical applications and tough computational challenges. An important generalisation of the classical CVRP is the so-called Heterogeneous Vehicle Routing Problem (HVRP), where a heterogeneous fleet of finite vehicles is stationed at the depot. In this study, we first consider the stochastic HVRP, and then move to a new and even more general variant known as stochastical Capacitated Multi-Depot Heterogeneous VRP. In the stochastic versions it is assumed that customer demands are not known for certain. There are many ways to deal with uncertainty. We present three models: two robust counterparts according to Ben-Tal & Nemirovski [1999] and Bertsimas & Sim [2004] and one chance-constrained. Our first step is to formulate the (stochastic) problems in such a way that the corresponding stochastic ones, according to the three frameworks, remain tractable. The second step is to solve the resulting models using a Branch-and-Cut approach. We present heuristic separation algorithms for some classes of valid inequalities.

Zhichao Zheng, National University of Singapore (with Chung Piaw Teo) Least square regret in stochastic discrete optimization We describe an approach to find good solution to combinatorial op-
Finding a conjectural variations equilibrium in a financial model by solving a variational inequality problem

In this paper, a general multi-sector, multi-instrument model of financial flows and prices is developed, in which the utility function for each sector is assumed to be quadratic and constraints satisfy a certain set of conditions. A system of variational inequalities with general mappings, which can be regarded as an extension of Lagrangian primal-dual systems of constrained problems, is considered. Many equilibrium type problems can be written in this format. In particular, we show that this problem is suitable for modelling various complex systems including spatial telecommunication, transportation, and economic ones. However, the basic mappings can be multi-valued and even non-monotone in real applications. This fact creates certain difficulties for providing convergence of many existing iterative methods.

In this talk, we describe several families of iterative solution methods for the above system which are adjusted to the mappings properties. In particular, they are applicable both for the single-valued and for the multi-valued case. Next, the methods are convergent under mild conditions and admit efficient computational implementation especially for the spatially distributed problems.

Alexander Zaslavski, The Technion – Israeli Institute of Technology

The extragradient method for solving variational inequalities in the presence of computational errors

In a Hilbert space, we study the convergence of the subgradient method to a solution of a variational inequality, under the presence of computational errors. Most results known in the literature establish convergence of optimization algorithms, when computational errors are summable. In the present paper, the convergence of the subgradient method for solving variational inequalities is established for non-summable computational errors. We show that the subgradient method generates a good approximate solution, if the sequence of computational errors is bounded from above by a constant.

Vyacheslav Kalashnikov, ITESM, Campus Monterrey (with Yazmin Acosta Sanchez, Nataliya Kalashnykova)

Finding a conjectural variations equilibrium in a financial model by solving a variational inequality problem

In this paper, a general multi-sector, multi-instrument model of financial flows and prices is developed, in which the utility function for each sector is assumed to be quadratic and constraints satisfy a certain accounting identity that appears in flow-of-funds accounts. Each sector uses conjectures of its influence upon the prices of instruments. The equilibrium conditions are first derived, and then the governing variational inequality is presented. Next, a criterion of consistency of the conjectures is derived, and a qualitative analysis of the model is conducted.

Yuan Yuan, The Logistics Institute, Northeastern University (with Tang Lixin)

Integrated ship plan of strip coil consolidation and stowage

In iron and steel industry, finished products such as strip coils are mainly transported by ship. The planning of ship transportation includes consolidation planning and stowage planning. Consolidation planning is to determine which coils to be loaded on a given ship according to the delivery dates, destinations and storage locations of the coils. Stowage planning is to allocate exact position to each coil based on the constraints about the ship’s stability. Ordinary researches divided the problem into two subproblems, and discussed them sequentially. The solution obtained by solving the two problems may not be very good or there may be many shifts, or even not all the coils in consolidation plan could be loaded. This is because the size of coils is irregular and the constraints for balance are rigorous, but the frame of ship was not considered by consolidation planning. The situation motivates us to integrate the two subproblems. We formulate the problem and relax it by a second order cone programming approach. An approximate solution is obtained by a heuristic method.

Bo Kyung Choi, Pukyong National University, Busan, Republic of Korea
We will present numerical experiments on academic and real-life test algorithms which contains both, the derivative-free approach and the L-BFGS method, and which is therefore able to optimally take into account efficient method for solving bound-constrained optimization problems characterized by different requirements. Depending on the availability of the gradient, different algorithms have been developed such as Derivative-Free Optimization (DFO) or gradient-based algorithms. The software BC-DFO (Bound-Constrained Derivative-Free Optimization), using a self-correcting property of the geometry and an active-set strategy to handle bound constraints, has shown to be efficient on a set of test problems of the CUTER collection. Here, we propose to extend this code by adding the possibility of handling noisy gradients. It is well known that the L-BFGS method is a very efficient method for solving bound-constrained optimization problems when accurate gradient information is provided. Whereas, this is often not the case in practice. We would like to propose a family of algorithms which contains both, the derivative-free approach and the L-BFGS method, and which is therefore able to optimally take into account the error occurring in the cost function and/or gradient of the problem. We will present numerical experiments on academic and real-life test cases.

Optimization algorithms are crucial to solve industrial optimization problems. Here we present a self-correcting property of the geometry and an active-set strategy to handle bound constraints, which has shown to be efficient for solving bound-constrained optimization problems when accurate gradient information is provided. Whereas, this is often not the case in practice. We would like to propose a family of algorithms which contains both, the derivative-free approach and the L-BFGS method, and which is therefore able to optimally take into account the error occurring in the cost function and/or gradient of the problem. We will present numerical experiments on academic and real-life test cases.

The presence of noise or uncertainty in function evaluations can negatively impact the performance of model based trust-region algorithms for derivative free optimization. One remedy for this problem is to use regression models, which are less sensitive to noise; and this approach can be enhanced by using weighted regression. But this raises questions of how to efficiently select sample points for model construction and how to manage the trust region radius, taking noise into account. This talk proposes strategies for addressing these questions and presents an algorithm based on these strategies.

In this paper Data Envelopment Analysis is used to select among different potential partners to form a joint venture which is the one that best fits the strategic goal of a horizontal cooperation. Since each potential partner has a different technology the one whose technology better complements ours is the one that will bring the greatest synergy to the technology of the joint venture. Models for the cases that the joint venture is planning to open one or several facilities are presented. A priori and ex-post measures of synergy between the partners are proposed. Also, a simple way of sharing the costs of the horizontal cooperation based on cooperative game theory is presented.

The computation of economic equilibria plays an important role in all applications of general economic equilibrium model. Despite the fact that some numerical methods have been proposed, how to compute economic equilibria efficiently remains a challenging issue. In this paper, we develop an interior-point path-following method for computing equilibria of an exchange economy with linear production technologies. The peculiar characteristic of our method is that we convert an exchange economy with linear production technologies to a pure exchange economy by ways of allocating the production to consumers’ endowments evenly. Resorting to an extra variable, we devise a new economy which deforms from a trivial exchange economy to the original one while the variable varies from 0 to 1. An application of Sard’s theorem and perturbations leads to the existence of a smooth interior-point path, which starts from the unique equilibrium of the exchange economy and leads to an economic equilibrium of the exchange economy with linear production technologies. A predictor-corrector method is proposed to numerically follow the path. Efficiency of the method is demonstrated through numerical examples.

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We reconsider the well-studied Selfish Routing game with affine latency functions. The Price of Anarchy for this class of games takes maximum value 4/3; this maximum is attained already for a simple network of two parallel links, known as Pigou’s network. We improve upon the value 4/3, for networks of parallel links, by means of Coordination Mechanisms.
Global optimization on the difference of sub-topical functions

We present the necessary and sufficient conditions for the global minimum of the difference of strictly sub-topical functions. We prove that if the objective function is the difference of two convex functions, then any local minimizer is a global minimizer. Furthermore, we show that the global minimizer can be found by solving a sequence of convex optimization problems.

Implementation & software

Modeling languages and software II

Organizer/Chair Robert Fourer, AMPL Optimization - Invited Session

Ronald Hochstein, WU Vienna University of Economics and Business

Optimization modeling using R

Simplifying the task of modeling optimization problems is an important task. Many commercial products have been created to support the modeling process, but none of these products has been adopted by a significantly large number of users. As soon as real-world decision problems under uncertainty have to be modeled, flexible and quick changes to the underlying model are necessary. Simplications are crucial to implement such optimization models into some business processes successfully. Furthermore, the learning overhead for users should be minimized. In this talk, we outline an approach on how to simplify optimization modeling using R and external optimization modeling languages as well as building model generators for specific application problems. Examples from the areas of Finance and Energy will substantiate the applicability of the chosen approach.

Arnaud Schulz, IBM (with Vincent Berardu, Frederic Delhauge)

Enterprise-class optimization-based solutions with CPLEX Optimization Studio and SPSS predictive analytics

The talk will focus on the integration of different analytics such as optimization (prescriptive analytics) and predictive analytics (SPSS Modeler), existing in the OPL language, integrated in the cplex Studio Integrated Development Environment. With this connection statistical algorithms/methods are available to feed with data any optimization model either written for math programming (cplex Optimizer) or constraint programming (CP Optimizer). This opens up the door for decision makers at line-of-business, IT professionals and analytics practitioners to take advantage of out-of-the-box capabilities for implementing custom planning and scheduling solutions, collaborative planning processes, to name a few.

Leo Lopes, SAS Institute

Network optimization and beyond in SAS/OR® Software

This paper demonstrates new features in the OPTMODEL procedure for network and combinatorial optimization. In CPLEX OPTMODEL, you can access a variety of network-based solvers by using only problem definitions instead of explicit formulations, greatly enhancing performance and scalability. You can also access most of the functionality of the SAS System by merging invocations of other SAS procedures with mathematical programming constructs that are built into the PROC OPTMODEL modeling language. The results can populate sets and arrays that can be processed further both within the modeling language itself and by using the full power of the SAS System.
An important consideration when applying neural networks is the effect of threshold and weight perturbations on them, i.e., which is the sharpest bound one may consider for weights and threshold to maintain the linearly separable function unchanged for designing a more robust and safer neural network. Two parameters have been introduced: the maximum relative errors in weights and threshold of strict separating systems: the tolerance (Hu 1960) and the greatest tolerance (Freixas and Molinero 2008). Given an arbitrary separating system we study which is the equivalent separating system that provides maximum tolerance and maximum greatest tolerance. We present new results for the maximum tolerance and the maximum greatest tolerance, for instance, we present when the maximum tolerance and maximum greatest tolerance among all equivalent strict separating (natural) systems are attained. We also give the strict separating (natural) system that attaches the maximum tolerance for $n$ variables. Similar results appear for the maximum greatest tolerance. Finally, we also give new results for the number of variables $n$ and the number of types of distinguished variables $k$.

Ané Müller, Freie Universität Berlin

Cycle free flows in large-scale metabolic networks

 Genome-scale metabolic networks are used to model all (usually around 2000) chemical reactions occurring in a biological cell. These networks are a generalization of directed hypergraphs (where the reactions are the arcs of the graph) and a specialization of realizable oriented matroids. We are interested in optimizing the flow through a given reaction in the network. We have the usual constraint of flow conservation and additionally the flow must not contain internal circuits. Internal circuits are flows that do not contain a specific subset of the reactions called exchange reactions.

We show that it is NP-hard to decide if a non-zero flow without internal circuits through a given reaction is possible. However, most genome-scale metabolic networks only contain few internal circuits. Using a specific branching strategy combined with a primal heuristic, we derive a tractability result that is also practically applicable. In fact, it very often suffices to solve only one LP.

For flow variability analysis, where we solve optimization problems for each reaction in the network, we obtain a speed-up of factor $90-300$ to previous methods.

Stefan Wiesberg, Institut fuer Informatik, Universität Heidelberg (with Gerhard Reinelt)

Computing role structures in networks

In network analysis, an established way to obtain structural information is to partition the vertices into so-called regular equivalence classes. In such a partitioning, two nodes $u$ and $v$ belong to the same class if for every neighbor of $u$, there is a neighbor of $v$ in the same class, and vice versa. Thus, for any two classes $C$ and $D$, either every or no member of $C$ has a neighbor in $D$. The relationships between the classes can hence be visualized by a graph, the so-called role graph. It is of interest in several fields, for example in sociology, economy, or condenser research. An NP-hard problem in this context is the following one: Given a network $G$ and a finite set $R$ of role graphs, which element of $R$ represents the role structure of $G$ in the best possible way? We present one of the first exact algorithms for this problem. It is based on an IP formulation with a quadratic objective function and solved by branch-and-cut. Significant running-time improvements compared to currently used methods are reported.

Thu.2.H 2013

Network analysis
Chair Stefan Wiesberg, Institut fuer Informatik, Universität Heidelberg

Xavier Molinero, Universitat Politècnica de Catalunya (UPC – EPEM) (with Josep Freixas)

Variations in strict separating systems representing a linearly separable function

An important consideration when applying neural networks is the effect of threshold and weight perturbations on them, i.e., which is the sharpest bound one may consider for weights and threshold to maintain the linearly separable function unchanged for designing a more robust and safer neural network. Two parameters have been introduced: the maximum relative errors in weights and threshold of strict separating systems: the tolerance (Hu 1960) and the greatest tolerance (Freixas and Molinero 2008). Given an arbitrary separating system we study which is the equivalent separating system that provides maximum tolerance and maximum greatest tolerance. We present new results for the maximum tolerance and the maximum greatest tolerance, for instance, we present when the maximum tolerance and maximum greatest tolerance among all equivalent strict separating (natural) systems are attained. We also give the strict separating (natural) system that attaches the maximum tolerance for $n$ variables. Similar results appear for the maximum greatest tolerance. Finally, we also give new results for the number of variables $n$ and the number of types of distinguished variables $k$.

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this allows us to resort to a branch-and-cut algorithm in which each subproblem includes one convex quadratic constraint. However, the ellipsoid can also be used to derive valid inequalities for the stable set polytope: a hyperplane tangent to the ellipsoid can be exploited to generate strong cutting planes by a sequential strengthening procedure. We discuss the performance of the resulting (LP-based) branch-and-cut algorithm through extensive experiments.

Laurence Widdick, CORE, Université Catholique de Louvain (with Mathias Van Vroo, Hilde Tuyau)

Thu.2 MA 176

Scheduling, assignment and matching in healthcare
Chair Sarah Kirchner, RWTH Aachen

Andrea Trautsamwieser, University of Natural Resources and Life Sciences, Vienna (with Patrick Hirsch)

A branch-and-price approach for solving medium term home health care planning problems

Medium term home health care planning is important because of additional legal working time regulations. Moreover, the clients (resp. nurses) prefer to know their visiting days and times (resp. working days and times) beforehand. In Austria, the planning of these services is typically done manually. However, several constraints make the planning a bit more transcriptional tasks. Usually, the clients have to be visited several times a week for a certain treatment at a certain time by appropriately skilled nurses. Additionally, working time regulations such as maximum allowed working time, breaks, and rest periods have to be considered. Furthermore, some clients need to be visited by two or more nurses at the same time and some visits cannot start before a certain time gap after another visit has elapsed. The objective is to minimize the total travelling times of the nurses. In order to solve this problem efficiently an algorithm is developed combining a Branch-and-Price approach and a metaheuristic solution approach based on Variable Neighbourhood Search. The algorithm is tested with real life data and compared to the solutions obtained with standard solver software.

Nahid, Iraj rashid, RMIT University (with Leonid Churilov, John Hearne)

Optimal individual matching to evaluate treatment in the stroke trails

The aim of this work is to make an individual matching of patients with multiple attributes from two groups of therapy. The problem is investigated at the outcomes of the two groups of patients in the stroke trails which some treated by alteplase and the others controlled by placebo. To address the problem we modeled the problem as an integer program using assignment formulation. Our proposed models will consider the trade-off between the three objectives: maximize the number of matches, minimize the same visit difference and minimize the age difference. We applied our models for two data sets EPI-THET and NINDS. To demonstrate the relationship between the sample size and the number of matches we did a simulation by generating thousands of patients and proved our assumptions.

Sarah Kirtner, RWTH Aachen (with Marco Lübbeke)

Appointment scheduling in a hospital environment

Currently appointments for patients are scheduled locally in most german hospitals. In every hospital unit a scheduler assigns appointments sequentially to incoming treatment requests. As the settlement amount for a patient is determined by his diagnoses and received treatments and not by the length of his hospitalization it is desirable for hospitals to reduce the average length of hospitalization. Therefore it is necessary to coordinate appointments for all treatments on a patients care pathway. This problem can be seen as a variant of the well known job shop scheduling problem where patients correspond to jobs and treatments for patients correspond to tasks of jobs. The problem is also related to scheduling problems with calendars, as resources in a hospital are mostly not available at night and treatments can not be interrupted when the resource becomes unavailable. The objective of our problem is to minimize the average number of days of hospitalization. In this talk we introduce this new scheduling problem and present first models and solution approaches.
We present new separation algorithms for the Boolean quadric polytope and cut polytopes, which are the polytopes associated with zero-one quadratic programs and the max-cut problem, respectively. Our approach exploits a non-trivial way, three known results in the literature: one on the separation of \( \{0, \frac{1}{2}\} \)-cuts, one on the symmetries of the polytopes in question, and one on the relationship between the polytopes. We remark that our algorithm for the cut polytope is the first combinatorial polynomial-time algorithm that is capable of separating over a class of valid inequalities that includes all odd bicycle wheel inequalities and all \((p, 2)\)-circulant inequalities.
measure. This bound has the same order as that for steepest-descent methods applied to unconstrained problems. Furthermore, complexity bounds of [optimal] order $e^{-3/2}$ are obtained if cubic regularization steps for a smooth least-squares merit function are employed in a similar target-following algorithmic framework, provided higher accuracy is required for primal than for dual feasibility.

Xiao Wang, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (with Ya-xiang Yuan)

**An augmented Lagrangian trust region method for nonlinear programming**

We present a new trust region method for solving equality constrained optimization problems, which is motivated by the famous augmented Lagrangian function. Different from the standard augmented Lagrangian method where the augmented Lagrangian function is minimized at each iteration, the new method, for fixed Lagrange multiplier and penalty parameter, tries to minimize an approximation model to the augmented Lagrangian function in a trust region to generate next iterate. Besides, new update strategies for Lagrange multipliers and penalty parameters are proposed. Global convergence of the new algorithm is proved in this paper. Moreover, we analyze the behavior of penalty parameters and figure out in which case when they are bounded. At last, we do some numerical experiments on the equality constrained problems from CUTER collection. We also consider extending the idea to general constrained optimization. Some numerical results are reported too.

Zhijun Wu, Iowa State University (with Yiping Hao, Wen Zhou)

**Computation of optimal strategies for evolutionary games**

Biological species (viruses, bacteria, parasites, insects, plants, or animals) replicate, mutate, compete, adapt, and evolve. In evolutionary game theory, such a process is modeled as a so-called evolutionary game. We describe the Nash equilibrium problem for an evolutionary game and discuss its computational complexity. We discuss the necessary and sufficient conditions for the equilibrium states, and derive the methods for the computation of the optimal strategies, including a specialized Snow-Shellley algorithm, a specialized Lemke-Howson algorithm, and an algorithm based on the solution of a complementarity problem on a simplex. Computational results are presented. Theoretical difficulties and computational challenges are highlighted.

Thu.2 H 0110

**Interior-point methods for linear programming**

Chair Luz-Rafael Santos, IMECC/Unicamp

Aurelio Oliveira, University of Campinas (with Lilian Berti, Carla Odivini, Jar Silva)

**Continued iteration and simple algorithms on interior point methods for linear programming**

Continued iteration and simple algorithms are applied between interior point iterations to speed up convergence. In the continued iteration, interior point methods search directions are projected along the blocking constraint in order to continue the iteration. The process can be repeated while the projected direction is a good one in some measure. In a similar fashion, a few iterations of simple algorithms can be applied to the current interior point. Numerical experiments show that the combining such approaches leads to promising results, reducing the total number of iterations for the interior point methods applied to linear programming problems.

Luciana Casacio, UNICAMP - University of Campinas (with Christiano Lyra, Aurelio Oliveira)

**New preconditioners for interior point methods in linear programming**

We are concerned with the KKT systems arising when an interior point method is applied to solve large-scale linear programming problems. We exploit the basic-nonbasic partition to design novel preconditioners for iterative methods applied to these systems. A two-phase iterative method is used which switches between different preconditioners. We provide a spectral analysis for the preconditioners and illustrate their practical behaviour on medium-scale problems from the Netlib collection.

Luz-Rafael Santos, IMECC/Unicamp (with Aurelio Oliveira, Clovis Perin, Fernando Villan-Blas)

**A polynomial optimization subproblem in interior-point methods**

In this work we study a primal-dual path-following interior point method for linear programming. Our approach, based on Mehrotra's predictor-corrector method, combines three types of directions to generate a better one by making an extensive use of real-valued polynomials on variables $(a, \mu, d)$, where $a$ is the step length, $\mu$ defines a more general central path, and $d$ models the weight that a predictor direction should have. We develop a merit function that is a polynomial in $(a, \mu, d)$ and that is used as a guide to combine those directions. This merit function is subjected to polynomial constraints, which are designed to keep the next point into a good neighbourhood of the central path – a generalization of Gondzio-Colombo's symmetric neighbourhood. A polynomial optimization problem (POP) arises from this approach and its global solution, in each iteration, leads to the choice of the next direction. Different methods for solving the POP are being experimented and the computational experiments are promising.

Xia Wang, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (with Ya-xiang Yuan)

Nonlinear programming

Thu.2 H 0112

**Semidefinite and DC programming**

Chair Ibraheem Alolyan, King Saud University

Ibraheem Alolyan, King Saud University

**Zeros of quadratic interval polynomials**

In this paper, we study the zeros of interval polynomials. We develop a method to compute all zeros of such polynomial with interval coefficients and give the characterization of the roots.

Nonlinear programming

Thu.2 H 1012

**Policy iteration algorithms and some applications**

Organizer/Chair Hasnna Zidani, ENSTA ParisTech & Inria - Invited Session

Hasnna Zidani, ENSTA ParisTech & Inria (with Olivier Bokanowski)

**Some convergence results for the policy iterations algorithm.**

In this talk, we will present some convergence results of Howard's algorithm for the resolution of equations in the form of $\min_{a} \max_{b} (b_{s} - c_{s}) = 0$, where $b_{s}$ is a matrix, $c_{s}$ is a vector, and $A$ is a compact set. We show a global superlinear convergence result, under a monotonicity assumption on the matrices $b_{s}$. An extension of Howard's algorithm for a max-min problem of the form $\max_{a} \min_{c} (b_{s}a - c_{s}) = 0$ will also be proposed.

The algorithms are illustrated on the discretization of nonlinear PDEs arising in the context of mathematical finance (American option and Merton's portfolio problem), of front propagation problems, and for the double-obstacle problem, and Hamilton-Jacobi equations.

Jan Hendrik Witte, University of Oxford (with Christopher Reisinger)

**Penalty methods for the solution of discrete HJB equations – continuous control and obstacle problems**

We present a novel penalty approach for the numerical solution of continuously controlled HJB equations and HJB obstacle problems. Our results include estimates of the penalisation error for a class of penalty terms, and we show that variations of Newton’s method can be used to obtain globally convergent iterative solvers for the penalised equations. Furthermore, we discuss under what conditions local quadratic convergence of the iterative solvers can be expected. We include numerical results demonstrating the competitiveness of our methods.

Stephane Gaubert, INRIA and CMAP, Ecole Polytechnique (with Marianne Akian, Jean-Cochet-Terrasson, Sylvie Dé肿瘤)

**Policy iteration algorithm for zero-sum stochastic games with mean payoff**

We develop a policy iteration algorithm to solve zero-sum stochastic games with finite state, perfect information and ergodic payoff [mean payoff per turn]. An initial version of this algorithm was introduced by Cochet-Terrasson and Guaybert in 2006, who assumed an exact model of the arithmetic and the finiteness of action spaces. This algorithm does not require any irreducibility assumption on the Markov chains determined by the strategies of the players. It is based on a discrete nonlinear analogue of the notion of reduction of a super-harmonic function, which ensures the convergence even in the case of degenerate iterations, in which the mean payoff is not improved. Hence, it can be applied to monotone discretizations of stationary Isaacs partial differential equations without any strong ellipticity assumption. We report examples on Isaacs equations, as well as on a discrete combinatorial game (variants of the infinity Laplacian on a graph) in which degenerate iterations do occur. We also discuss numerical issues due to ill-conditioned linear problems.
of stochastic bilevel problems. These problems can for example arise at the pricing of energy delivery contracts, when instead of a replication approach a game-theoretic approach to pricing is chosen. In the latter case, the exercise price set by the seller anticipates the exercise strategy of the buyer that will be triggered by this particular exercise price. The special, case where constraints on the seller’s risk are included in the model, we call risk averse bilevel problem. This particular type of bilevel problem where the seller’s constraints depend on the buyer’s exercise strategy has so far received little attention, since in general it leads to a nonconvex optimization problems where the feasible set may be nonconnected. We demonstrate the properties and particular difficulties of this problem and present algorithms suitable for solving it. We apply an iterative solution method on some real data and investigate the numerical behavior.

Mark Jennings, Imperial College London (with David Fisk, Nilay Shah)

Optimization of technology investments and capital management in an urban energy system housing retrofit project. Use of rolling horizons in a London borough study

We consider formulations optimizing the technological and capital decisions taken when retrofitting urban energy systems at the large-scale. This study can be considered a minimum cost strategic capital management problem, incorporating a resource-task network representation of the housing stock’s demand and supply side energy systems. We use real data on existing housing conditions from a London borough seeking to minimise its housing stocks’s greenhouse gas emissions. We seek to answer two research questions: (i) what is the effect of rolling horizons on investments which retrofit housing technologies?, and (ii) to what degree does the abstraction of the temporally dynamic technological operations in separate LP, MILP, and MINLP formulations impact upon the optimization’s fidelity, piecewise special ordered set branching error, and processing unit solution time respectively? Initial insights suggest that expected reductions in energy demand may be adversely affected by investor attitudes to shorter time horizons. MILP formulations of housing retrofit projects may offer the best tradeoffs between fidelity/accuracy and reasonable solution times.

Thu.2.H 0111

PDE optimization in medicine II
Organizer/Chair Anton Schiela, TU Berlin - Invited Session

Martin Frank, RWTH Aachen University (with Richard Baranz, Michael Herty)

Optimal radiotherapy treatment planning using minimum entropy models

We study the problem of finding an optimal radiotherapy treatment plan. A time-dependent Boltzmann particle transport model is used to model the interaction between radiative particles with tissue. This model allows for the modeling of inhomogeneities in the body and allows for anisotropic sources modeling distributed radiation and external beam sources. We study two optimization problems: the deviation from a spatially-dependent prescribed dose through a quadratic tracking functional; and minimizing the survival of tumor cells through the use of the linear-quadratic model of radiobiological cell response. For each problem, we derive the optimality systems. In order to solve the state and adjoint equations, we use the minimum entropy approximation; the advantages of this method are discussed. Numerical results for real patient data are presented.

Chamakuri Nagiah, Johann Radon Institute for Computational and Applied Mathematics (RICAM) (with Karl Kunisch, Gerot Frank)

Numerical solutions for boundary control of bidomain equations in cardiac electrophysiology

The bidomain equations are widely accepted as one of the most complete descriptions of the cardiac bioelectric activity at the tissue and organ level. The model consists of a system of elliptic partial differential equations coupled with a non-linear parabolic equation of reaction-diffusion type, where the reaction term, modeling ionic transport is described by a set of ordinary differential equations. The numerical solution approach is based on minimizing a properly chosen cost functional $J(v, l)$ depending on the extracellular current $I$, as input, which must be determined in such a way that wave-fronts of transmembrane voltage $v$ are smoothed in an optimal manner. The boundary control formulation is presented. The numerical realization of the optimality system is described in detail and numerical experiments, which demonstrate the capability of influencing and terminating reentry phenomena, are presented. We employ the parallelization techniques to enhance the solution process of the optimality system and a numerical feasibility study.

Thu.2.H 0111

PDE-constrained opt. & multi-level/multi-grid meth.

Thu.2.A 554

Optimization in energy systems
Organizer/Chair Guillaume Erbs, GDF SUEZ - Invited Session

Guillaume Erbs, GDF SUEZ (with Romain Apparajitio)

Application of stochastic dual dynamic programming to the analysis of natural gas markets

With the liberalization, the natural gas markets constitute an increasingly complex and uncertain environment. In order to model such a system, one has to take into account the various assets that are used along the chain: production, transport (pipeline or LNG) and storage. In this presentation, we make the assumption of perfect competition and we focus on the uncertainty on consumption (i.e., we make the assumption of a risk neutral central planner).

The considered problem is a multiperiod stochastic problem with a great number of assets and periods. The stochastic dual dynamic programming algorithm [Pereira and Pinto 1991] is well suited for this kind of problems. It constructs an approximation of the Bellmann functions by sampling the uncertainty and is widely used for hydro-power systems planning for its performance in practice. We will talk about its application to a natural gas system.

Abida Ibrahim, GDF SUEZ (with Jouvet Pierre André)

A stochastic generalized Nash-Cournot model for the European gas market. The S-GaMMES model

We present a Stochastic Generalized Nash-Cournot model of the gas markets. The major gas chain players are depicted. We consider market power and the demand representation captures the fuel substitution and the fluctuation of the oil price. Long-term contracts as well as production and pipeline investments are endogenous. The model has been applied to represent the European gas market and forecast consumption, prices, production and foreign dependence till 2030. Finally, we have calculated the value of the stochastic solution.

Argirios Tzamargou, NTNU (with Lars Hellermo, Kjetil Midthun, Adrian Werner)

Multi-stage stochastic programming for natural gas infrastructure design

We present a multi-stage stochastic model that analyzes investment in natural gas fields and infrastructure. New projects are evaluated together with existing infrastructure and planned expansions. Several uncertain factors both upstream and downstream such as reservoir volumes, the composition of the gas in new reservoirs, market demand and price levels can influence the optimal decisions. The model focuses also on the impact of the sequencing of field developments and new infrastructure on the expected security of supply. In order to analyze all these aspects in one model, we propose a novel approach to scenario trees; combining long-term and short-term uncertainty. Dimensionality and solution times of realistic investment cases from the Norwegian Continental Shelf are discussed. Experience from a parallel implementation of branch-and-fix coordination is summarized.

Thu.2.A 554

Bilevel programming and housing retrofit
Chair Mark Jennings, Imperial College London

Eugene Zak, Alston Grid Inc. (with Sami Ammar, Kwok Chung)

Bilevel Programming for combinatorial auctions in electricity markets

In advanced electricity markets some bids and offers extend over a block of several consecutive time periods so that the block bid/offer has to be cleared entirely for all time periods comprising the block. According to a typical market rule a block bid can be cleared only if its price is not lower than the average market price. Similarly, a block offer can be cleared only if its price is not higher than the average market price. The dilemma occurs: block bids/offers selection as a primal solution cannot be properly exercised without knowing the prices as a dual solution, and the prices depend on the selection decisions. We propose a model harmonizing such complex “primal-dual” market rules. The model, based on bilevel programming, ties together the primal and dual variables so that the “primal-dual” market rules become a part of the overall model. The model is a non-linear Mixed Integer Program (MIP). We have implemented an exact algorithm to solve this model. The computational results demonstrate the adequacy of the modeling and algorithmic approaches and their practical value for several European electricity markets with combinatorial auctions.

Peter Gross, Universität Wien (with Raimund Kovacevic, Georg Pflug)

Risk averse bilevel problems in energy markets

Our work introduces risk averse bilevel problems as a special case of bilevel problems. These problems can for example arise at the pricing of energy delivery contracts, when instead of a replication approach a game-theoretic approach to pricing is chosen. In the latter case, the exercise price set by the seller anticipates the exercise strategy of the buyer that will be triggered by this particular exercise price. The special case where constraints on the seller’s risk are included in the model, we call risk averse bilevel problem. This particular type of bilevel problem where the seller’s constraints depend on the buyer’s exercise strategy has so far received little attention, since in general it leads to a nonconvex optimization problems where the feasible set may be nonconnected. We demonstrate the properties and particular difficulties of this problem and present algorithms suitable for solving it. We apply an iterative solution method on some real data and investigate the numerical behavior.

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of the Lagrange-Newton-Krylov method in a parallel environment will be shown.

Malik Kicherer, Zuse Institute Berlin (ZIB)

Large deformation diffeomorphic metric mapping using conforming adaptive finite elements

Automatic registration of anatomical objects is an important task in medical imaging. One crucial prerequisite is finding a pointwise mapping between different shapes.

Currents are linear functionals providing a unified description of those shapes of any positive integer dimension $m \leq d$ embedded in $\mathbb{R}^d$. The Large Deformation Diffeomorphic Mapping (LDDMM) framework (Joshi and Miller, IEEE Transactions on Image Processing, 2000) solves the correspondence problem between them by evolving a displacement field along a velocity field.

In this talk we propose three aspects making this ODE/PDE optimization problem numerically practical. We compute the temporal propagation of $m$-currents using a spatially discretized velocity field on conforming adaptive finite elements. A hierarchical approach from coarse to fine lattices improves performance and robustness of our method. The adaptive refinement process is driven by some residual estimator based on the Riesz representative of shape differences.

$\text{Thu.2 MA 015}$

Theory and methods for PDE-constrained optimization problems with inequalities

Organizer/Chair Michael Ulbrich, Technische Universität München - Invited Session

Francisco José Silva Alvarez, Dipartimento di Matematica "Guido Castelnuovo", La Sapienza (with Organizer/Chair Michael Ulbrich, Technische Universität München. Invited Session

Characterization of quadratic growth for strong minima in the optimal control of semi-linear elliptic equations

In this work, we are concerned with the following optimal control problem:

$$\min_u J(u) := \int_\Omega \ell(x, y(x), u(x)) \, dx,$$

under bounds constraints on the control $u$, and where $y_u$ is the unique solution of

$$-\Delta y(x) + \varphi(x, y(x), u(x)) = 0, \quad \text{for } x \in \Omega, \quad y(x) = 0, \quad \text{for } x \in \partial \Omega.$$ 

We extend to strong solutions classical second order analysis results, which are usually established for weak solutions. We mean by strong solution a control $u$ that satisfies:

There exists $\varepsilon > 0$ such that $J(u) \leq J(\bar{u})$ for all $u$ with $\|y_u - y_{\bar{u}}\| \leq \varepsilon$.

The study of strong solutions, classical in the Calculus of Variations, seems to be new in the context of the optimization of elliptic equations. Our main result is a characterization of local quadratic growth for the cost function $J$ around a strong minimum.

Martin Weiser, Zuse Institute Berlin

Goal-oriented estimation for nonlinear optimal control problems

In optimal control problems with elliptic PDE constraints,

$$\min_{(y, u)} J(y, u) \quad \text{s.t.} \quad c(y, u) = 0,$$

the value of the cost functional is a natural quantity of interest for goal-oriented error estimation and mesh refinement. The talk will discuss the difference between the all-at-once error quantity $f(u^h, p^h) - f_{opt}$ introduced by Becker/Kapp/Rannacher and the black-box error quantity $f(u^h, p^h) - f_{opt}$. Both qualitative and quantitative differences will be addressed for linear-quadratic problems.

In the second part, the black-box approach will be extended to smooth nonlinear problems and will result in a novel accuracy matching for inexact Newton methods. Quantitative aspects are illustrated on numerical examples including interior point regularizations of inequality constrained problems.

Florian Kruse, Technische Universität München (with Michael Ulbrich)

An infeasible interior point method for optimal control problems with state constraints

We present an infeasible interior point method for pointwise state constrained optimal control problems with elliptic PDEs. A smoothed constraint violation functional is used to develop a self-concordant barrier approach in an infinite-dimensional setting. For the resulting algorithm we provide a detailed convergence analysis in function space. This includes a rate of convergence and a rigorous measure for the proximity of the actual iterate to both the path of the minimizers and the solution of the problem. Moreover, we report on numerical experiments to illustrate the efficiency and the mesh independence of this algorithm.

$\text{Thu.2 MA 004}$

Multistage robustness

Organizer/Chair Ulf Lorentz, Technische Universität Darmstadt - Invited Session

Jan Weit, Technische Universität Darmstadt (with Ulf Lorentz)

Accelerating nested Benders decomposition with game-tree search techniques to solve quantified linear programs

Quantified linear programs (QLPs) are linear programs with variables being either existentially or universally quantified. The problem is similar to two-person zero-sum games with perfect information, like, e.g., chess, where an existential and a universal player have to play against each other. At the same time, a QLP is a variant of a linear program with a polyhedral solution space. On the one hand it has strong similarities to multi-stage stochastic linear programs with variable right-hand side. On the other hand it is a special case of a multi-stage robust optimization problem where the variables that are affected by uncertainties are assumed to be fixed. In this paper we show how the problem’s ambiguity of being a two-person zero-sum game, and simultaneously being a convex multi-stage decision problem, can be used to combine linear programming techniques with solution techniques from game theory. Therefore, we propose an extension of the Nested Benders Decomposition algorithm with two techniques that are successfully used in game-tree search – the $\varepsilon$-heuristic and move-ordering.

Kai Habermann, TU Darmstadt (with Stefan Ulbrich)

Robust design of active trusses via mixed integer nonlinear semidefinite programming

This work is an extension of Ben-Tal and Nemirovski’s approach on robust truss topology design to active trusses. Active trusses may use active components (e.g., piezo-actuators) to react on uncertain loads. The aim is to find a load-carrying structure with minimal worst-case compliance, when actuators may be used to react on uncertain loadings. This problem leads to a min-max-min formulation.

The approach is based on a semidefinite program formulation, which is a well-known optimization approach for robust truss topology design. By introducing actors into the model, it becomes a nonlinear semidefinite program with binary variables. We use a sequential semidefinite programming approach within a branch-and-bound framework to solve these problems.

Different uncertainty sets are analyzed for the robust optimization approach – mainly polyhedral and ellipsoidal uncertainty sets. These different approaches have their specific advantages and disadvantages. A combined approach seems to be the best way to deal with active elements in robust truss topology design. Several solution methods (e.g., Cascading techniques, projection approaches) and numerical results will be presented.

Marc Goerigk, Universität Göttingen (with Emilio Carrizosa, Anita Schöbel)

A geometric approach to recovery robustness

Finding robust solutions of an optimization problem is an important issue in practice, as solutions to optimization problems may become infeasible if the exact model parameters are not known exactly. Roughly speaking, the goal in robust optimization is to find solutions which are still valid if the input data changes, thus increasing the practical applicability of optimization algorithms in real-world problems.

Various concepts on how to define robustness have been suggested. A recent model follows the idea of recovery robustness. Here, one looks for a first-stage solution which is recoverable to a feasible one for any possible scenario in the second stage. Unfortunately, finding recovery robust solutions is in many cases computationally hard.

In this talk we propose the concept of “recovery to feasibility”, a variation of recovery robustness based on geometric ideas, that is applicable for a wide range of problems. In particular, an optimal solution can be determined efficiently for linear programming problems and problems with quasi-convex constraints for different types of uncertainties. For more complex settings reduction approaches are proposed.

$\text{Thu.2 H 1028}$

Nonconvex sparse optimization

Organizer/Chair Wenbo Yin, Rice University - Invited Session

Zaixun Wen, Shanghai Jiaotong University

Alternating direction augmented Lagrangian methods for a few nonconvex problems

Recently, the alternating direction augmented Lagrangian methods
(ADM) have been widely used in convex optimization. In this talk, we show that ADM can also be quite efficient for solving nonconvex problems such as phase retrieval problem in X-ray diffractive imaging and an integer programming problem in portfolio optimization.

Francesco Solombrino, RICAM (with Massimo Fornasier)

**Linearily constrained nonsmooth and nonconvex minimization**

Motivated by variational models in continuum mechanics, we introduce a novel algorithm for performing nonsmooth and nonconvex minimizations with linear constraints. We show how to construct an algorithm that is actually a natural generalization of well-known non-stationary augmented Lagrangian methods for convex optimization. The relevant features of this approach are its applicability to a large variety of nonsmooth and nonconvex objective functions, its guaranteed global convergence to critical points of the objective function, and its simplicity of implementation. In fact, the algorithm results in a nested double loop iteration, where in the inner loop an augmented Lagrangian algorithm performs an adaptive finite number of iterations on a fixed quadratic and strictly convex perturbation of the objective function, while the external loop performs an adaptation of the quadratic perturbation. To show the versatility of this new algorithm, we exemplify how it can be easily used for computing critical points in inverse free-discontinuity variational models, such as the Mumford-Shah functional, and, by doing so, we also derive and analyze new iterative thresholding algorithms.

Ming-Jun Lai, University of Georgia (with Louis Yang)

**On the Schatten p-quasi-norm minimization for low rank matrix recovery**

We provide a sufficient condition to show when the Schatten p-quasi-norm minimization can be used for matrix completion to recover the rank minimal matrix. The condition is given in terms of the restricted isometry property in the matrix version. More precisely, when the restricted isometry constant \( \delta_p \leq \frac{1}{1 - \rho} \), there exists a real number \( p_0 < 1 \) such that any solution of the \( \ell_p \) minimization is the minimal rank solution for \( p \leq p_0 \).

Thu.2 MA 144

**Two-stage stochastic programming and beyond**

Organizers: Rüdiger Schultz, University of Duisburg-Essen - Invited Session

Dimitri Drapkin, University of Duisburg-Essen (with Rüdiger Schultz)

**Decomposition methods for optimization problems with stochastic order constraints induced by linear recourse**

We develop linear programming equivalents for two-stage stochastic optimization models with linear recourse and dominance constraints of first and second order. In the favourable case, where only continuous variables are present in the second stage, cutting-plane decomposition algorithms are proposed and discussed along with the computational results.

Charlotte Henkel, University of Duisburg-Essen (with Rüdiger Schultz)

**Some remarks on linear stochastic bilevel programs**

Compared to linear stochastic two-stage programs, linear stochastic bilevel problems (LSBP) exhibit a strongly increased complexity. Starting from a deterministic linear bilevel problem, we derive structural properties for LSBPs using state-of-the-art parametric optimization techniques. As an outcome, we obtain rather weak analytical results. This significantly affects risk measures and solution algorithms for this kind of problem. We emphasize our results by instructive examples.

Nadine Wollenberg, University of Duisburg-Essen (with Uwe Clausen, Rüdiger Schultz, Sascha Wahlgemuth)

**Stochastic vehicle routing in forwarding agencies**

The performance of forwarding agencies handling less-than-truckload freight is mainly influenced by uncertainty in terms of customer demand and travel times. In the talk we discuss two-stage stochastic integer programs with different objective functions such as minimizing the total travel time or minimizing the number of vehicles used for a feasible routing. For the ranking of the resulting stochastic cost profiles we employ different stochastic quality measures leading to risk neutral models and those quantifying some aversion against risk. Algorithmically we rely on scenario decomposition achieved by Lagrangean relaxation of nonanticipativity. Some first computational experiments with realistic problem instances relevant for forwarding agencies in the Ruhr Area are presented.

Thu.2 MA 144

**Large-scale and multi-stage stochastic optimization**

Chair: Alos Pichler, University of Vienna

Anna Timorina, University of Vienna

**Multi-stage stochastic optimisation and approximations with applications**

Multi-stage stochastic optimization problems play a very important role in management of financial portfolios, energy production, insurance portfolios etc. The exact analytical solution for such problems can be found only in very exceptional cases and the necessity of an approximation arises of mediatey. The aim of this research is to study the approximation of the stochastic process by the probability valued finite tree. We use the concept of nested distribution to describe the information structure keeping the setup purely distributional and the concept of nested distance to measure the distance between nested distributions and to quantify the quality of approximation. We introduce the algorithm for calculating the nested distance between tree and stochastic process given by its distribution. Minimization of this distance can lead to the new method for generating values from some specific distribution along with Monte Carlo generating and optimal Quantization. The main advantage of this algorithm is that it takes into account distributions at each stage, that allows to approximate a large class of processes.

Jose Nino-Mora, Carlos III University of Madrid (Q-2181029-G)

**Sufficient indexability conditions for real-state restless bandit projects via infinite-dimensional LP-based partial conservation laws**

The multiarmed restless bandit (RB) problem concerns the optimal dynamic allocation of a shared resource to multiple stochastic projects, modeled as RBs, i.e., binary-action (active/passive) Markov decision processes. Although the problem is generally intractable, a unified approach to construct heuristic policies based on the Whittle priority index, or extensions thereof, has been shown to perform well in a variety of models. Deploying such an approach requires to establish the indexability, i.e., existence of the index) for the constituent RBs, and to evaluate the index numerically. This work presents the first general sufficient conditions for indexability of real-state RBs, motivated by applications that have drawn recent research attention. The conditions are based on an infinite-dimensional LP extension of partial conservation laws, an approach formerly introduced by the author to provide sufficient indexability conditions for discrete-state RBs. The approach further provides a practical means to evaluate the index. Applications will be discussed.

Alos Pichler, University of Vienna

**Approximation of stochastic processes**

We deal with extremely large scale and high dimensional optimization, where managerial decisions are allowed at consecutive instants of time with uncertainties reflecting future states of the world, are considered random. It is well known how to deal with these types of stochastic optimization problems with an expectation in the objective, but we want to additionally address risk. The newly introduced notion of a process distance (PfLug) allows quantifying approximations. We address approximations, which allow reasonable computation times and give viable bounds in comparison to the original problem. The results are general enough to involve risk measures, which (historically) appeared first in finance and insurance. Finally the approximating processes can be improved by different means to improve their approximating quality.

Thu.2 MA 3002

**Network clustering**

Organizers/Chair: Sergiy Butenko, Texas A&M University - Invited Session

Michael Ouellette, University of Maryland (with Andreas Geyer-Schulz)

**Ensemble learning for combinatorial optimization: Modularity maximization and beyond**

Modularity maximization is the NP-hard problem of identifying a graph partition with a maximal value of the quality measure modularity. Modularity maximization is a well-studied problem in the area of community detection in networks and attracted much attention in computer science as well as physics. A vast number of algorithms have been proposed for this problem. The core groups graph clustering (CGGC) scheme is an ensemble learning clustering method with very high optimization quality. This method combines the local solutions of several base algorithms to form a good start solution (core groups) for the final algorithm. Especially iteratively finding good restart points showed to result in very good optimization quality. We will draw an analogy between the discrete problem of modularity maximization with nonlinear optimization in finite dimensions. We will show that core groups
are the discrete counter-parts of saddle-points and that they constitute good restart points for greedy algorithms. While we developed the CGSC scheme for graph clustering, we believe this optimization scheme can be applied to many other combinatorial optimization problems as well.

Andrea Schum, KarlTrobe Institute of Technology (with Robert Görke, Dorothea Wagner)

Experiments on density-constrained graph clustering

Clustering a graph means identifying internally dense subgraphs which are only sparsely interconnected. Formalizations of this notion lead to measures that quantify the quality of a clustering and to algorithms that actually find clusterings. Since, most generally, corresponding optimization problems are hard, heuristic clustering algorithms are used in practice, or other approaches which are not based on an objective function. In this work we conduct a comprehensive experimental evaluation of the quality of various heuristic algorithms. Our focus is on graph-based applications with the objective of greedy bottom-up heuristics driven by cut-based objectives and constrained by intracluster density, using both real-world data and artificial instances. Our study documents that a greedy strategy based on local-moving is superior to one based on merging. We further reveal that the former approach generally outperforms alternative setup and reference algorithms from the literature in terms of its own objective, while a modularity-based algorithm performs surprisingly well. Finally, we exhibit which combinations of cut-based inter- and intracluster measures are suitable for identifying a hidden reference clustering in synthetic random graphs.

Cong Sun, Academy of Mathematics and Systems Science, Chinese Academy of Sciences

Low complexity interference alignment algorithms for desired signal power maximization problem of MIMO channels

The Interference alignment technique is newly brought into wireless communication to solve the interference signal power maximization problem, which is a nonconvex complex matrix optimization problem. First we use a curtien penalty function technique to combine the objective function as desired signal power with the interference constraint, leaving only the orthogonal constraints. By introducing the Householder transformation, the matrix problem turns into vector optimization problem. Applying the alternating direction method and the two-dimensional subspace method, the computational complexity of the algorithm is greatly reduced. To overcome the disadvantage of this algorithm to converge slowly around the local optimal solution, it is combined with a higher complexity algorithm which helps to perfectly eliminate interference and satisfy the original constraints. Simulations show that compared to the existed algorithms, the hybrid algorithm needs less computing time and achieves good performance.

Alvârdo Franco, Instituto de Matemática e Estatística - Universidade de São Paulo (with Carlos Ferreira)

A new linear time algorithm to construct dominator trees of reducible flow graphs

A flow graph $G = (V,E,r)$ is a directed graph, where $r$ is a vertex in $G$ that reaches any vertex $v$ in $G$. A vertex $w$ dominates vertex $v$ if any path from $v$ to $v$ passes through $w$. A vertex $w$ is the immediate dominator of $v$ if it dominates $v$ and any dominator of $v$ dominates $w$. It is well known that for each vertex $v \neq r$ there is a single vertex $w$ that dominates immediately $v$. The graph $G = (V,E')$, where $E' = \{(i,v) : v \in V \setminus \{r\}\}$ is a rooted tree (root in $r$) called dominator tree of $G$. Sophisticated algorithms have been proposed to construct a dominator tree of a flow graph (e.g., Georgiadis and Tarjan, 2004). Even if the flow graph is reducible the algorithms existing are hard to implement (e.g., the linear implementation of Ramalingam and Reps algorithm, 1994). We develop a linear time algorithm to construct a dominator tree of $G$ (reducible). It uses simpler data structures to determine whether there are internally vertex-disjoint paths from $r$ to $w$ and from $r$ to $v$, for all pairs of vertices $u,v$ in $G$, and to answer lowest common ancestor queries in a depth-first spanning tree of $G$.

Elena Fernandez, Technical University of Catalonia (with Carlos Luna Mota, Gerhard Reinelt)

A compact formulation for the optimum communication spanning tree problem

The optimum communication spanning tree problem (OCSTP) is a difficult combinatorial optimization problem with multiple applications in telecommunications and transportation. In the OCSTP, the communication requirements $n_e$ exist between pairs of nodes, and the communication cost between $i,j$, over a given spanning tree $T$, depends on $n_e$ and on the distance on $T$ between $i$ and $j$. Looking for a balance between construction and communication costs, the objective in the OCST is to find a spanning tree of minimum total communication cost. We present a formulation with two index decision variables, which models any partial order as a rooted tree. We further specialize the above formulation to model the OCSTP, by incorporating additional decision variables to represent the distance on the tree between pairs of nodes. We discuss some properties and improvements of the formulation, which is compared with a classical formulation with four index variables. Some numerical computational results are presented and analyzed.

Peter Olver Lindberg, KTH Royal Inst. Technology (with Johan Holmström)

Updating shortest path subproblem solutions in large scale optimization

In many large scale optimization applications, one repetitively solves shortest path (SP) subproblems, with slowly varying and possibly convex problem characteristics. It’s worthwhile to update the subproblem solutions, rather than solving from scratch. In this paper we describe simplex-like updating of the SP trees, using thread labels. We suggest three improvements to the standard approach: 1. Thread following link scan, 2. bucketed link scan, and 3. acyclic thread

In thread following link scan, we only need a single traversal of the thread to find all entering links. In the bucketed link scan, we do partial pricing. Instead of scanning all arcs, we keep and update a “bucket” of promising links. This gives suboptimal subproblem solutions, but speeds up the convergence. Every now and then, we do a complete scan, and then add and delete links to/from the buckets. In acyclic thread, the thread is modified to scan an acyclic graph, i.e., the graph of bucket links. The acyclic thread scans the nodes in the graph-induced order, and does not need to be updated, unless new arcs are added. We will present computational results for small to large scale traffic assignment problems.

Thu.2 3559

Paths, trees and flows

Chair Álvaro Franco, Instituto de Matemática e Estatística - Universidade de São Paulo

Álvaro Franco, Instituto de Matemática e Estatística - Universidade de São Paulo (with Carlos Ferreira)

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A Mumford-Shah type approach for tomography data

We present a Mumford-Shah-type approach for the simultaneous reconstruction and segmentation of a function from its tomography data (Radon transform). The sought-after function is modeled as a piecewise-constant image, and studied this subject systematically from various viewpoints. By using some tools from Variational Analysis, this paper investigates the stability of the solution set with respect to the perturbations of all the components of its data set \( \{A, b, c\} \).

Esther Kanne, University of Linz

A Mumford-Shah type approach for tomography data

We present a Mumford-Shah-type approach for the simultaneous reconstruction and segmentation of a function from its tomography data (Radon transform). We connect the levelsets of the minimizers \( a_j \) of the predictive ability and the choice of the regularization parameter are discussed and illustrated by simulated and real data examples.

Christiane Pöschl, Alpen-Adria Universität Klagenfurt (with Vicent Caselles, Matteo Novaga)

Approximation & online algorithms

A polylogarithmic-competitive algorithm for the \( k \)-server problem

In this talk, we will consider one of the fundamental problems in online optimization: the \( k \)-server problem. This problem captures many online scenarios – in particular, the widely studied caching problem – and is considered by many to be the “holy grail” problem of the field.

Alekseandr Madry, EPFL (with Nikhil Bansal, Naor Buchbinder, Joseph Nair)

Online mixed packing and covering

In many problems, the inputs arrive over time, and must be dealt with irrevocably when they arrive. Such problems are called online problems. A common method of solving online problems is to first solve the corresponding linear program online, and then round the fractional solution obtained. We give algorithms for solving mixed packing and covering linear programs, when the covering constraints arrive online. No prior sublinear competitive algorithms are known for this problem. We give the first such – a polylogarithmic-competitive algorithm for mixed packing and covering online. We also show a nearly tight lower bound.

Umang Bhaskar, Dartmouth College (with Lisa Fleischer)

Simultaneous adversarial and stochastic approximations for budgeted allocation problems

We study the problem of simultaneous approximations for the adversarial and stochastic online budgeted allocation problem. Consider a bipartite graph \( G = (X, Y, E) \). When a node of \( X \) arrives online, the algorithm can match it to a neighbor in \( Y \). The goal is to maximize the weight of the matching, while respecting the capacities. We seek algorithms that achieve very good competitive ratio on average while achieving an optimal ratio \( 1 - \frac{1}{e} \) in the worst case. For unweighted graphs, under some mild assumptions, we show an algorithm that achieves a competitive ratio of \( 1 - \epsilon \) in the random permutation model. For weighted graphs, however, we prove this is not possible; we show that no online algorithm that achieves an approximation factor of \( 1 - \frac{1}{e} \) for the worst case inputs may achieve an average approximation factor better than \( 97.6 \) for random inputs. In light of this hardness result, we aim to design algorithms with improved approximation ratios in the random arrival model while getting a \( 1 - \frac{1}{e} \) in the worst case.

Vahab Mirrokni, Google Research NTC (with Shayan Oveisgharan, Morteza Zadimoghaddam)
Optimization methods for geometric problems
Organizers/Chairs Sándor Fekete, TU Braunschweig, Alexander Kröller, TU Braunschweig - Invited Session
Dan Halperin, Tel-Aviv University
Multi-objective path optimization in motion planning: From the particular to the general
When planning collision-free paths for mobile objects (robots or other creatures) in environments cluttered with obstacles, it is often desirable to simultaneously consider several path-quality criteria. We start with a combination of criteria, which is commonplace in this setting: length and clearance. Namely, we wish that the path will be short and the moving object will be well away from the obstacles. We review several planning techniques specifically tailored to optimizing this combination. We then move on to a general optimization technique that simultaneously address a large variety of objectives and does not assume any specific path-planning approach. It is based on a simple path-hybridization method, it is easy to implement, and it has proved itself highly effective for a wide range of problems, as we shall demonstrate.

Cid de Souza, University of Campinas (with Pedro de Rezende, Davi Tozoni)
Towards solving to optimality the art gallery with point-guards problem
We present our progress towards the development of an exact and effective algorithm to solve the NP-hard art gallery problem with point-guards problem (AGPG). A set of points is said to cover a polygon \( P \) if the union of their visibility polygons is \( P \). In AGPG, one seeks a minimum-sized set of points in \( P \) that covers \( P \). Despite its theoretical complexity, we give experimental evidence that AGPG can be solved to proven optimality even for large sized instances of a thousand vertices. To this end, we developed an algorithm which iteratively produces lower and upper bounds on the number of guards needed to cover \( P \). These bounds are computed via integer programming models and rely on a theoretical result showing that for a finite set \( W \) of witnesses in \( P \) there exists an optimal solution covering \( W \) for which the guards belong to a well-defined set of points whose size is polynomial in \(|W|\). We tested this algorithm on a benchmark composed of several classes of polygons of various sizes, all of which obtained from the literature. Our algorithm solves most of these instances in only tens of minutes in a standard desktop computer.

Alexander Kröller, TU Braunschweig (with Tobias Baumgartner, Sándor Fekete, Mahdi Moeini, Christiane Schmidt)
Practical solutions and bounds for art gallery problems
The classical Art gallery problem asks for the minimum number of guards that achieve visibility coverage of a given polygon. It is known to be NP-hard, even for very restricted and discrete special cases. Even though it has been extensively studied in almost 40 years, practical algorithms to find optimal solutions or almost-optimal bounds are not known. We present a primal-dual algorithm based on mathematical programming, which provides lower bounds on the necessary number of guards, and – in case of convergence and integrality – ends with an optimal solution. It has been implemented and extensively tested on different classes of polygons; experimental results will be discussed. Additionally we show how to extend the procedure to practical applications of the Art Gallery Problem. These occur in laser scanning of buildings, but come with additional constraints – such as limited viewing range and loss in quality over distances.

Recent advances in matching algorithms
Organizer/Chair Piotr Sankowski, University of Warsaw - Invited Session
Manoj Gupta, IIT Delhi (with Surender Baswana, Sandeep Sen)
Fully dynamic maximal matching in \( O(\log n) \) update time
We present an algorithm for maintaining maximal matching in a graph under addition and deletion of edges. Our data structure is random and that it has expected amortized time \( O(\log n) \) for each update where \( n \) is the number of vertices in the graph. While there is a trivial \( O(n) \) algorithm for edge update, the previous best known result for this problem for a graph with \( n \) vertices and \( m \) edges is \( O(n + m \sqrt{n/d_{max}}) \) which is sub-linear only for a sparse graph. For the related problem of maximum matching, Onak and Rubinfeld designed a randomized structure that achieves time \( O(2\log^2 n) \) amortized time for each update for maintaining a \( c \)-approximate maximum matching for some large constant \( c \). In contrast, we can maintain a factor two approximate maximum matching in \( O(\log n) \) expected time per update as a direct corollary of the maximal matching scheme. This in turn also implies a two approximate vertex cover maintenance scheme that takes \( O(\log n) \) expected time per update.

Chien-Chung Huang, Humboldt-University (with Dokepalvi Kanth)
Efficient algorithms for maximum weight matchings in general graphs with small edge weights
Let \( G = (V, E) \) be a graph with positive integral edge weights. Our problem is to find a matching of maximum weight in \( G \). We present a simple iterative algorithm for this problem that uses a maximum cardinality matching algorithm as a subroutine. Using the current fastest maximum cardinality matching algorithms, we solve the maximum weight matching problem in \( O(\sqrt{n} \log \log (n^2/m)) \) time, or in \( O(n \log^* n) \) time with high probability, where \( n = |V|, m = |E| \). \( W \) is the largest edge weight, and \( w < 2.376 \) is the exponent of matrix multiplication. In relatively dense graphs, our algorithm performs better than all existing algorithms with \( W = o(\log^{1.5} n) \). Our technique hinges on exploiting Edmonds’ matching polytope and its dual.

Mohammad Mahdian, Google (with Jig Tig)
Online bipartite matching with random arrivals: An approach based on strongly factor-revealing LPs
Karp, Vazirani, and Vazirani show that a simple ranking algorithm achieves a competitive ratio of \( 1 - 1/e \) for the online bipartite matching problem in the standard adversarial model. Their result also implies that in the random arrivals model defined by Goel and Mehta, where the online nodes arrive in a random order, a simple greedy algorithm achieves a competitive ratio of \( 1 - 1/e \). In this paper, we study the ranking algorithm in the random arrivals model, and show that it has a competitive ratio of at least \( 0.696 \), beating the \( 1 - 1/e = 0.632 \) barrier, in the adversarial model. Our analysis has two main steps. First, we exploit properties of the ranking algorithm to derive a family of factor-revealing linear programs [LPs]. Second, to obtain a good lower bound on the optimal value of all these LPs, we simulate the performance of the algorithm, we derive a family of modified LPs such that the optimal value of any single one of these LPs is a lower bound on the competitive ratio of the algorithm. This enables us to leverage the power of computer LP solvers to solve for large instances of the new LPs to establish bounds that would otherwise be difficult to attain by human analysis.

Discrete structures and algorithms III
Organizer/Chair Satoru Fujishige, Kyoto University. Invited Session
Yusuke Kobayashi, University of Tokyo (with Xin Yin)
An algorithm for finding a maximum \( t \)-matching excluding complete partite subgraphs
For an integer \( t \) and a fixed graph \( H \), we consider the problem of finding a maximum \( t \)-matching not containing \( H \) as a subgraph, which we call the \( H \)-free \( t \)-matching problem. This problem is a generalization of the problem of finding a maximum 2-matching with no short cycles, which has been well-studied as a natural relaxation of the Hamiltonian circuit problem. When \( H \) is a complete graph \( K_{t+1} \) or a complete bipartite graph \( K_{t,t} \), in 2010, Bérczi and Végh gave a polynomial-time algorithm to a \( H \)-free \( t \)-matching problem on the competitive ratio of the maximum degree at most \( t + 1 \). Our main contribution is to extend this result to the case when \( H \) is a \( t \)-regular complete partite graph. We also show that the problem is \( NP \)-complete when \( H \) is a connected \( t \)-regular graph that is not complete partite. Since it is known that, for a connected \( t \)-regular graph \( H \), the degree sequences of all \( H \)-free \( t \)-matchings in a graph form a jump system if and only if \( H \) is a complete partite graph, our results show that the polynomial-time solvability of the \( H \)-free \( t \)-matching problem is consistent with this condition.

Shin-ichi Tanigawa, Kyoto University (with Nashi Kato)
Rooted-tree decompositions with matroid constraints and the infinitesimal rigidity of frameworks with boundaries
As an extension of classical \( t \)-partition problem, we consider decompositions of graphs into edge-disjoint rooted-trees with an additional matroid constraint. Specifically, suppose we are given a graph \( G = (V, E) \), a multiset \( R = \{r_1, \ldots, r_s\} \) of vertices in \( V \), and a matroid \( M \) on \( R \). We prove a necessary and sufficient condition for \( G \) to be decomposed into \( t \)-edge-disjoint rooted-trees as graphs \( G_t = (V_t, T_t) \) such that \{i\} for each \( i \in R \), \( G_i \) is a tree with \( r_i \in V_i \), and \{i\} for each \( i \in V \), the multiset \( \{r_i \in R \mid V_i \in M\} \) is a base of \( M \). If \( M \) is a free matroid, this is a decomposition into \( t \)-edge-disjoint spanning trees; thus, our result is a proper extension of Nash-Williams’ tree-partition theorem.

Such a matroid constraint is motivated by combinatorial rigidity theory. As a direct application of our decomposition theorem, we present characterizations of the infinitesimal rigidity of frameworks with non-generic “boundary”, which extend classical Laman’s theorem.
for generic 2-rigidity of bar-joint frameworks and Tay’s theorem for generic 4-rigidity of body-bar frameworks.

Kiyohito Nagano, University of Tokyo (with Kanyuki Ahta, Roshinoru Kawahara) 
Size-constrained submodular minimization through minimum norm basis

A number of combinatorial optimization problems in machine learning can be described as the problem of minimizing a submodular function. It is known that the unconstrained submodular minimization problem can be solved in strongly polynomial time. However, additional constraints make the problem intractable in many settings. In this paper, we discuss the submodular minimization under a size constraint, which is NP-hard, and generalizes the densest subgraph problem and the uniform graph partitioning problem. Because of NP-hardness, it is difficult to compute an optimal solution even for a prescribed size constraint.

In our approach, we do not give approximation algorithms. Instead, the proposed algorithm computes optimal solutions for some of possible size constraints in polynomial time. Our algorithm utilizes the basic polyhedral theory associated with submodular functions. Additionally, we evaluate the performance of the proposed algorithm through computational experiments.

We design a deterministic algorithm that finds a universal scheduling sequence with a solution value within four times the value of an optimal clairvoyant algorithm that knows the machine behavior in advance. A randomized version of this algorithm attains in expectation a ratio of $e$. We show that both performance guarantees are best possible for any unbounded cost function.

When jobs have individual release dates, the situation changes drastically. Even if all weights are equal, there are instances for which any universal solution is a factor of $O(n \log n / \log \log n)$ worse than an optimal sequence for any unbounded cost function. If the processing time of each job is proportional to its weight we present a non-trivial algorithm with a worst case of $5$. 

Martin Groß, TU Berlin (with Jan-Philipp Kappmeier, Daniel Schmidt, Melanie Schmidt)
Approximating earliest arrival arrival flows in arbitrary networks

The earliest arrival flow problem is motivated by evacuation planning. It consists of computing a flow over time in a network with supplies and demands, such that the satisfied demands are maximum at every point in time. For a single source and sink, the existence of such flows has been shown by Gale [1959]. For multiple sources and a single sink the existence follows from work of Minieka [1973] and an exact algorithm has been presented by Baumann and Skutella [FOCS ’06]. If multiple sinks exist, it is known that earliest arrival flows do not exist in general.

We address the open question of approximating earliest arrival flows by time or flow-value in arbitrary networks and show the first constructive results for them. We give tight bounds for the best possible approximation factor in most cases. In particular, we show that there is always a 2-flows-value approximation of earliest arrival flows and that no better approximation factor is possible in general. Furthermore, we describe an FPTAS for computing the best possible approximation factor along with the corresponding flow for any given instance (which might be better than 2).

Jan-Philipp Kappmeier, TU Berlin (with Sandro Bosio, Janik Matuschke, Britta Peis, Martin Skutella)
Flows over time with negative transit times and arc release dates

A common generalization of the classical network flow setting are network flows over time. In contrast to the classical model, here a notion of time is incorporated that represents the time needed to travel over an arc. We present two generalizations of the maximum flow over time problem, one which allows to use negative transit times on arcs, and the other with arc release dates. In contrast to the standard maximum flow over time problem, the computational tractability of either of the generalizations depends on the possibility of flow storage at intermediate nodes. Both problems can be solved in polynomial time by reduction to the quickest transshipment problem if storage at intermediate nodes is allowed. However, if storage is forbidden, both problems are weakly NP-hard. The generalizations can both be used to answer questions on a bipartite matching over time problem, which is a generalization of the classical matching problem also incorporating a notion of time.

Artur Pogosyan, Moscow State University (with Alexey Izmailov, Mikhail Solodov)
Semismooth Newton-type methods for lifted mathematical programs with complementarity constraints

We consider a reformulation of mathematical programs with complementarity constraints, where by introducing an artificial variable the constraints are converted into equalities which are once but not twice differentiable. This approach can be regarded as a development of the lifted reformulation of complementarity constraints proposed earlier by O. Stein. We show that the Lagrange optimality system of such a reformulation is semismooth and $BD$-regular at the solution under reasonable assumptions. Thus, fast local convergence can be obtained by applying the semismooth Newton method. Moreover, it turns out that the squared residual of the Lagrange system is continuously differentiable (even though the system itself is not), which opens the way for a natural globalization of the local algorithm. However, from the practical viewpoint, it seems more promising to use a non-smooth exact penalty function instead of the squared residual of the Lagrange system which leads to the semismooth sequential quadratic programming method. Preliminary numerical results for problems from MacMPEC test collection demonstrate that the approach is very promising.

Erygey Erk, Koc University (with Alexey Izmailov, Mikhail Solodov)
Global convergence of augmented Lagrangian methods applied to...
optimization problems with degenerate constraints, including problems with complementarity constraints

We consider global convergence properties of the augmented Lagrangian methods on problems with degenerate constraints, with a special emphasis on mathematical programs with complementarity constraints (MPCCs). In the general case, we show convergence to stationarity points of the problem under an error bound condition for the feasible set (which is weaker than constraint qualifications), assuming that the iterates have some modest features of approximate local minimizers of the augmented Lagrangian. For MPCCs, we obtain a rather complete picture, showing that under the usual in this context MPCC-linear independence constraint qualification accumulation points of the iterates are C-stationary for MPCCs (better than weakly stationary), but in general need not be M-stationary (hence, neither strongly stationary). Numerical results demonstrate that in terms of robustness and quality of the outcome augmented Lagrangian methods are absolutely competitive with the best existing alternatives and hence, they can serve as a promising global strategy for problems with degenerate constraints.

Walter Morari, George Mason University

Efficient computation of a canonical form for a generalized P-matrix

We use recent results on algorithms for Markov decision problems to show that a canonical form for a generalized P-matrix can be computed, in some important cases, by a strongly polynomial algorithm.

Senshan Ji, The Chinese University of Hong Kong (with Anthony Man-Cho So)

Approximating a KKT point of Schatten p-quasi-norm minimization in polynomial time, with applications to sensor network localization

In this talk, we consider the Schatten p-quasi norm minimization problem, which has previously found applications in compressed sensing and matrix completion. We propose a potential reduction algorithm for this problem, which has previously found applications in compressed sensing and matrix completion. We show that our algorithm is a fully polynomial-time approximation scheme, taking no more than polynomial time, with applications to sensor network localization.

Yang Yang, The Hong Kong University of Science and Technology (with Daniel Palomar, Francisco Rubio, Muddapaka Gowda, University of Maryland, Baltimore County)

On the nonhomogeneity and the bi-linearity rank of a completely positive cone

Given a closed cone C in \( R^n \), the completely positive cone of C is the convex cone \( K \) generated by matrices of the form \( \omega A \) as \( \omega \) varies over C. Examples of completely positive cones include the positive semidefinite cone (when \( C = R^n \)) and the cone of completely positive matrices (when \( C = R \)). Completely positive cones arise, for example, in the reformulation of a nonconvex quadratic minimization problem over an arbitrary set with linear and binary constraints as a conic linear program. This talk deals with the questions of when (or whether) \( K \) is self-dual, irreducible, and/or homogeneous. We also describe the bi-linearity rank of \( K \) in terms of that of C.

Muddapaka Gowda, The University of Electro-Communications

Conic optimization and signal processing applications

Senshan Ji, The Chinese University of Hong Kong (with Anthony Man-Cho So)

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Muddapaka Gowda, The University of Electro-Communications

A perturbed sums of squares theorem for polynomial optimization and its applications

We prove a property of positive polynomials on a compact set with a smooth perturbation. When applied to a POP (polynomial optimization problem), it says that the optimal value of the corresponding SDP relaxation with sufficiently large order is bounded below by \( \lambda^* - \varepsilon \) and above by \( \lambda^* + \varepsilon(n + 1) \), where \( \lambda^* \) is the optimal value of the POP, \( n \) is the number of variables, and \( \varepsilon \) is the perturbation. In addition to extending this property to some directions, we propose a new sparse SDP relaxation based on it. In this relaxation, we optimally exploit the numerical errors naturally introduced by numerical computation. An advantage of our SDP relaxation is that they are of considerably smaller dimension than Lasserre’s, and in many situations is much smaller than the sparse SDP relaxation proposed by Waki et al. We present some applications and the results of our computational experiments.

Farid Alizadeh, Rutgers University

Some geometric applications of abstract algebraic sum-of-squares cones

We have established that sum-of-squares (SOS) cones in abstract algebras are semidefinite representable. By combining this fact and the classical theorem of Youla, it can be shown that a wide variety of cones are in fact SOS with respect to some algebra, and thus SDP representable. We review some applications of such cones in geometric optimization. We examine the minimum volume ellipsoid, the minimum volume rectangular box, the minimum volume simplex, etc., containing a space curve. We also examine the diameter of a space curve, distance of a point to a space curve, and possible optimization problems with constraints on such parameters. For instance we examine design of a space curve with constraints on its curvature. We will also comment on similar problem for higher dimensional surfaces.

José Mario Martínez, University of Campinas (with Luís Felipe Bueno, Ana Friedlander, Francisco Sobral)

The mesh adaptive direct search (MADS) class of algorithms is designed for blackbox optimization where the objective function and constraints are typically computed by launching a time-consuming computer simulation. The core of each iteration of the algorithm consists of launching the simulation at a finite number of trial points. These candidates are constructed from MADS directions. The current and efficient implementation of MADS uses 2n directions at each iteration, where \( n \) is the number of variables. The scope of the present work is the reduction of that number to a minimal possible spanning set of \( n + 1 \) directions. This transformation is generic and can be applied to any method that generates more than \( n + 1 \) MADS directions.

José Mario Martínez, University of Campinas (with Luis Felipe Bueno, Ana Friedlander, Francisco Sobral)

Inexact restoration method for derivative-free optimization with smooth constraints

A new method is introduced for solving constrained optimization problems in which the derivatives of the constraints are available but the derivatives of the objective function are not. The method is based
Modern portfolio optimization
Chair Elgius Hendrix, Málaga University
Süleyman Özbekci, Koç University (with Turan Bulmus)

Portfolios with hyperexponential utility functions
We analyze a single-period portfolio selection problem where the investor maximizes the expected utility of the terminal wealth. The utility function is hyperexponential. This is due to the fact that the risk tolerance of the investor at the end of the period when the terminal wealth is realized depends on the random state of the market at that time. This setting is also applicable in cases where an investment consultant is not sure about the risk profile of a client. It is well-known that an investor is memoryless in wealth for exponential utility functions with some known risk tolerance. In other words, the investment portfolio consisting of risky stocks does not depend on the level of wealth. However, we show that this is no longer true if the utility function is hyperexponential. We also obtain a number of interesting characterizations on the structure of the optimal policy.

Elgius Hendrix, Málaga University (with Lecocadio Casado, Juan Francisco Herrera, Michiel Janssen)

On finding optimal portfolios with risky assets
Since the introductory work of Markowitz, the questions of finding optimal portfolios in order to maximize return and minimize risk, have been made explicit in terms of optimization models. As long as returns are described by normal distributions, analytical expressions can be derived for finding optimal portfolio weights. The optimal mix is more difficult to find when we are dealing with so-called fat tails. This means that probabilities on extreme outcomes are typically higher than in the normal distribution, thus providing a challenge for the composition of low risk portfolios. To do so is to combine simulation of rare events with optimization tools. In this context, a specific weight adjusting algorithm is described and compared to the use of standard nonlinear optimization solving an equivalent problem.

Elgius Hendrix, Málaga University (with Leoncio Casado, Juan Francisco Herrera, Michiel Janssen)

Optimal hedging of foreign exchange risk in uncertain cash flows using stochastic programming
We build a stochastic programming framework for optimal hedging of foreign exchange risk in uncertain cash flows. By incorporating term premia we are able to estimate the cost of hedging, and we determine the optimal hedge by minimizing a convex combination of risk (measured as CVaR) and cost. The importance of expected returns for the optimal hedge is verified through numerical results. In this framework, trades are made at market prices and transaction costs are included. The framework offers great flexibility regarding distributional assumptions of the underlying risk factors and the types of financial instruments which can be included.

Rohollah Garmanjani, University of Coimbra (with Luis Nunes Vicente)

Smoothing and worst case complexity for direct-search methods in non-smooth optimization
For smooth objective functions it has been shown that the worst case cost of direct-search methods is of the same order as the one for steepest descent. Motivated by the lack of such a result in the non-smooth case, we propose, analyze, and test a class of smoothing direct-search methods for the optimization of non-smooth functions. Given a parameterized family of smoothing functions for the non-smooth objective function, this class of methods consists of applying a direct search for a fixed value of the smoothing parameter until the step size is relatively small, after which the smoothing parameter is reduced and the process is repeated. One can show that the worst case complexity (or cost of this procedure is roughly one order of magnitude worse than the one for direct search or steepest descent on smooth functions. The class of smoothing direct-search methods is also showed to enjoy asymptotic global convergence properties. Numerical experience indicates that this approach leads to better values of the objective function, apparently without an additional cost in the number of function evaluations.

Thur.3.H 3021
Finance & economics
Modern portfolio optimization
Chair: Elgius Hendrix, Málaga University
Süleyman Özbekci, Koç University (with Turan Bulmus)

Portfolios with hyperexponential utility functions
We analyze a single-period portfolio selection problem where the investor maximizes the expected utility of the terminal wealth. The utility function is hyperexponential. This is due to the fact that the risk tolerance of the investor at the end of the period when the terminal wealth is realized depends on the random state of the market at that time. This setting is also applicable in cases where an investment consultant is not sure about the risk profile of a client. It is well-known that an investor is memoryless in wealth for exponential utility functions with some known risk tolerance. In other words, the investment portfolio consisting of risky stocks does not depend on the level of wealth. However, we show that this is no longer true if the utility function is hyperexponential. We also obtain a number of interesting characterizations on the structure of the optimal policy.

Elgius Hendrix, Málaga University (with Lecocadio Casado, Juan Francisco Herrera, Michiel Janssen)

On finding optimal portfolios with risky assets
Since the introductory work of Markowitz, the questions of finding optimal portfolios in order to maximize return and minimize risk, have been made explicit in terms of optimization models. As long as returns are described by normal distributions, analytical expressions can be derived for finding optimal portfolio weights. The optimal mix is more difficult to find when we are dealing with so-called fat tails. This means that probabilities on extreme outcomes are typically higher than in the normal distribution, thus providing a challenge for the composition of low risk portfolios. To do so is to combine simulation of rare events with optimization tools. In this context, a specific weight adjusting algorithm is described and compared to the use of standard nonlinear optimization solving an equivalent problem.

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Elgius Hendrix, Málaga University (with Leoncio Casado, Juan Francisco Herrera, Michiel Janssen)
Software piracy and price determination

We consider a monopolistic producer offering software that is updated periodically but, by the end of one period, a pirated version is available at a transaction cost. This presents the heterogeneous consumer with possible strategies for either buying a new product or pirating it. We address pricing and protection investment strategies to regain the profits affected by the piracy. In particular, we find that even when the transaction cost is exogenous, the producer does not necessarily want to fully price out the piracy. The decisive factor in such a case is the level of product newness relative to the transaction cost. If the producer is able to achieve high newness for the updated product relative to the transaction cost, then a high retail price ensures that he will gain the largest profit possible even though some of the demand will be lost due to piracy. On the other hand, when the transaction cost is endogenous, the producer may have two alternatives: pricing the software out or investing heavily in software protection. As newness levels rise, the option of pricing out the piracy becomes increasingly preferable.

Camila Winzen, Max-Planck-Institut für Informatik (with Benjamin Doerr, Reto Spohel, Rennling Thomas)

Playing mastermind with many colors

We consider the black–peg version of Mastermind with $n$ holes and $k \leq n$ colors. For the most interesting case $k = n$, by combining previous approaches of Chvátal [Combinatorica 3 (1983), 325–329] and Goodrich, Information Processing Letters 109 (2009), 675–678, we show that there exists a deterministic winning strategy that allows the codebreaker to find the secret code with $O(n \log^{1/2} n)$ guesses. This improves the previously best known bounds of Chvátal, Goodrich, and others, which are all of order $n \log n$: both for the black–peg version of Mastermind and the original game with both black and white answer pegs. More generally, one of the key arguments, the success probability of random sampling, can be applied to the Mastermind game with any number $k \leq n$ of colors, and it yields a winning strategy using $O(n \log k / \log(n/k))$ guesses.

Christian Valente, OptiRisk Systems (with Gautam Mitra, Victor Zverovich)

Optimization under uncertainty: Software tools for modelling and solver support

Algebraic modelling languages are now well established as a formulation tool used by practitioners and academics in the field of operational research. We describe an integrated modelling and solver platform for investigating stochastic and robust optimisation models. We consider the following well known approaches: stochastic programming (SP) with recourse, chance constrained programming, integrated chance constrained programming, and robust optimisation.

In an earlier work Valente et al. introduced Stochastic extensions of AMPL called SAMPL. The extended language constructs are used to represent two- and multi-stage SP problems. In this paper we describe a set of extensions to SAMPL for representing robust optimisation problems and the additional classes of SP problems listed above. We not only describe syntax and semantics of the extensions but also discuss solver requirements, reformulation techniques and connection between the modelling system and external solvers. In particular, we show that direct representation of some of the modelling constructs not only makes the models easier to understand but also facilitates the use of specialised solution algorithms.

Vincent Bardadie, IBM Industry Solution (with Ferenc Kata, Arnaud Scholz)

Modeling best practices: How to write good optimization models efficiently thanks to IBM ILOG CPLEX Optimization Studio’s Integrated Development Environment (IDE) and its debugging support

A good optimization model has to execute fast, but also it has to be scalable to adapt to changes in data and/or constraints. Therefore at development time, debugging support is a crucial factor to deliver scalable optimization models into solutions. This interactive demo will show the debugging capabilities to deal with optimization model testing in IBM ILOG CPLEX Optimization Studio. The talk will consist in a showcase on an application developed by IBM. It will describe in fair amount of details how OPL language and its IDE helps its users to detect memory and time bottlenecks in an optimization model. It will show how OPL provides its users introduction of debugging mechanices to detect issues early on, to avoid them, and eventually to eliminate errors as soon as possible in the development process. We will also discuss how the OPL language and Studio ensure quality throughout the entire application life-cycle, from design to deployment.
In particular, we lay focus on two special kinds of heuristics, namely large neighborhood search and diving heuristics. The former explore a MIP neighborhood of one or more given feasible (or at least LP feasible) solutions. The latter perform a depth-first search on the branch-and-bound tree, where they may branch either on the original variables or the master variables. We will investigate the impact of these heuristics and give a comparison to classical heuristic approaches.

Primal heuristics for branch-and-price
Primal heuristics have become an essential component in mixed integer programming (MIP). Generic heuristic paradigms of the literature remain to be extended to the context of a column generation solution approach. As the column generation formulation is typically tighter than the original compact formulation, techniques based on rounding its linear programming solution have better chance to yield good primal solutions. However, the dynamic generation of variables requires specific adaptation of heuristic paradigms. We develop diving methods and consider their combination with sub-MIPing, relaxation induced neighborhood search, truncated backtracking using a Limited Discrepancy Search, and feasibility pump. These add-ons serve as local-search or diversification/intensification mechanisms.

Christian Puchert, RWTH Aachen University (with Marco Lübbecke)

Branch-and-price IV: Primal heuristics
Chair Timo Berthold, ZIB / Matheon

In many MIP applications, a problem with a particular structure is to be solved. For those problems, the branch-and-price scheme using the column generation procedure has proven to be a successful approach, which relies on the Dantzig-Wolfe decomposition.

The performance of this scheme may be improved by supplying it with additional features such as primal heuristics. We present heuristics that are specially tailored for Column Generation and exploit a given problem structure, but are still generic in that they are not restricted to any particular problem.

Nam Dung Hoang, Vietnam National University Hanoi (with Thorsten Koch)

Steiner tree packing revisited
The Steiner tree packing problem (STPP) in graphs is a long studied problem in combinatorial optimization. In contrast to many other problems, where there have been tremendous advances in practical problem solving, STPP remains very difficult. Most heuristics schemes are ineffective and even finding feasible solutions is already NP-hard. What makes this problem special is that in order to reach the overall optimal solution non-optimal solutions to the underlying NP-hard Steiner tree problems must be used. Any non-global approach to the STPP is likely to fail. Integer programming is currently the best approach for computing optimal solutions. In this talk we review some classical STPP algorithms.
instances which model the underlying real world application only in a reduced form. Through improved modelling, including some new cutting planes, and by employing recent advances in solver technology we are for the first time able to solve those instances in the original 3D grid graphs to optimality.

**Mathematical modeling of disease**

Chair: Rujira Ouncharoen, Chiang Mai University (with Thongchai Dumrongpokaphan, Siriwan Intawichai)

**Logistics and transportation**

Chair: Kaj Holmberg, Linköping University

**Fleet deployment optimization model for tramp and liner shipping**

We present a generic mixed integer mathematical programming model to tackle operational and tactical planning problems faced by liner and tramp shipping companies in maritime logistics. The liner shipping company’s pickup and deliveries to the ports and the liner company’s truck routes need to be planned. To this end, we model the planning problem as a problem of minimizing the total transportation cost. The problem is modeled as a Mixed Integer Programming (MIP) model, and the solution is obtained using a commercial MIP solver. The model is applied to a real-world case study, and the results are compared with the current operational practices of the company. The results show that the model is able to significantly reduce the transportation cost and improve the service quality.

**Prize-Collecting Steiner forest (PCSF), and more generally Submodular Prize-Collecting Steiner forest (SPCSF), on planar graphs (and on bounded-genus graphs) to the corresponding problems on graphs of bounded treewidth.**

**Prize-Collecting Steiner network problems on planar graphs**

In this paper, we reduce Prize-Collecting Steiner TSP (PC-TSP), Prize-Collecting Steiner forest (PCSF), and Prize-Collecting Steiner Tree (PCST) to the corresponding problems on graphs of bounded treewidth. More precisely, for each of the mentioned problems, an $\alpha$-approximation algorithm for the problem on graphs of bounded treewidth implies an $(\alpha + \epsilon)$-approximation algorithm for the problem on planar graphs of bounded genus, for any constant $\epsilon > 0$. PCS, PC-TSP, and PCST can be solved exactly on graphs of bounded treewidth and hence we obtain a PTAS for these problems on planar and bounded-genus graphs. In contrast, we show that PC-TSP is APX-hard on series-parallel graphs, which are planar graphs of treewidth at most 2. Besides ruling out a PTAS for PCSF on planar graphs and bounded-treewidth graphs, this result is also interesting since it gives the first provable hardness separation between the approximability of a problem and its prize-collecting version. We show similar hardness for Euclidean PCSF.

**Mathematical modeling of amylodin isolation from plum kernel using response surface methodology**

Amylodin belongs to the group of anticancer agents. It has a high application in treatment of cancer, because of its selective impact on the normal and cancerous cells. The aim of this study was to develop and optimize the isolation process of amyloidin from plum kernel (Nucleus Prunus Domestica) using a response surface methodology. The time of extraction, ethanol concentration, the ratio of plant material to solvent and temperature were used as independent variables, while the yield of amyloidin as dependent variable for central composite design. The second order polynomial model was successfully applied for mathematical modeling of this process. A correlation coefficient of 0.7748 indicates a good fitting of observed with predicted data. By desirability function, the extraction process was optimized. The optimal amyloidin yield of 15.83 g/100 g d.e. was achieved after 120 min using 20% ethanol at the solvomodule temperature of 78°C.

**Stability of HIV aphaeresis model**

The new approach in treating the human immunodeficiency virus (HIV) infection is apheresis. It is a method of collecting large quantities of blood components that can safely be collected through a simple blood draw. In this paper, we investigate the effect of HIV apheresis in a model of HIV infection. Sufficient conditions are given to ensure that the endemic equilibrium point is stable which means that the viral load is under control.
Mixed-integral nonlinear programming
Organizer/Chair Jon Lee, University of Michigan - Invited Session

Shmuel Onn, Technion - Israel Institute of Technology
Integer programming in polynomial time via Graver bases
I will overview our algorithmic theory which uses Graver bases to solve linear and nonlinear integer programming problems in variable dimension in polynomial time. I will demonstrate the power of this theory by describing some of its many applications including to multiway statistical table problems, multidmodity flows and stochastic integer programming, and will show that this theory is universal and provides a new parametrization of all integer programming. I will also mention a very recent drastic improvement from polynomial to cubic running time. The talk draws from my recent monograph on nonlinear discrete optimization and is based on several papers joint with several colleagues including R. de Loera, Hemmecke, Lee, Romanchuk, Rothblum and Weismantel.

Renata Sotiro, Tilburg University
SDP relaxations for the graph partition problem
In [R.- Sotiro. A powerful semidefinite programming relaxation for the graph partition problem. Manuscript 2011] we derived a semidefinite programming relaxation for the general graph partition problem (GPP) that is based on matrix lifting. This relaxation provides competitive bounds that can be computed with little computational effort for graphs with up to 100 vertices.

Here, we further investigate matrix and vector lifting SDP relaxations for the GPP on highly symmetric graphs, and improve the best known bounds for certain graphs with symmetry.

Raymond Hemmecke, TU Munich (with Shmuel Onn, Lyubov Romanchuk)
N-fold integer programming in cubic time
In this talk we present a cubic-time algorithm for solving N-fold integer programs together with some first computational experiments on its performance.

Preference structures in multi-objective optimization
Organizer/Chair Gabriele Eichfelder, TU Ilmenau - Invited Session

Gabriele Eichfelder, TU Ilmenau
A procedure for solving vector optimization problems with a variable ordering structure
Vector optimization problems with a variable ordering structure have recently gained interest due to several applications for instance in image registration and portfolio optimization. Here, the elements in the image space are compared using a cone-valued map, called ordering map, which defines an ordering cone for each element of the image space individually. This leads to a binary relation, which is in general not transitive and also not compatible with the linear structure of the space.

We present in this talk a numerical method for determining an approximation of the optimal solution set of such (nonlinear and smooth) vector optimization problems.

In a first step, using classical adaptive approximation methods, a superset of the set of optimal solutions is determined. In a second step, using new nonlinear scalarization results for variable ordering structures, the optimal elements are selected. First numerical results are presented.

Behnam Soleimani, Martin-Luther-Universität Halle-Wittenberg
Approximate solutions of vector optimization with variable order structure
We introduce concepts for approximate minimal and nondominated solutions of vector optimization problems with variable order structure. Furthermore, we introduce a scalarization method by means of nonlinear functionals and present a characterization of approximate minimal and nondominated solution by using this scalarization method.

Refail Kasimbeyli, Anadolu University
Characterization of properly nondominated elements in vector optimization with variable ordering structures
This paper studies properly nondominated elements in vector optimization problems with variable ordering structures. We introduce several notions for properly nondominated elements and investigate nonlinear scalarization approach for their characterizations. A new concepts presented in the paper are compared to existing in literature ones. The new type of nonlinear scalarizing functions is introduced and their properties are discussed. These functions are used to characterize the properly nondominated elements.

Algorithms and applications II
Organizer/Chair Yu-xiang Yuan, Chinese Academy of Sciences - Invited Session

Jinyan Fan, Shanghai Jiao Tong University
Accelerating the modified Levenberg-Marquardt method
In this talk, we will present an accelerated version of the modified LM method for nonlinear equations, which not only computes a LM step but also an approximate LM step with line search at every iteration. Under the local error bound condition which is weaker than nonsingularity, we show the convergence order of the accelerated modified LM method is a continuous function with respect to the LM parameter. We compare the new method with both the LM method and the modified LM method and observe significantly competitive performance.

Polynomial optimization and semidefinite programming
Organizer/Chair Jiawang Nie, University of California, San Diego - Invited Session

Yanfei Wang, Institute of Geology and Geophysics, Chinese Academy of Sciences
Optimizing inversion methods for seismic imaging
In this talk we address several migration and optimizing inversion methods in seismic imaging. In particular, regularizing least squares migration and inversion imaging techniques are discussed. Preconditioning technique is also introduced. Numerical tests are made to show the performance of the methods. Since the interferometric migration and the least squares migration both aim to improve the resolution of seismic imaging, a numerical experiment is also made to discuss their ability in improving imaging resolution.

Limited memory updating and quadratic overestimation for NLP
We pursue the approach of solving non-linear constraint problems using an active set strategy without the complete evaluation of Jacobians or Hessians. The linearized KKT systems are solved approximately on the basis of limited derivative information and compact storage schemes. The resulting step corresponds to a projected Hessian who's positive definiteness is ensured with the help of quadratic overestimation. We will present theoretical arguments and numerical experiments.

Symmetry in polynomial optimization
Solving polynomial optimization problems is known to be a hard task in general. In order to take the recently emerged relaxation paradigms into efficient tools for these optimization questions it is necessary to exploit further structure whenever presented in the problem structure. In this talk we will focus on the situation of optimization problems that are given by symmetric polynomials in order to highlight several approaches to take advantage of symmetry. The techniques presented in the talk will also give a better understanding of the cones of symmetric sums of squares and symmetric non negative forms and the symmetric mean inequalities associated to these. In particular, we will show that in degree four, symmetric mean inequalities are characterized by sum of squares decomposition.

Christian Kanzow, Universität Kaiserslautern
The sums of squares dual of a semidefinite program
It is now commonly known that many polynomial optimization problems can be modeled or at least approximated by semidefinite programs.
In this talk we go the other way around: We consider an SDP from the perspective of polynomial optimization and real algebraic geometry. We will see that, from this perspective, the standard duality of an SDP can be seen as a theorem on representation of positive polynomials. We will prove that natural variants of this theorem hold true, and these can be refined with some effort to yield what we call the sums of squares duals of a semidefinite program. This dual has polynomial size in the primal and, unlike the standard dual, ensures always strong duality. Based on completely different ideas, another dual with this property has already been given by Matt Raman in 1995. However, we think that our dual is interesting because it shows that ideas from real algebraic geometry might lead very naturally to seriously exploitable concepts in optimization.

Optimal massively parallel algorithms for large QP/QPQC problems arising in mechanics

We review our results in development of optimal algorithms for the minimization of a strictly convex quadratic function subject to separable convex constraints and/or equality constraints. A unique feature of our algorithms is the bound on the rate of convergence in terms of the bounds on the spectrum of the Hessian of the cost function, independent of constraint descriptions. When applied to the class of convex QP or QPQC problems with the spectrum in a given positive interval and a sparse Hessian matrix, the algorithms enjoy optimal complexity.

The efficiency of our algorithms is demonstrated on the solution of contact problems of elasticity with or without friction by our TFETI domain decomposition method. We prove numerical scalability of our algorithms, i.e., their capability to find an approximate solution in a number of matrix-vector multiplications that is independent of the discretization parameter. Both numerical and parallel scalability of the algorithms is documented by the results of numerical experiments with the solution of contact problems with millions unknowns and analysis of industrial problems.

Applications of domain decomposition to topology optimization

When modelling structural optimization problems, there is a perpetual need for increasingly accurate conceptual designs, with the number of degrees of freedom used in obtaining solutions continually rising. This impacts heavily on the overall computational effort required by a computer and it is therefore natural to consider alternative possibilities. One approach is to consider parallel computing and in particular domain decomposition. The first part of this talk will discuss the application of domain decomposition to a typical optimization problem via an interior point approach. This method has the potential to be carried out in parallel and therefore can exploit recent developments in the area. The second part of the talk will focus on a nonlinear reaction diffusion system solved using Newton's method. Current work considers applying domain decomposition to such a system using a Newton-Krylov Schur [NKS] type approach. However, strong local nonlinearities can have a drastic effect on the global rate of convergence. Our aim is to instead consider a three step procedure that applies Newton's method locally on subdomains in order to address this issue.

Inherently nonlinear decomposition and multilevel strategies for non-convex minimization

We present and discuss globally convergent domain decomposition and multilevel strategies for the solution of non-convex – and possible constrained – minimization problems. Our approach is inherently nonlinear in the sense that we decompose the original nonlinear problem into many small, but also nonlinear, problems. In this way, strongly local nonlinearities or even heterogenous problems can be handled easily and consistently. Starting from ideas from Trust-Region methods, we show how global convergence can be obtained for the case of a nonlinear domain decomposition as well as for the case of a nonlinear multilevel method – or combinations thereof. These ideas also allow us for deriving a globally convergent variant of the ASPIN method (G–ASPIN). We will illustrate our findings along examples from computational mechanics in 3D.
These have analogies in perfectly competitive electricity markets where agents maximize profits in a deterministic setting. When the system involves hydro reservoirs with uncertain inflows, the social optimum is the solution to a multi-stage stochastic program. This corresponds to a competitive equilibrium when all agents are risk-neutral and share the same view of the future. We explore what happens in this setting when risk-averse agents optimize using coherent risk measures.

**Optimization in energy systems**

**Thu.3 MA 550**

**Gas transport in networks**
Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen - Invited Session

Martin Schmidt, Leibniz Universität Hannover (with Marc Steinbach)

**An extended interior point method for nonsmooth nonlinear optimization in gas networks**

Detailed physical and technical modeling of cost minimization in gas transport networks leads to nonsmooth nonlinear mixed-integer optimization models (NSMINLPs). After fixing prescribed discrete decisions given by an enclosing MIP framework we concentrate on the remaining nonsmooth nonlinear optimization problem (NSNLIP). These problems cannot be seriously tackled by standard interior point methods due to the violation of C2-assumptions.

We present a modified interior point method using a special kind of generalized gradients for the search direction computation and an extended step length computation ensuring that the line-search sub-procedure is only applied to smooth regions of the nonsmooth problem functions. The applicability of the proposed method is demonstrated by numerical experiments on large-scale real world instances.

Imke Joormann, TU Darmstadt

**Analyzing infeasibility in natural gas networks**

Infeasibilities in the mathematical description of natural gas networks in real-world applications can arise for different reasons, including defective data, modeling issues and plain physical impracticability. In the considered case, we start with a mixed integer linear program (MILP) modeling the validation of nominations on the network, i.e., the task of deciding whether it is possible to transport a given flow amount with specific supply and demand nodes.

Our main purpose is to analyze this MILP and find physical reasons for the infeasibility of a given instance. To achieve this, we implemented and tested various approaches based on slack models. In addition, we investigated the explanatory power of irreducible infeasible subsystems, since it is possible to calculate them at least in a heuristic way. The remaining task is to transfer the gained information from the MILP back to the network. Complementing the modeling aspects we present computational results and derive cautious suggestions as to which model should be used, depending on the practical application.

Ralf Gollmer, University of Duisburg-Essen (with Rüdiger Schultz, Claudia Stangl)

**Stationary gas transport - Structure of the problem and a solution approach**

Detecting feasibility of transportation orders (nominations) in gas networks is a problem of growing practical interest due to the regulatory requirements in the course of unbundling gas trading and transport. In the stationary flow case, already, this nonlinear non-convex mixed-integer problem poses challenging mathematical questions. In particular, we discuss some structural properties of the problem in slightly simplified form. We sketch a heuristic solution approach choosing switching decisions (the integer variables) from the solution of an aggregated linear transshipment problem and referring to the so called loop formulation when solving the resulting NLIP. This approach is successful when applied to real-world instances met in a meshed gas network of a German utility.
norm, $q \in (0, 1)$, of image gradient as regularization. Such a regularization is a nonconvex compromise between support minimization and convex total-variation model. In finite-dimensional setting, existence of minimizer is proven, a semismooth Newton solver is introduced, and its global and locally superlinear convergence is established. The potential non-uniqueness of Hessian is handled by a trust-region based regularization scheme. Finally, the associated model in function space is discussed.

**Robust optimization**

Thu.3.MA 004
Regret with robustness: Models, algorithms and applications
Organizer/Chair: Karthik Natarajan, Singapore University of Technology and Design - Invited Session

Dongian Uichanco, National University of Singapore (with Karthik Natarajan, Kim Chuan Toh)

A probabilistic model for minmax regret combinatorial optimization

We propose a probabilistic model for minimizing anticipated regret in combinatorial optimization problems with distributional uncertainty in the objective coefficients. The interval uncertainty representation of data is supplemented with information on the marginal distributions. As a decision criterion, we adopt a worst-case conditional value-at-risk of regret measure. The proposed model includes standard interval data minmax regret as a special case. For the class of combinatorial optimization problems with a compact convex hull representation, a polynomial sized mixed integer linear program (MILP) is formulated when (a) the range and mean are known, and (b) the range, mean and mean absolute deviation are known while a mixed integer second order cone program (MISOCP) is formulated when (c) the range, mean and standard deviation are known. For the subset selection problem, the probabilistic regret model is shown to be solvable in polynomial time for instances (a) and (b).

Andrew Lim, University of California (with George Stantksumar, Cah-Ti Yahn)

Robust portfolio selection with learning in the framework of relative regret

We formulate single and multi-period portfolio choice problems with parameter uncertainty in the framework of relative regret. We solve the relative regret problem by showing that it is equivalent to a certain Bayesian problem which we analyze using stochastic control methods. The Bayesian problem is unusual in that the prior distribution is endogenously chosen, and the objective function involves the family of benchmarks from the relative regret problem. The solution of the Bayesian problem (and hence the relative regret problem) involves a “tilted” posterior, where the posterior comes from Bayesian updating of the endogenous prior, and tilting is defined in terms of a likelihood ratio that depends on the family of benchmarks.

Juile Uchanco, MIT (with Reted Lev, Georgia Perakis)

Regret optimization for stochastic inventory models with spread information

We study a minimax regret approach to the newsvendor problem. Using a distribution statistic, called absolute mean spread (AMS), we introduce a new family of demand distributions under the minmax regret framework. We propose order policies that only require a distribution’s mean and information on the AMS. Our policies have several attractive properties. First, they take the form of simple closed-form expressions. Second, we can quantify an upper bound on the resulting regret. Third, under an environment of high profit margins, they are provably near-optimal under mild technical assumptions on the failure rate of the demand distribution. And finally, the information that they require is easy to estimate with data. We show in extensive numerical simulations that when profit margins are high, even if the information in our policy is estimated from (sometimes few) samples, they often manage to capture at least 95% of the optimal expected profit.

**Sparse optimization & compressed sensing**

Thu.3.M 128
Variational signal processing – algorithms and applications
Organizer/Chair: Junfeng Yang, Nanjing University - Invited Session

Wenxing Zhang, Nanjing University (with Michael K.Ng, Xiaoming Yuan)

On variational image decomposition model for blurred images with missing pixel values

In this talk, we develop a decomposition model to restore blurred images with missing pixel values. Our assumption is that the true image is the superposition of cartoon and texture parts. We use the total variation (TV) norm to regularize the cartoon part and its dual norm to regularize the texture part, respectively. We recommend an efficient numerical algorithm based on the variable splitting method to solve the problem. Theoretically, the existence of minimizer to the energy functional and the convergence of the algorithm are guaranteed. In contrast to recently developed methods for deblurring images, this algorithm not only gives the restored image, but also gives a decomposition of cartoon and texture parts. These two parts can be further used in segmentation and inpainting problems. Numerical comparisons between this algorithm and some state-of-the-art methods are also reported.

Jufeng Yang, Nanjing University (with Xin Li, Yin Zhang)

Convergence of a class of stationary iterative methods for saddle point problems

The alternating direction method (ADM) was originally proposed in the 1970s. In the literature, very restrictive conditions, such as convexity of the objective function over the entire domain and separability into exactly two blocks, have been imposed to guarantee convergence of the ADM. Moreover, the convergence rate of ADM remains unclear. In this paper, we carry out a unified study on the convergence of a class of stationary iterative methods, which includes the ADM as a special case, for quadratic programming problems with linear equality constraints or linear saddle point problems. We establish global and $q$-linear convergence results without assuming convexity of the objective function and in the absence of separability of variables. Some numerical results are presented to support our findings, and extension to nonlinear saddle point problems is also discussed.

Yilian Wang, University of Electronic Science and Technology of China (with Wotao Yin)

Sparse signal reconstruction based on iterative support detection

We present a novel sparse signal reconstruction method based on iterative support detection (ISD, for short), aiming to achieve fast reconstruction and a reduced requirement on the number of measurements compared to the classical $l_1$ minimization approach. ISD addresses failed reconstructions of $l_1$ minimization due to insufficient measurements. It estimates a support set from a current reconstruction and obtains a new reconstruction by solving a revised $l_1$ minimization problem, and it iterates these two steps for a small number of times. While introducing the general idea of ISD, we will present some recent thoughts about it.

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Stochastic bilevel optimization problems with applications to telecom

We consider several stochastic bilevel optimization problems which have applications to supply chain management and information economics, where the system under consideration is composed from several independent actors. We consider solution methods that utilize analysis of analytical properties of the problem with stochastic optimization techniques.

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Chance constrained stochastic optimization

Yongia Song, University of Wisconsin-Madison (with Sime Günlük, James Luedtke)

A branch-and-cut algorithm for the chance-constrained knapsack problem

We consider a probabilistic version of classical 0-1 knapsack problem, where we have a set of items with random weight and a random knapsack capacity. The objective is to choose a set of items that maximizes profit while ensuring the knapsack constraint is satisfied with probability higher than a given threshold. We introduce a simple decomposition algorithm based on a probabilistic extension of cover inequalities to solve a sample average approximation (SAA) of this problem. We propose a probabilistic sequential lifting procedure to strengthen them, leveraging successful computational strategies for the deterministic knapsack problem. Exact lifting is hard, but we obtain an effective upper bound for the lifting problem using a scenario decomposition approach. Additional valid inequalities are proposed to further strengthen the bounds. A key advantage of our algorithm is that the number of branch-and-bound nodes searched is nearly independent of the number of scenarios used in the SAA, which is in stark contrast to formulations with a binary variable for each scenario.

Thue.3 MA 144

Overall aircraft design based on chance-constrained programming

Jessie Birman, Airbus Operation S.A.S.

Preliminary Overall Aircraft Design (OAD) is classically carried out using a deterministic optimization of a strategic criterion under operational constraints. The risk, which may appear all along the aircraft development, is mitigated by using a “margin philosophy” applied to some design parameters. A robustness study has highlighted the shortcomings of this way of doing, which does not offer the best protection possible against deviation to ensure requirement satisfaction. In the last decades, many researches have been done in the area of optimization of complex processes under uncertainty. Attention has been put on methods reported in Stochastic Programming or Chance-Constrained Programming (CCP). The aim of the study is to propose a new methodology based on CCP to perform OAD. For this purpose, the main source of uncertainty affecting the system is identified and quantified. Then, a new formulation of the aircraft pre-design optimization is stated according to the CCP framework. Particular attention is put on the choice of the objective function and the design parameters. This method is also used to assess the uncertainty involving an unconventional aircraft configuration.

Stochastic linear programming with joint chance constraints

Jiuniang Cheng, LIRL, University of Paris-Sud (with Abdel Lisser)

This paper deals with a special linear programs with joint chance constraints, where the left-hand side of chance constraints is normally distributed stochastic coefficients and the columns of the matrix are assumed independent to each other. We approximate this problem by solving its corresponding stochastic dual problem and there is a weak duality between them, i.e., the optimum objective value of the dual problem is a lower bound of the primal minimum problem. For the dual problem, it can be approximated by one SOCP problem. Furthermore, the optimum of the SOCP problem provides an upper bound of the dual problem. Finally, numerical experiments on random data are given to evaluate the approximation.

Organizer: Chair Ritha Mahjoub, Université Paris-Dauphine - Invited Session

Viet Hung Nguyen, LIP6 - Université Pierre et Marie Curie Paris 6

A direct algorithm for detecting negative cost cycles in undirected graphs

Given an undirected, arbitrarily weighted graph \( G = (V, E) \) with \( n = |V| \) and \( m = |E| \). We consider the problem of checking whether \( G \) contains a negative cost cycle (UNCCD). It is known that the corresponding problem in directed graphs (NCCD) can be solved by applying directly the Bellman-Ford algorithm. The UNCCD problem is much harder than the NCCD problem. In our knowledge, for solving the UNCCD, there is no direct algorithm and we should reduce it to either the \( b \)-matching problem or the \( T \)-join problem in some extended graphs derived from \( G \). The latter reduction runs in \( O(n^4) \) time while the former, running in \( O(n^3) \) time, is less efficient. In this paper, we improve the time complexity by using a direct algorithm for the UNCCD problem which runs in \( O(mn + n^2 \log(n)) \) time. The algorithm, which is based on a polyhedral characterization of the cone of circuit by Seymour, is a variant of Edmonds’ blossom algorithm for matching.

Amal Benhamiche, Orange Labs/LAMSADE (with Ali Ritha Mahjoub, Nancy Perrot, Eduardo Uchoa)

On the optical multi-band network design problem

User demand in traffic is steadily increasing and telecommunication operators are now interested in high bandwidth capacitated networks to upgrade the transmission capacity of optical backbone networks. This evolution leads to a new variant of multi-layer network design problem: the optical multi-band network design (OMBND) problem. It consists in selecting the minimum number of subbands to install on the physical layer so that the traffic can be routed and there exists a path in the physical layer associated to each subband. We propose a path formulation based on an implicit model for the problem and describe some additional valid inequalities. We then present a column generation procedure to solve the linear relaxation of OMBND that uses a two-stage pricing problem. The column generation procedure is embedded in a branch-and-price approach with a specific branching rule to derive an integer solution. Some computational results are presented for realistic instances of network and illustrate the efficiency of this approach to solve huge instances.

Rassia Gharabia, LAMSADE / Université Paris-Dauphine (with Sylvie Borne, Virginie Gabriel-Willemin, A. Ritha Mahjoub)

Models and algorithms for the survivable multilayer network design problem

We are interested in the problem of survivability of the WDM layer in bilayer IP-over-WDM networks. Given a set of traffic demands for which we know a survivable logical routing in the IP layer, our purpose is to search the corresponding survivable topology in the WDM layer. We give two integer formulations for the problem. The first one uses cut constraints and the second is a path-based formulation. We discuss the polyhedron associated to the cut formulation and introduce some valid constraints. We also discuss the pricing problem and the branch-and-price strategy for the path formulation. We finally present primal heuristics and give some experimental results for the two formulations.

Organizer/Chair Arie Koster, RWTH Aachen University. Invited Session

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Finally, we present computational results comparing the branch-and-price formulation and the default ILP.

Peter Hoffmann, TU Chemnitz (with Christoph Helmberg)  
Robust and chance constraint models of failure scenarios in the design of telecommunication networks  
Given a backbone network for telecommunication with possibly uncertain demand between each pair of nodes, the task is to find capacities for the edges in the network so that all demand can be routed through the network. We consider here failure scenarios where nodes or edges may fail. In the single failure scenario a standard approach is to require the presence of a node disjoint cycle for each pair of nodes, so that in case of failure there still is a path between each two intact nodes. In this study we want to exploit the differing probabilities of the failure of network items (nodes or edges), so that even in the case of two or more failures the probability that more than a prespecified value of demand is unrouteable is kept below a given level. If the failure probabilities follow a normal distribution this leads to a model with a chance constraint, that couples the node and edge failures and the resulting loss in routable demand. An implementable variant is based on a semidefinite relaxation of bilinear terms and a second order cone constraint replacing the chance constraint.

Daniel Karch, TU Berlin (with Andreas Bley, Fabio d’Andragogianis)  
Fiber replacement scheduling  
During the operation of large telecommunication networks, it is sometimes necessary to replace components in a big part of a network. Since a network resource, such as a router or an optical fiber cable, is usually in shared use by several connections, all of these connections will have to be shut down while the component is being replaced. Since the number of workers that perform the upgrade is limited, not all of the affected connections can be upgraded at the same time, and disruptions of services cannot be avoided. Our goal is to schedule the replacement of the fibers in such a way, that the number of workers necessary in each period of the discretized planning horizon does not exceed the given budget, and the sum of all connections’ disruption times is minimized. We will present exact mathematical formulations for the problem, discuss some consequences of the linear arrangement problem, and give first results on the hardness of approximation.

Andreas Hamel, Humboldt University Berlin (with Andreas Bley, Michael Kupper)  
Lagrangian type duality theorem for set-valued optimization  
A Lagrange type duality theorem for set-valued optimization problems is presented. New features include set-valued Lagrangians and saddle set (rather than point) theorems based on infima and suprema in appropriate spaces of sets. An application to multivariate utility maximization is given.

Martin van Brink, Maastricht University (with Alexander Grigoriev, Tjark Vredeveld)  
Express delivery of packages  
We consider a capacitated, fixed-charge, multimmodity flow problem with indivisible commodities. The commodities are transported with trucks, which all have the same capacity, and we assume there is an unlimited number of trucks. We show that, unless \( P = \text{NP} \), there cannot exist a polynomial time \( O(\log K) \)-approximation algorithm, where \( K \) is the number of commodities. Applying randomized rounding, we obtain an approximation ratio of \( K + 1 \), and we show that this ratio is tight. Next, we restrict the underlying network to cycles. We prove that the problem remains \( \text{NP} \)-hard and we develop a \( 4 \)-approximation. If we assume that the total volume of all commodities is at most the capacity of a single truck, we get an integer linear programming formulation with a totally unimodular constraint matrix. Thus, we can obtain the optimal solution in polynomial time. Finally, we consider the case where we have a fixed number of commodities, and show that for 2 and 3 commodities the problem can be also solved in polynomial time.

Jesus Caro, Diego Portales University (with Juan Segovia, Oscar Vasquez)  
An efficient decision making process for vehicle operations in underground mining based on a mixed-integer programming model  
Mining operations can be seen as a vertically positioned threefold process: production, transportation and transportation. The workload of levels is pushed top-down by a plan-driven strategy, that contains the number of ore bucketfuls to be extracted at the production level. Unfortunately, the goal of minimizing makespan in the production level would be not always optimal when taking into consideration the coordination...
levels. In this paper, a mixed integer programming model to minimize makespan of drift workload subject to the coordination between production and reduction levels is formulated. The problem NP-hardness in strict sense is proved, the value of 2 as upper bound for polynomial algorithm in the off and on-line case is given, and 1.25-approximation algorithm for its resolution is proposed. Next, a set of decision rules obtained from the above algorithm is integrated into a simple-to-execute decision making process for LHD operators. Currently, a numerical analysis based on Chilean underground copper mine El Teniente data is being realized to explore the practical potential of the DMP proposed. The preliminary results show an average value 1.08.

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New models for network connection problems with interval data

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

Combinatorial optimization

Approximation algorithms for hard problems

We address a pickup and delivery vehicle routing problem with multiple depots, where routes have to be constructed to satisfy customer requests, which either involve the pickup or delivery of a single commodity. A fleet of homogeneous vehicles is available to fulfill the demand and supply of the customers under the objective to minimize the total distance traveled. Each vehicle has unit capacity and the commodities which are collected from the pickup customers can be used to accommodate the demand of the delivery customers. We model this problem as an integrated integer nonlinear programming problem that simultaneously solves an assignment and a routing problem, linked via coupling constraints. Exact solution approaches based on the classical and the generalized Benders decomposition are presented to optimally solve the problem.

Combinatorial optimization in logistics

In cumulative scheduling, conflict analysis is one of the key ingredients to solve these problems efficiently. Thereby, the computational complexity of explanation algorithms that explain infeasibilities or bound changes plays an important role. Their role is even more substantial when we are facing a backtracking system where explanations need to be constructed on the fly. In this talk we present complexity results for computing minimum-size explanations for the propagation algorithms time-tabling, edge-finding, and energetic reasoning. We show that it is possible to compute in polynomial time minimum-size explanations for bound changes which result from energetic reasoning and edge-finding. In case of time-tabling, we prove that an important special case is already weakly NP-hard. In the context of bound-widening, the problems all become NP-hard. To this end, we establish a relation to unsplittable flow problems on the path. We evaluate different heuristic approaches and exact approaches to explain bound changes derived by these algorithms. Using these minimum-size explanations pays off in total compared to using faster but weaker explanation algorithms.

Benders decomposition for a 1-full-truckload pickup-and-delivery vehicle routing problem

We address a pickup and delivery vehicle routing problem with multiple depots, where routes have to be constructed to satisfy customer requests, which either involve the pickup or delivery of a single commodity. A fleet of homogeneous vehicles is available to fulfill the demand and supply of the customers under the objective to minimize the total distance traveled. Each vehicle has unit capacity and the commodities which are collected from the pickup customers can be used to accommodate the demand of the delivery customers. We model this problem as an integrated integer nonlinear programming problem that simultaneously solves an assignment and a routing problem, linked via coupling constraints. Exact solution approaches based on the classical and the generalized Benders decomposition are presented to optimally solve the problem.

Approximation algorithms for scheduling parallel machines with capacity constraints

In this paper, we consider the classical scheduling problem on parallel machines with capacity constraints. We are given $m$ identical machines, where each machine $k$ can process up to $c_k$ jobs. The goal is to assign the $n \leq \sum_{k=1}^m c_k$ independent jobs on the machines subject to the capacity constraints such that the makespan is minimized. This problem is a generalization of $c$-partition, which is strongly NP-hard for $c > 3$ and the best known approximation algorithm of which has a performance ratio of $4/3$ due to Babel et al.

We deal with the general problem and improve the previous results by establishing an efficient polynomial time approximation scheme (EPTAS) whose running time is at most $2^{O(1/\epsilon^2 \log(1/\epsilon))} + poly(1/\epsilon, \log n) + O(\log n)$. We develop a best-fit schedule for small jobs, and then handle the assignment of big jobs through a mixed integer programming algorithm (MILP). Such an MILP consists of a huge number of integer variables which is not even a constant, however, we would provide a greedy rounding technique to modify it iteratively so that the number of its integer and fractional variables is sharply reduced.

Approximation algorithms for parallel open shop scheduling

This paper investigates a new scheduling problem, namely the parallel open shop scheduling. In this problem, each job consists of two operations, which must be non-preemptively processed by one of the $m$ two-stage parallel open shops. The objective is to minimize the makespan. As the problem is NP-hard, we provide the first approximation algorithm with a worst case ratio of 2 for $m$ machines, and for $m = 2$, an improved algorithm with worst case ratio $3/2$ is further proposed. Both algorithms run in $O(n \log n)$ time.

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

Yuri Faenza, Università di Padova (with Giandomenico Grossi, Gautier Stauffer)
Separating stable sets in claw-free graphs through extended formulations

The stable set polytope in claw-free graphs is a well-known generalization of the matching polytope. A linear description of the latter only requires rank inequalities (i.e., with $0/1$ coefficients), while the associated separation problem can be solved via a purely combinatorial routine. For ssp-cf the situation is quite different: no complete description is known, and there exist examples of facets with arbitrarily high coefficients. Moreover, the only known separation routine relies on the ellipsoid method.

In this talk, we provide linear programming extended formulations for ssp-cf, together with polynomial time separation routines for those formulations (they are not compact). Those formulations rely on combinatorial optimization, polyhedral combinatorics, and structural graph theory results. We then exploit one of those extended formulations to prove a new polytime algorithm for solving the separation problem for ssp-cf. This routine combines the separation algorithm for the matching polytope and the solution of (moderate size) compact linear programs, hence it does not require the application of the ellipsoid method.

Paolo Nobili, Università del Salento (with Antonio Sassano)
A decomposition algorithm for the weighted stable-set problem in claw-free graphs

In this paper we describe a new characterization of a line-graph $G(V,E)$ in terms of forbidden substructures. Unlike the classical characterization due to Bermond and Meyer based on forbidden induced subgraphs, we rely upon the properties of a suitable maximal stable set $S$ of $G$. Following Lovász, we say that two nodes $u$ and $v$ in $V \setminus S$ are similar if $N(u) \cap N(v) = N(u) \cap S$. Moreover, extending a definition due to Schrijver, we say that a node $x$ in $S$ is clique-splittable in $G$ with respect to $S$ if the nodes in $N(x)$ can be partitioned in two cliques $(X_i,Y_i)$ with the property that each dissimilar pair of nodes $z \in N(x)$ is adjacent if and only if both belong to $X_i$ or $Y_i$. Our main result is that a claw-free graph $G$ is a line graph if and only if every node $x \in S$ is clique-splittable and $S$ does not define two special structures in $G$, namely a pair of cross-linked nodes or a free-strip.

Combinatorial optimization

Fri, 1.3.2013
Extended formulations
Chair Ralf Borndörfer, Zuse Institute Berlin
Paolo Serafini, University of Udine – Italy (with Giuseppe Lancia)
Compact formulations for large-scale LP problems

There are many combinatorial problems which can be effectively dealt with via Integer Linear Programming by using column-generation or constraint-generation techniques. When the pricing for column generation can be solved by Linear Programming, it is possible to embed the positive reduced cost condition into the dual of the relaxed integer primal. Similarly, for constraint generation, if the separation problem is a Linear Program, it can be embedded into the integer primal. The new model has polynomial size and has the same lower bounds as the original exponential size model. We call “compact” this reformulation. The compact reformulation may provide new insights into the problem structure and sometimes exhibits a computational better performance than the original formulation. It is possible to develop compact models for the following problems: Bin packing, Max cut, Stable set, TSP, Minimum routing cost tree, Steiner tree, Cycle packing, Alternating cycle decomposition, Job Shop, Protein fold comparison and various variant of TSP, like Prize collecting TSP and Time window TSP.

Achim Hildenbrandt, Universität Heidelberg (with Olga Heismann, Gerhard Reinelt)
An extended formulation for the target visitation problem

The target visitation problem (TVP) is concerned with finding a route to visit a set of targets starting from and returning to some base. In addition to the distance traveled, a tour is evaluated also by taking preferences into account addressing the sequence in which the targets are visited. The problem thus is a combination of two well-known combinatorial optimization problems: the traveling salesman and the linear ordering problem. The TVP was introduced to serve the planning of routes for unmanned aerial vehicles (UAVs) and it can be employed to model several kinds of routing problems with additional restrictions. In this talk we want to point out some properties of the polyhedral structure of an associated polytope and also present an extended formulation. We will use this formulation to develop a branch-and-price algorithm. Computational results will be discussed.

Ralf Borndörfer, Zuse Institute Berlin (with Olga Heismann, Manika Karbstein, Markus Reuther, Thomas Schlechte, Steffen Weider)
Configuration models for solving integrated combinatorial optimization problems

In the talk proposes configuration models as an effective approach to combinatorial optimization problems that integrate several types of constraints. Configurations are local building blocks of primal solutions. They can be used to express complex requirements, that would be difficult to formulate in terms of constraints, using an exhaustive, but local, and hence manageable, enumeration of variables. This often gives rise to large, but combinatorially clean packing and covering type models, and it often produces strong LP bounds. Configuration models can be seen as an approach to construct extended formulations; these, in turn, lend themselves to column generation methods. Examples of successful applications of the model include location allocation (the configurations are occupations of track segments over time), vehicle rotation planning (the configurations correspond to train compositions), and line planning (configurations correspond to line bundles on an infrastructure segment).

Claudia Snel, Università di Roma Tor Vergata (with Flavia Bonomo, Gianpaolo Oriolo)
Minimum weighted clique cover on strip-composed perfect graphs

On a perfect graph $G$ where a non negative weight function on the vertices $w : V \rightarrow \mathbb{R}^+$ is given, the minimum weighted clique cover problem (MWCC), consists on finding a collection of cliques $C$, each one with a non-negative value $y_C$, such that for every vertex $v \in V$ $\sum_{C \in \mathcal{C}, v \in C} y_C \geq w(v)$ and the weight $\sum_{C \in \mathcal{C}} y_C$ is minimum.

The only available combinatorial algorithm for the MWCC in claw-free perfect graphs is due to Hsu and Nemhauser and dates back to 1984. More recently, Chudnovsky and Seymour in 2005 introduced a composition operation, strip-composition, in order to define their structural results for claw-free graphs; however, this composition algorithm is general and applies to non-claw-free graphs as well.

In this paper, we show that a MWCC of a perfect strip-composed graph, with the basic graphs belonging to a class $\mathcal{G}$, can be found in polynomial time, provided that the MWCC problem can be solved on $\mathcal{G}$ in polynomial time. We also design a new, more efficient, combinatorial algorithm for the MWCC problem on strip-composed claw-free perfect graphs.
Complementarity & variational inequalities

Algorithms for complementarity and related problems II
Chair Goran Lesaja, Georgia Southern University
Mauro Passacantando, University of Pisa (with Giancarlo Bigi)
Gap functions and penalization for solving equilibrium problems with nonlinear constraints
Several descent methods for solving equilibrium problems (EPs) have been recently proposed. They are based on the reformulation of EP as a global optimization problem through gap functions. Most approaches need to minimize a convex function over the feasible region in order to evaluate the gap function, and such evaluation may be computationally expensive when the feasible region is described by non-linear convex inequalities. In this talk we introduce a new family of gap functions which rely on a polyhedral approximation of the feasible region rather than on the feasible region itself. We analyze some continuity and generalized differentiability properties and we prove that monotonicity type assumptions guarantee that each stationary point of a gap function is actually a solution of EP. Finally, we proposed two descent algorithms for solving EPs. Unlike most of the available algorithms, we consider a search direction which could be unstable, so that the use of an exact penalty function is required. The two algorithms differ both for the updating of regularization and penalization parameters and for the assumptions which guarantee their global convergence.
Goran Lesaja, Georgia Southern University

Infeasible full-Newton step interior-point method for linear complementarity problems
We present an infeasible Full-Newton-Step Interior-Point Method for Linear Complementarity Problems. The advantage of the method, in addition to starting from an infeasible starting point, is that it uses full Newton-steps, thus avoiding the calculation of the step size at each iteration. However, by suitable choice of parameters iterates are forced to stay in the neighborhood of the central path, thus, still guaranteeing the global convergence of the method. The number of iterations necessary to find epsilon-approximate solution of the problem matches the best known iteration bounds for these types of methods.

Conic programming

Recent developments of theory and applications in conic optimization II
Organizers/Chairs Hayato Waki, Kyushu University; Masakazu Muramatsu, The University of Electro-Communications - Invited Session
Mira Tanaka, Tokyo Institute of Technology (with Kazuhide Nakata, Hayato Waki)
Numerical computation of a facial reduction algorithm and an inexact primal-dual path-following method for doubly nonnegative optimization problems
In this talk, we introduce an effective approach to solve doubly nonnegative relaxation (DNR) problems for mixed binary nonconvex quadratic optimization problems. In our approach, we convert a given DNR problem into another one that is smaller than the original one exploiting degeneracy. We can expect numerical stability of interior-point methods for the DNR problem to be improved because this conversion can be regarded as an incomplete facial reduction algorithm. In a previous approach, we can find degeneracy only relevant to semidefiniteness analytically. In our approach, to also find degeneracy relevant to non-negativity, we compute a dense optimal solution of a linear optimization problem with an interior-point method. Moreover, we propose an inexact primal-dual path-following method for the reduced DNR problems. In our algorithm, to compute search directions, we solve large linear systems via the preconditioned symmetric quasi-minimal residual (PSQMR) method. To accelerate the convergence of the PSQMR method, we develop some preconditioners. Numerical results show that we can solve some instances of DNR problems quickly and accurately.
Matsukawa Tatsuki, University of Toyko (with Yoshise Akiko)

A primal barrier function phase I algorithm for nonsymmetric conic optimization problems
We call the set of positive semidefinite matrices whose elements are nonnegative the doubly nonnegative (DNN) cone. The DNN cone can be represented as a projection of a symmetric cone given by the direct sum of the semidefinite cone and the nonnegative orthant. Using the symmetric cone representation, the authors demonstrated the efficiency of the DNN relaxation and showed that it gives significantly tight bounds for a class of quadratic assignment problems while the computational time is long. The result suggests a primal barrier function approach for the DNN optimization problem. However, existing studies on the approach have assumed the availability of a feasible interior point which is not practical. Motivated by these observations, we propose a primal barrier function Phase I algorithm for solving conic optimization problem over the closed convex cone $K$ such that (a) $K$ is not necessarily symmetric, (b) a self-concordant function is defined over the interior of $K$, and (c) its dual cone is not explicit or is intractable, all of which are observed when $K$ is the DNN cone. We analyze the algorithm and provide a sufficient condition for finite termination.
Victor Magron, École Polytechnique INRIA (with Xavier Allamigeon, Stéphane Gaubert, Benjamin Werner)

Certification of inequalities involving transcendental functions using semidefinite programming
We consider the optimization problem $\min_{x\in K} f(x)$, where $f$ is a multivariate transcendental function and $K$ is a compact semi-algebraic set. Recent efforts have been made to produce positivity certificates for these problems, and to verify these certificates with proof assistants such as Coq. Our motivation is to automatically verify inequalities from the proof of Kepler conjecture by Thomas Hales.
We will present a certification framework, combining semi-definite programming with semi-algebraic approximations of transcendental functions. Our method consists in an iterative decomposition of the set $K$ into subsets in which the inequalities to be certified are expected to be either tight or coarse. Coarse inequalities are checked by global optimization methods (solving a hierarchy of relaxed problems using SOS solvers such as SparsePOP). Then, the feasible points generated by these methods are used to refine iteratively the semi-algebraic approximations of transcendental functions until the needed accuracy is reached. Tight inequalities are certified locally by Taylor-type models. Experimental results will illustrate numerical and scalability issues.
Sabine Burgdorf, École Polytechnique Fédérale de Lausanne (with Kristijan Cafuta, Igor Klep, Janez Povh)

Lasserre relaxation for trace-optimization of NC polynomials
Given a noncommuting (NC) polynomial $f$, what is the smallest trace $f(A)$ can attain for a tuple $A$ of symmetric matrices? This is a nontrivial extension of minimizing a polynomial in commuting variables or of eigenvalue optimization of an NC polynomial – two topics with various applications in several fields. We propose a sum of Hermitian squares relaxation for trace-minimization of an NC polynomial and its implementation as an SDP. We will discuss the current state of knowledge about this relaxation and compare it to the behavior of Lasserre relaxations for classical polynomial minimization and for eigenvalue optimization respectively.
Raman Sanyal, Freie Universität Berlin (with Anamit Bhargava, Philipp Rostalski)

Deciding polyhedrality of spectrahedra
Spectrahedra, the feasible regions of semidefinite programs, form a rich class of convex bodies that properly contains that of polyhedra. It is a theoretical interesting and practically relevant question to decide when a spectrahedron is a polyhedron. In this talk I will discuss how this can be done algorithmically by making use of the geometry as well as the algebraic structure of spectrahedra.
A surrogate model algorithm for computationally expensive mixed-integer black-box global optimization problems

We present a surrogate model algorithm for computationally expensive mixed-integer black-box global optimization problems that may have computationally expensive constraints. The goal is to find accurate solutions with relatively few function evaluations. A radial basis function surrogate model is used to select candidates for integer and continuous decision variable points at which the computationally expensive objective and constraint functions are to be evaluated. In every iteration, multiple new points are selected based on different methods, and the objective and constraint functions are evaluated in parallel. The algorithm converges to the global optimum almost surely. The performance of this new algorithm (SO-MI) is compared to a branch and bound algorithm for nonlinear problems, a genetic algorithm, and the NOMAD (Non-smooth Optimization by Mesh Adaptive Direct Search) algorithm for mixed-integer problems on test problems from the literature, and application problems arising from structural optimization. The numerical results show that SO-MI reaches significantly better results than the other algorithms.

Joshua Griffin, SAS (with Steven Gardner)

A parallel hybrid derivative-free SAS procedure for MINLP

We present a new parallel derivative-free SAS procedure for mixed-integer nonlinear optimization. The solver is motivated by recent work on the EAGLS (Evolutionary Algorithms Guiding Local Search) algorithm developed for simulation-based groundwater optimization problems. The SAS procedure makes minimal assumptions on the structure of the nonlinear objective/constraint functions; it is discontinuous, noisy, and expensive to evaluate. Integer variables are handled by running multiple genetic algorithms concurrently. In addition to crossover and mutation, a “growth step” permits selected members of the population (based on fitness and diversity) to benefit from local optimization over the real variables. Load imbalance is exploited by both global and local algorithms sharing evaluation threads running across multiple processors. Unique evaluations are cached. Linear constraints are handled explicitly using tangent search directions and the SAS/OR OPTLP procedure.

Joshua Griffin, SAS (with Steven Gardner)

The efficient frontiers of mean-variance portfolio selection problems

We formulate several portfolio selection problems which are nonlinear programming problems. Two of them are minimum variance type problems and the other two are maximum expected return type problems. Taking into account various hypotheses on the covariance matrix and on the vector of means the duality between minimum variance type problems and maximum expected return type problems is investigated. We are interested when the efficient frontier sets of the minimum variance type problems and of the maximum expected return type problems are equal. Generalization of the problems studied to the case of mean-risk models is suggested.

Constanta Radulescu, National Institute for Research and Development in Informatics (with Marius Radulescu, Sorin Radulescu)
We construct a mechanism for distributing advertisement space to two competing players. The mechanism is not specific to any particular model for influence spread; it applies to most previously-studied models. Our mechanism yields a constant factor approximation to the optimal total product influence, and is strategyproof in the sense that advertisers maximize their expected total product diffusion by reporting their advertising demands truthfully. We also discuss extensions of our mechanism to three or more players under additional restrictions that are satisfied by many models studied in the literature.

Nicoló Immonen, Northwestern University (with Christina Brandt, Gautam Kamath, Robert Kleinberg)

Social networks and segregation

Social networks form the basic medium of social interaction. The structure of these networks significantly impacts and co-evolves with the behavioral patterns of society. Important societal outcomes – the global reach of an epidemic, the degree of cooperation in an online network, the adoption of new technologies – are dictated by social networks.

In this talk, we explore the impact of networks on segregation. In 1969, economist Thomas Schelling introduced a landmark model of racial segregation in which individuals move out of neighborhoods where their ethnicity constitutes a minority. Simple simulations of Schelling’s model suggest that local behavior can cause global segregation effects. In this talk, we provide a rigorous analysis of Schelling’s model on ring networks. Our results show that, depending on how one interprets the outcome, the exercise is nearly integrated: the average size of an ethnically-homogenous region is independent of the size of the society and only polynomial in the size of a neighborhood.

Markus Mobius, Microsoft Research New England (with Adam Seydl, Phan Tuân)

Treasure hunt

We seed a large real-world social network with binary information and analyze subsequent social learning. A unique feature of our field experiment is that we measure both the pre-existing social networks and the actual conversation network. Our experiment allows us to test how rational agents behave when processing information that originates within their social network. We find that information decays quickly with social distance and that agents mainly incorporate information within social distance 2. Conversations through common friends do not increase the weight that a subject places on signals from direct friends but linearly increases the weight on signals from indirect friends. This suggests that agents are able to avoid double-counting information from indirect friends. We propose a simple “streams model” of social learning that is consistent with the evidence from our experiment.

Nicolas Gillis, University of Waterloo (with Stephen Vavasis)

Fast and robust recursive algorithm for separable nonnegative matrix factorization

In this paper, we present an extremely fast recursive algorithm for nonnegative matrix factorization under the assumption that the nonnegative data matrix is separable (i.e., there exists a cone spanned by a small subset of the columns containing all columns). We prove that our technique is robust under some small perturbations of the data matrix, and experimentally show that it outperforms, both in terms of accuracy and speed, the state-of-the-art vertex component analysis algorithm of Nascimento and Bioucas-Dias.

Jiming Peng, University of Illinois at Urbana-Champaign
which generalize the well-known problems on bipartite graph matchings, such as the Linear and Quadratic Assignment Problems, and are also known as multidimensional assignment problems (MAPs). Properties of large-scale randomized instances of MAPs are studied under assumption that their assignment costs are iid random variables. In particular, we consider linear and quadratic problems with sum and bottleneck objectives. For a broad class of probability distributions, we demonstrate strong convergence properties of optimal solutions of random MAPs as problem size increases. The analysis allows for identifying a subset of the feasible region containing high-quality solutions. We also investigate the average-case behavior of Linear Sum MAP in the case when the assumption regarding independence of the assignment costs is relaxed, and a correlation structure is present in the array of assignment costs. In particular, we consider the case of LSMAP with decomposable assignment costs.

Global optimization

Advances in global optimization IV
Chairs Syuji Yamada, Niigata University

Syuji Yamada, Niigata University (with Tamaki Tanaka, Tetuco Tanino)

Global optimization methods utilizing partial separating hyperplanes for a canonical dc programming problem

In this talk, we consider a canonical dc programming problem (CDC) to minimize a linear function over the difference between a compact convex set and an open bounded convex set. It is known that many global optimization problems can be transformed into CDC. Hence, for CDC, many approximation algorithms based on outer approximation methods and branch-and-bound procedures have been proposed. However, since the volume of data necessary for executing such algorithms increases in proportion to the number of iterations, such algorithms are not effective for large scale problems. To address this issue, we propose a new iterative solution method. To avoid the growth of data storage, the proposed methods find an approximate solution of (CDC) by rotating a partial separating hyperplane around a convex set defining the feasible set at each iteration. Moreover, in order to improve the computational efficiency of the proposed methods, we utilize the polar coordinate system.

Open source software for modeling and optimization
Organizer/Chair Theodore Ralphs, Lehigh University - Invited Session

Gus Gassmann, Dalhousie University (with Jun Ma, Kipp Martin)

Optimization services: Connecting algebraic modelling languages to several solvers using a web-aware framework

A common paradigm in mathematical optimization uses a modular approach consisting of an instance generator, e.g., an algebraic modeling language (AML), and a solver. Loosely coupled systems allow the substitution of one solver or AML for another. This is especially attractive when one considers open-source software, such as the suite of solvers that make up the COIN-OR project. However, the communication of solver options is often overlooked detail. Solver developers often use options specific to their own solvers, and even where two solvers use the same option, syntax and interpretation may differ. This can be cumbersome, especially if the AML and solver reside on different computers. In addition, open-source solvers are often layered on top of other solvers, which adds to the complexity, since solver options may have to be directed at different levels in the solver hierarchy.

Optimization Services is a web-aware framework that provides a common interface between AMLs and a variety of open-source and commercial solvers. In addition, open-source solvers are often layered on top of other solvers, which adds to the complexity, since solver options may have to be directed at different levels in the solver hierarchy.

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A bit of CLP (accelerated?)

With the availability of multi-core cpus, graphical processing units and new instructions, it may be time to revisit some ideas on accelerating the simplex method. This talk gives a progress report on a dual simplex code derived from COIN-OR to take advantage of new architectures.

SearchCol algorithms for the level bin packing problem

SearchCol, short for "metaheuristic search by column generation", is an algorithmic framework for approximately solving integer programming/combinatorial optimization problems with a decomposable structure. Each iteration of a SearchCol algorithm is made of three phases: (i) column generation is used to generate solutions to subproblems, (ii) a metaheuristic is used to search the [integer] solution space, and (iii) additional constraints, forcing or forbidding attributes of the incumbent solution, are included in the restricted master problem of column generation before solving it. In this talk, we apply SearchCol algorithms to a bin packing problem where it is intended to minimize the number of used rectangular bins to pack a given set of rectangular items. Additionally, the items must be packed in levels. We present computational results demonstrating the effectiveness of our approach.
A heuristicsitic for competence building with the use of nurse rec-rostering

The global nursing shortage makes efficient use of these resources vital. Good nurse rosters assist but are often static and span over a long period while the daily personnel situation is more dynamic: nurses get sick, take short notice days off, etc. Commonly, these absences are handled by hiring extra nurses when needed. However, earlier analysis has shown that nurse rotation in combination with hiring is a more efficient solution. Moreover, re-rostering gets easier if the hospital possesses the best mix of experience level and special skills. In other words, more suitable competence profiles make re-rostering more beneficial. Nurse rotation (work regularly in another department) builds up competence, which allows for a more robust competence profile – departments become better suited to handle future personnel absences. We present a heuristicsitic that optimizes the competence profile under the assumption that nurse rotation is allowed and/or the hospital can buy in competence. Our preliminary experiments on small instances show how a more robust competence profile is much more efficient up to 40%.

Marcos Boschetti, University of Bologna (with Turrinchi Elisa, Gofarel Matteo, Rizi Stefano, Manicco Vittorio)

A Lagrangian heuristic for the sprint planning in agile methods

Agile methods have been adopted by an increasing number of companies to make software development faster and nimble. Most methods divide a project into sprints (iterations), and include a sprint planning phase that is critical to ensure the project success. Several factors impact on the optimality of a sprint plan, e.g., the estimated complexity, business value, and affinity of the user (functionalities) included in each sprint, which makes the planning problem difficult.

We present an approach for the sprint planning in agile methods based on a MIP model. Given the estimates made by the project team and a set of development constraints, the optimal solution is a sprint plan that maximizes the business value perceived by users.

Solving to optimality the model by a MIP solver (e.g., IBM Ilog Cplex) takes time and for some instances even to find a feasible solution requires too large computing times for an operational use. For this reason we have developed a heuristic based on a relaxation of the proposed model and some greedy algorithms. Computational results on both real and synthetic projects show the effectiveness of the proposed approach.

Valentina Cacchiani, University of Bologna (with Alberto Caprara, Paolo Toth)

Fixed job scheduling with resource constraints

We study the following general scheduling problem: a set of fixed jobs has to be scheduled in time and weight on a set of machines having a capacity, a cost and capable of executing at most one job at a time. Each job must be executed by a set of machines such that their overall capacity satisfies the job weight. In addition, a setup time must be respected between the execution of two jobs on the same machine, that depends on the two jobs. The goal is to determine the minimum cost schedule. We also study some variants of the problem, one of them having application in Train Unit Assignment. All the considered scheduling problems are NP-hard. We provide a heuristic algorithm based on the optimal solution of the restricted problem associated with a peak period, i.e., a subset of simultaneous jobs that must be executed on distinct machines. The heuristic algorithm is tested on real-world instances of the Train Unit Assignment and on realistic instances for all the variants and the general case. The results obtained are compared with results in the literature, showing the effectiveness of the new algorithm in providing good solutions in short computing time.

Riley Clement, University of Newcastle (with Natasha Boland, Hamish Waterer)

A big-bucket time-indexed formulation for nonpreemptive single machine scheduling problems

Nonpreemptive single machine scheduling problems require a set of jobs to be scheduled on a single machine such that each job is processed exactly once without interruption and the machine processes at most one job at a time. The classical time-indexed (TI) formulation of this problem discretizes a planning horizon into periods of unit length. We present a big-bucket time-indexed (TIBB) formulation in which the length of each period is no larger than the processing time of the shortest job. The two models are equivalent in the case that this job has unit processing time. When the minimum processing time is larger than the greatest common divisor of the problem input data the TIBB model has fewer periods than the TI model. We show how to adapt facet-defining inequalities for the TI model to the TIBB model and describe conditions under which they are facet-defining. Computational experiments compare the performance of the TIBB model to the TI model for both weighted completion time and weighted tardiness instances described in the literature.

Hamish Waterer, University of Newcastle (with Natasha Boland, Thomas Kalinowski, Zheng Lian)

Maintenance scheduling in critical infrastructure networks

Many infrastructure systems critical to modern life take the form of a flow in a network over time. For example, utilities such as water, sewerage and electricity all flow over networks. Products are manufactured and transported via supply chain networks. Such networks need regular, planned maintenance in order to continue to function. A maintenance job causes arc outages for its duration, potentially reducing the capacity of the network for that period. The coordinated timing of maintenance jobs can have a major impact on the network capacity lost to maintenance. This issue drives an annual maintenance scheduling process at the Hunter Valley Coal Chain, which supplies the world’s largest coal export operation at the port of Newcastle, Australia, and has motivated this work. Here we describe the background to the problem, how we model it, and our solution approach. The results on instances derived from real-world data will be presented.

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The laser sharing problem with fixed tours

In the Laser Sharing Problem (LSP), a set of industrial arc welding robots has to perform a series of welding seams. For this task, they need to be connected to a laser source supplying them with the necessary energy. In principle, a laser source can serve up to six robots but only one at a time. The task of the LSP is to find an assignment of a given set of laser sources to robots and collision-free robot tours so that welding seams performed using the same laser source do not overlap in time and the overall makespan is minimal.

Prescribing the robot tours, we obtain a pure scheduling problem referred to as LSP-T. We will show that LSP-T can be seen as an extension of the famous job-shop problem. Then we extend the geometric approach of Akers for the two-job-shop problem to LSP-T leading to a polynomial algorithm for the two robot case.

Since the job-shop problem is a special case of LSP-T, the three robot case is already NP-hard. We will propose a pseudo-polynomial algorithm for it based on transversal graphs and show how to derive an FPTAS. By this we fully settle the complexity of LSP-T with a constant number of robots.

Wolfgang Wietz, TU Berlin
Conflict-free job assignment and tour planning of welding robots

In welding cells, a certain number of robots performs spot welding tasks on a workpiece. The tours of the welding robots are planned in such a way that all weld points on the component are visited and processed within the cycle time of the production line. During this operation, the robot arms must not collide with each other and safety clearances have to be kept. On the basis of these specifications, we show an approach how methods of discrete optimization can be used in combination with nonlinear optimization to find solutions for the stated problem. Intermediate results from the combinatorial collision-aware dispatching problem can be used to identify promising tours. Calculating the exact trajectories for those tours only keeps the computational expensive calculations to a minimum. The discrete part leads to a Vehicle Routing based problem with additional scheduling and timing aspects induced by the necessary collision avoidance. This problem can be solved as an integer linear program by column generation techniques. In this context, we adapt a version of the shortest path problem with time windows so that it can be used to solve the pricing problem with collision avoidance.

Jürgen Pannek, University of the Federal Armed Forces Munich
Collision avoidance via distributed feedback design

We consider a distributed non cooperative control setting in which systems are interconnected via state constraints. Each of these systems is governed by an agent which is responsible for exchanging information with its neighbours and computing a feedback law using a nonlinear model predictive controller to avoid collisions. For this setting we present an algorithm which generates a parallelizable hierarchy among the systems. Moreover, we show both feasibility and stability of the closed loop using only abstract properties of this algorithm. To this end, we utilize a trajectory based stability result which we extend to the distributed setting.

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optimization methods are not directly applicable. This follows from the discrete constraints that force the pipe to form a path or even a Steiner tree. The underlying physics of the pipe can be expressed via a SOCP formulation. Additional combinatorial constraints, that are used to force the pipe to a certain design, call for the use of binary variables which renders the problem a MISOPCP. In our real-world application a rough outline of the admissible region, a start and end point are given. In addition to the self-weight of the pipe we are also asked to place hangers that provide support for the pipe. Furthermore we use Timoshenko beams for our pipe to consider a more accurate physical model. We give some numerical results and show how to speed up the solving process by discrete optimization techniques to obtain global optimality.

Fri,1.0 1029
Bilevel optimization and risk management
Chair Frank Rohde, University of Graz
Johannes Jahn, University of Erlangen-Nuremberg (with Dietmar Fey, Steffen Lemmer)
GPU implementation of a multiobjective search algorithm
In this talk we discuss the use of graphics processing units (GPU) in multiobjective optimization. For a known multiobjective search algorithm with subdivision technique we describe a possible implementation and we present numerical results for test problems together with the achieved speed ups.

Joerg Fliege, University of Southampton (with Konstantinos Karapatis, Haifu Xu)
Reformulations of multiobjective bilevel problems
We present new approaches for multiobjective bilevel optimization, derived from an optimality condition for the lower level problem that leads naturally to a nonsmooth equality constraint. The nonsmoothness of the new constraint stems from its derivation as an optimal value function of a particular direction search problem. Preliminary numerical results on bilevel problems occurring in electricity markets show the efficiency of the approach. Further, we consider possible extensions to the multilevel case.

Frank Heyde, University of Graz (with Andreas Hamel, Birgit Rudloff, Benjamin Weilting)
Set-valued average value at risk
Since the seminal paper of Artzner, Delbaen, Eber and Heath (1999), coherent measures of risk are considered to be an important tool for risk management. The most prominent example of a coherent risk measure is the “Average (Conditional) Value at Risk (AVaR)”. In the presence of transaction costs it turned out that set-valued risk measures are in general better suited to cope with multiple markets than real-valued functions. A general theory of set valued convex risk measures was developed by Hamel, Heyde (2010) and (Zamel, Heyde, Rudloff (2011)). Within this framework we will present a set-valued version of the AVaR. A primal and dual description will be given which extend the real-valued case to the set-valued framework. The equivalence of the two descriptions is shown using a set-valued Fenchel–Rockafellar duality theorem developed by Hamel (2011).

Fri,1.0 012
Complexity issues in optimization
Chair Jiannming Shi, Muroran Institute of Technology (MuIT)
Stefan Koenig, Technische Universitat Muenchen (with Christian Kanzow, Daniel Wernier)
Norm maximization is W[1]-hard
The problem of maximizing the pth power over a half-space bounded polytope in $\mathbb{R}^d$ is a convex maximization problem which plays a fundamental role in computational convexity. It has been known since 1986 that this problem is NP-hard for all values $p \in \mathbb{N}$, if the dimension $d$ of the ambient space is considered as part of the input.

In recent years, the theory of parametrized complexity has become a helpful tool in analyzing how the hardness of problems depends on specific parameters of the input. In this talk, we will briefly discuss the pre-requisites from parametrized complexity and then investigate the complexity of norm maximization with the natural choice of $d$ as parameter.

More precisely, we show that, for $p = 1$, the problem is fixed parameter tractable (i.e., it can be considered as computationally feasible if only the dimension $d$ is small) but that, for all $p \in \mathbb{N} \setminus \{1\}$, norm maximization is W[1]-hard. The presented reduction also yields that, under standard complexity theoretic assumptions, there is no algorithm with running time $o^*(d)$ that answers the problem correctly.

Claudio Santiago, Lawrence Livermore National Laboratory (with Maria Helena Jardim, Nelson Maculan)
An efficient algorithm for the projection of a point on the intersection of two hyperplanes and a box in $\mathbb{R}^d$
In this work, we present an efficient strongly polynomial algorithm for the projection of a point on the intersection of two hyperplanes and a box in $\mathbb{R}^d$. Interior point methods are the most efficient algorithms in the literature to solve this problem. While efficient in practice, the complexity of interior point methods is bounded by a polynomial in the dimension of the problem and in the accuracy of the solution. In addition, their efficiency is highly dependent on a series of parameters depending on the specific method chosen (especially for nonlinear problems), such as step size, barrier parameter, accuracy, among others. We propose a new method based on the KKT optimality conditions. In this method, we write the problem as a function of the barrier parameter and multipliers of the hyperplanes and seek to find the pair of multipliers that corresponds to the optimal solution. We prove that the algorithm has complexity $O(d^2 \log d)$.

Jiannming Shi, Muroran Institute of Technology (MuIT) (with Shu Jiannming)
A computational geometric approach for solving linear programming: Toward strong polynomial
The complexity of linear programming (LP) is still open because we don’t know whether there exists a strongly polynomial algorithm for solving a Linear program. This talk is an effort toward this long-standing open problem.

Unlike previous approaches, the algorithm proposed in talk does not require the information of the vertices of the feasible region. Under the assumption that an interior point in the feasible region is available, we reformulate a LP as a computational geometric problem with a convex hull of the data points (vectors).

We will report the experiments results comparing the new approach and the existing methods, like the interior point method, Simplex method.
Optimal solutions has been a question of interest for decades. Often it is a tool for planning, real-time operations and market auctions. Electricity industry. Over the last two decades it has become a standard where we use AC linear power flows instead of the DC power flow algorithm, ACCPM the effects on the convex hull under the assumption of a metric topology graph polytope of the topology graph. In addition, we will discuss the method and nonlinear conjugate gradient algorithms.

Optimality conditions in nondifferentiable multiobjective fractional programming
A nondifferentiable multiobjective fractional programming problem is considered. Fritz John and Kuhn-Tucker type necessary and sufficient conditions are derived for a weak efficient solution. Kuhn-Tucker type necessary conditions are shown to be sufficient for a properly efficient solution. This result gives conditions under which an efficient solution is properly efficient. An example is discussed to illustrate this result.

Solving unconstrained nonconvex programs with ACCPM
We suggest the use of ACCPM and proximal ACCPM, well known techniques for convex programming problems, in a sequential convex programming method based on ACCPM and convexification techniques to tackle unconstrained problems with a non-convex objective function, by adding a proximal term to the objective. We also report a comparison of our method with some existing algorithms: the steepest descent method and nonlinear conjugate gradient algorithms.

We use a sequence of convex functions and show that the global minimizers of these convex functions converge to a local minimizer of the original nonconvex objective function $f$. These convex functions are minimized by using ACCPM-prox, a code developed by J. P. Vial.

We use the set problem CUTER and tested two version of our algorithm, ACCPMAdaptToI and ACCPMFixToI on 158 problems of this set. The number of variables on these 158 problems varies from 2 to 20,000. This software presents ACCPMAdaptToI as the best solver on more than 22% of the problems and it can solve approximately 85% of the problems.

Power flow modelling and mechanism design
We present an optimal combinatorial auction mechanism for the virtual power plant (VPP) formation problem in a smart grid with renewable energy sources. The VPP planner can source electricity from various suppliers generating electricity from renewable energy sources. The planner has to solve the VPP formation problem to determine which VPP to form at any given point of time. We take into consideration the uncertainty in availability of renewable energy sources due to changing weather patterns.

To the best of our knowledge this is the first attempt at developing an optimal mechanism for the VPP formation problem. We incorporate the uncertainty in availability of energy from renewable resources in the auction formulation to minimize the associated risks. We have stated and proved the necessary and sufficient conditions for Myerson optimal auction for VPP formation problem in the presence of single-minded suppliers.

Optimal control
We present an optimal combinatorial auction mechanism for the virtual power plant (VPP) formation problem in a smart grid with renewable energy sources. The planner has to form the VPP to meet the demand for electricity at any given point of time. We take into consideration the uncertainty in availability of renewable energy sources due to changing weather patterns.

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Local solutions of optimal power flow problem
Optimal power flow (OPF) is a well studied optimization problem in electricity industry. Over the last two decades it has become a standard tool for planning, real-time operations and market auctions. OPF is nonlinear optimization problem and the existence of locally optimal solutions has been a question of interest for decades. It is conjectured that OPF feasible region is convex. In this talk, we present examples of local solutions of OPF on a range of power systems networks. We also show that a recent reformulation of OPF as SDP problem sometimes fails to recover feasible solutions of OPF.

Optimal control of PDEs with advection terms
We present a local optimization problem in electricity industry. Over the last two decades it has become a standard tool for planning, real-time operations and market auctions. OPF is nonlinear optimization problem and the existence of locally optimal solutions has been a question of interest for decades. It is conjectured that OPF feasible region is convex. In this talk, we present examples of local solutions of OPF on a range of power systems networks. We also show that a recent reformulation of OPF as SDP problem sometimes fails to recover feasible solutions of OPF.

Optimal boundary control for nonlinear hyperbolic conservation laws with source terms
Hyperbolic conservation laws arise in many different applications such as traffic modelling or fluid mechanics. The difficulty in the optimal control of hyperbolic conservation laws stems from the occurrence of moving discontinuities (shocks) in the entropy solution. This leads to the fact that the control-to-state mapping is not differentiable in the usual sense.

In this talk we consider the optimal control of a scalar balance law on a bounded spatial domain with controls in source term, initial data and the boundary condition. We show that the state depends shift-differentially on the control by extending previous results for the control
of Cauchy problems. Furthermore we present an adjoint-based gradient representation for cost functionals. The adjoint equation is a linear transport equation with discontinuous coefficients on a bounded domain which requires a proper extension of the notion of a reversible solution. The presented results form the basis for the consideration of optimal control problems for switched networks of nonlinear conservation laws.

Mohamed Al-Lawafia, Sultan Qaboos University

A rational characteristic method for advection diffusion equations

We present a rational characteristic method for the solution of the two-dimensional advection diffusion equations which uses Wachspress-type rational basis functions over polygonal discretizations of the spatial domain within the framework of the Eulerian-Lagrangian localized adjoint methods [ELLAM]. The derived scheme maintains the advantages of previous ELLAM schemes and generates accurate numerical solutions even when large time steps are used in the simulation. Numerical experiments are presented to illustrate the performance of the method and to investigate its convergence numerically.

Andreas Schmidt, RW. Universitat Heidelberg (with Hans-Georg Bock, Stefan Körkel)

POD reduced-order modeling in the context of direct-approach optimization

To solve optimization problems that involve PDE constraints in general two approaches are distinguished, namely the direct and the indirect approach where we either ‘first discretize – then optimize’ or ‘first optimize – then discretize’. If Proper Orthogonal Decomposition (POD) is used to reduce the size of the optimization problem in most of the applications this takes place in the indirect setting. We will consider the use of POD in a direct approach setting together with time-dependent PDEs. We can see that a naive application of POD will result in a reduced-order model that lacks the essential property to reflect derivative information of the original high-fidelity model. A remedy to overcome this is the inclusion of derivative information obtained from the high-fidelity model. We will see that the resulting ‘enriched’ reduced-order model has very beneficial properties. More specifically we obtain accurate approximations to the original problem of either forward derivatives or adjoint derivatives. Furthermore the derivatives will always be consistent even for changing parameter configurations.

Daniela Koller, Technische Universität Darmstadt (with Stefan Ulbrich)

Optimal flow control based on POD and MPC for the cancellation of Tollmien-Schlichting waves by plasma actuators

The occurrence of a transition in a flat plate boundary layer is characterized by the formation of growing disturbances inside the boundary layer, the Tollmien-Schlichting waves. Successful damping of these waves can delay transition for a significant distance downstream, lowering the skin friction drag of the body. We consider plasma actuators which induce a body force for active flow control. By optimal control of the plasma actuator parameters it is possible to reduce or even cancel the Tollmien-Schlichting waves and delay the turbulence transition. We present a Model predictive control (MPC) approach for the cancellation of Tollmien-Schlichting waves in the boundary layer of a flat plate. We use proper orthogonal decomposition (POD) for the low-order description of the flow model and the optimization of the control parameters is performed within the reduced system. Furthermore, we will show methods for improving the reduced model whose quality is verified in comparison to the results of a fine element-based simulation for the considered problem. Finally, we present our cancellation results with this MPC approach in a numerical simulation.

Jane Ghiglieri, Technische Universität Darmstadt (with Stefan Ulbrich)

Optimal control of hydroforming processes based on POD

The sheet metal hydroforming process is a complex forming process, which involves contact, friction and plasticity to manufacture curved sheet metal with bifurcated cross section. These sheet metal products are examined within the Collaborative Research Centre (CRC) 666. Mathematically, the sheet metal hydroforming process leads to an evolution quasi-variational inequality. We seek for optimal controls of the process relevant control variables, e.g., the time dependent blank holding force. Since the resulting VI-constrained optimization problem is very complex and computationally intensive, we apply model reduction techniques. We use Proper Orthogonal Decomposition (POD) to obtain a low-order model of the hydroforming process. Based on a Galerkin approximation and a semismooth reformulation we will discuss the derivation of a reduced model for the evolution variational inequality. Numerical results of a simplified engineering application for the optimal control of hydroforming processes will be presented.
number of variables. Modern statistical estimators developed over the past decade have statistical or sample complexity that depends only weakly on the number of parameters when there is some structure to the problem, such as sparsity. A central question is whether similar advances can be made in their computational complexity as well. In this talk, we propose strategies that indicate that such advances can indeed be made. In particular, we investigate greedy coordinate descent algorithms, and note that performing the greedy step efficiently weakens the dependence on the problem size provided the solution is sparse. We then propose a suite of methods that perform these greedy steps efficiently by a reduction to nearest neighbor search. We also develop a practical implementation of our algorithm that combines greedy coordinate descent with locality sensitive hashing, using which we are not only able to significantly speed up the vanilla greedy method, but also outperform cyclic descent when the problem size becomes large.

Prateek Jain, Microsoft Research Lab (with Indrjit Dhillon, Ambuj Tewari)

**Orthogonal matching pursuit with replacement**

In this paper, we consider the problem of compressed sensing where the goal is to recover almost all the sparse vectors using a small number of fixed linear measurements. For this problem, we propose a novel partial hard-thresholding operator that leads to a general family of iterative algorithms. While one extreme of the family yields well-known hard thresholding algorithms such as OMP (Iterative Thresholding with Inverse Hard Thresholding Pursuit), the other end of the spectrum leads to a novel algorithm that we call Orthogonal Matching Pursuit with Replacement (OMPR). OMP, like the classical greedy algorithm OMP, adds exactly one coordinate to the support at each iteration. We provide brief introduction to the classical variant and the criteria for OMP, also adding one coordinate to the support. This simple change allows us to prove that OMP has the best guarantees for sparse recovery in terms of the Restricted Isometry Property (a condition on the measurement matrix). Our proof techniques are novel and flexible enough to also permit the tightest known analysis of popular iterative algorithms such as CoSaMP and Subspace Pursuit.

David Woodruff, UC Davis (with Jean-Paul Watson, Roger Wets)

**Bundling scenarios in progressive hedging**

In this paper, we provide theoretical background and describe computational experience with schemes for bundling scenarios to improve convergence rates and reduce computational effort for Progressive Hedging (PH). Although the idea was floated (Wets 89, Wets 91) at about the same time PH was first described, it has received very little attention. As we will show, bundling can be an important component in PH. We provide brief introduction to the current residual. However, unlike OMP, OMPR also removes one coordinate from the support. This simple change allows us to prove that OMPR has the best guarantees for sparse recovery in terms of the Restricted Isometry Property (a condition on the measurement matrix). Our proof techniques are novel and flexible enough to also permit the tightest known analysis of popular iterative algorithms such as CoSaMP and Subspace Pursuit.

Jia Kang, Texas A&M University (with Carl Laird, Jean-Paul Watson, David Woodruff, Daniel Day)

**Parallel solution of structured nonlinear problems using Pyomo and PySP**

Nonlinear programming has proven to be an effective tool for dynamic optimization, parameter estimation, and nonlinear stochastic programming. However, as problem sizes continue to increase, these problems can exceed the computing capabilities of modern desktop computers using serial solution approaches. Block structured problems arise in a number of areas, including nonlinear stochastic programming and parameter estimation. Pyomo, an open-source algebraic modeling language, and PySP, a python-based stochastic programming framework, are used to formulate and solve these problems in parallel. In this work, we compare two approaches for parallel solution of these problems. Rockafellar and Wets' progressive hedging algorithm is used to solve the original parameter estimation problem. In the mixed-integer case, we use a parallel IP2OPT (a nonlinear interior-point package) used as the subproblem solver. As well, an internal decomposition approach that solves the structured linear KKT system in parallel is also used. We compare these parallel solution approaches with serial methods and discuss our experience working within Pyomo and PySP.

Jean-Paul Watson, Sandia National Laboratories (with Roger Wets, David Woodruff)

**Asynchronous progressive hedging**

Progressive Hedging (PH) is a scenario-based decomposition strategy for solving multi-stage stochastic programs. An attractive feature of PH is the ease with which it can be parallelized, by assigning sub-problems to each of many available processors; sub-problems may be linear programs, mixed-integer linear programs, or non-linear programs. The PH algorithm as stated parallelizes synchronously, in that all scenario sub-problems are solved before averages and sub-gradients are computed. However, for large-scale parallelization, such barrier synchronization leads to poor parallel efficiency, especially as sub-problems solve more independently. To address this issue, we introduce the Asynchronous Progressive Hedging (APH) algorithm, where updates are done without waiting for all scenario sub-problem solves to complete. APH is critical on parallel computing architectures that are inherently heterogeneous and unreliable, or when so many compute nodes are employed that at least one of them is likely to fail during execution. We show that key convergence properties of PH hold in APH, and report computational experiences on mixed-integer linear and non-linear stochastic programs.

Paul Kantor, Rutgers University (with Endre Boros, Fred Roberts, Brian Thomson)

**Labeled screening of public events: Models and challenges**

Public events must screen against many threats. Stakeholders’ interests diverge – owners seek revenue, patron experience, and safety against minor disturbances, and major attacks. Patrons seek to enjoy the game, to drink, etc. Events are protected by layers of agents (county police, stadium workers, etc.) and authorities, and with each part with its own screens. For each “violation” there are several terminologies. A guest with a knife, or beer may be asked to surrender the object, or go home. A cost matrix (C, e, s, J) depends on the state of the threat (harmless, etc.) and the terminal action imposed by the authorities (confiscate but admit; send home; arrest, etc.), as seen by stakeholders class J.

Given imperfect screens (metal detector; wand; dogs; pat-down; etc.) we seek optimal routing rules for arriving patrons. Assignment to further screens, and choice of actions, depends on results of earlier screens. One screened for metal may be labeled admit; wait; pat-down; etc. We need throughput for all patron classes, with acceptable costs for all. We give a polytope approach, a dynamic programming approach, rigorous results, and simulations.

Christian Klaus, Naval Postgraduate School (with Nedialko Dimitrov)

**Increasing network reliability by introducing warehouses**

Humanitarian assistance cargo is shipped by filling available space on regularly scheduled transportation routes. Regularly scheduled transportation can be modeled as a network consisting of source, destination, and transshipment nodes, where the edges represent the scheduled transportation routes. The edge capacities are random variables, the space available on a particular mission. An empirical distribution of the capacities can be obtained from historical data. For the stochastic nature of the network, an analysis of the network’s reliability in shipping cargo is done by sampling. The analysis shows sufficient ability to deliver the cargo. In order to increase the reliability of the network to ship cargo, we consider creating warehouses on selected transshipment nodes, where goods can be stored until space for further shipment is available. The introduction of the warehouses can be modeled using a network with multiple time layers. We address the question of how to select the best warehouse. The problem can be modeled as a two stage stochastic program, where the first stage decision variables select warehouse locations, including storage capacity.

Mehit Gelik, Georgia Institute of Technology (with Odem Ergun, Pinar Keskinocak)

**The post-disaster debris clearance problem with uncertain debris amounts**

In this study, we focus on the clearance stage of post-disaster debris management process, which spans the first few days following the disaster, when clearance resources are extremely limited. Given that a set of roads in the network are blocked, the objective is to determine the road clearance sequence in each period so that the total expected penalty due to unsatisfied relief commodity demand over all periods is minimized. We assume that the amount of debris to be cleared is uncertain, and that all scenario sub-problem solves before averages and sub-gradients are computed. However, for large-scale parallelization, such barrier synchronization leads to poor parallel efficiency, especially as sub-problems solve more independently. To address this issue, we introduce the Asynchronous Progressive Hedging (APH) algorithm, where updates are done without waiting for all scenario sub-problem solves to complete. APH is critical on parallel computing architectures that are inherently heterogeneous and unreliable, or when so many compute nodes are employed that at least one of them is likely to fail during execution. We show that key convergence properties of PH hold in APH, and report computational experiences on mixed-integer linear and non-linear stochastic programs.

**Stochastic optimization**

Organizer/Chair Nedialko Dimitrov, Naval Postgraduate School - Invited Session

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On a survivable network design problem with one or two failing links and elementary path-flows

A well known problem in survivable network design consists in minimizing the cost of links under a single link failure scenario (any link can fail but only one at a time) assuming flow restoration. The problem, denoted by FR, assumes bifurcated primary and restoration flows, and stub release (the capacity of links released by failing flows is used for restoration). FR can be expressed as a linear program but only in a non-compact formulation with NP-hard separation. Because of that, FR is regarded as NP-hard itself although this has not been proved. The paper considers a version of FR when only one predefined link or only two predefined links can fail. We assume that the primary paths cannot contain loops – an assumption commonly neglected. We show that the case with one failing link is polynomial while the case with two failing links is NP-hard. This is a new result that sheds light on FR also for the single link failure scenario. As a byproduct of the one-failing link case, we obtain an example of a non-compact LP formulation with NP-hard separation which actually describes a polynomial problem. Such an example has not been commonly known to the network design community before.

Gianluigi Carello, Politecnico di Milano (with Bernardetta Addis, Federico Malucelli)
A network loading problem with shared protection and SRG: Formulations and ILP based hybrid heuristics

Failure resiliency is an important issue in telecommunication networks. In real networks different links may share physical structures and therefore may be affected by the same physical fault. This complexity is captured by Shared Risk Groups (SRGs), which represent sets of links affected by the same fault. We focus on a shared protection scheme, according to which the backup capacity can be shared among different demands, provided that they are not affected by the same faults. We address a network loading problem where SRG and shared protection are considered. We propose a couple of mathematical models. As the problem seems extremely challenging from the computational point of view, we explore the possibility of adding some valid inequalities that have been successful in standard network design problem. Besides, we present some ILP based hybrid heuristic approaches. One approach considers the dynamic addition of constraints, while the other approach is based on a combination of greedy and local search. We report an extensive experimental comparison of all the proposed approaches.

Uwe Steglich, Chemnitz University of Technology (with Thomas Bauschert)
Robust multi-layer network design under traffic demand uncertainty

We present an mixed-integer linear programming approach for a multi-layer network design problem under traffic demand uncertainty. This problem arises in the planning of IP (Internet Protocol) based networks, where the IP routers are interconnected by logical links that are paths in an underlying transport network. The transport network in turn might consist of different layers and technologies, e.g., an OTN layer (with electrical switching capability on ODU granularity) and a DWDM layer (with pure optical switching capability on wavelength granularity) which allows for optimum grooming and layer bypassing. Demand uncertainty results from daytime usage fluctuations, user behavior and external effects like BGP route flapping or server load balancing mechanisms. Our approach considers the dynamic addition of constraints, while the other approach is based on a combination of greedy and local search. We report an extensive experimental comparison of all the proposed approaches.

Shanshan Zhang, Cornell University (with Adrian Lewis)
On second-order Fritz John type duality for variational problems

A second-order dual variational problem is presented. This dual uses the Fritz John type necessary optimality conditions instead of the Karush-Kuhn-Tucker type necessary optimality conditions and thus, does not require a constraint qualification. Weak, strong, Mangasarian type strict-converse, and Huard type converse duality theorems between primal and dual problems are established. A pair of second-order dual variational problems with natural boundary conditions is constructed, and it is briefly indicated that the duality results for this pair can be validated analogously to those for the earlier models dealt with in this research. Finally, it is pointed out that our results can be viewed as

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the dynamic generalizations of those for nonlinear programming problems, already treated in the literature.

Dmitry Drusvyatskiy, Cornell University (with Adrian Lewis)

Identifiability and the foundations of sensitivity analysis

Given a solution to some optimization problem, an identifiable subset of the feasible region is one that captures all of the problem’s behavior under small perturbations. Seeking only the most essential ingredients of sensitivity analysis leads to identifiable sets that are in a sense minimal. In particular, critical cones – objects of classical importance – have an intuitive interpretation as tangential approximations to such sets. I will discuss how this new notion leads to a broad (and intuitive) variational-analytic foundation underlying active sets and their role in sensitivity analysis.

Variational analysis

Diehard Pallaschke, Karlruhe Institute of Technology (KIT) (with Ryszard Urbanski)

Quasidifferential calculus and minimal pairs of compact convex sets

The quasidifferential calculus developed by V.F. Demyanov and A.M. Rubinov provides a complete analogue to the classical calculus of differentiation for a wide class of non-smooth functions. Although this looks at the first glance like a generalized subgradient calculus for pairs of subdifferentials it turns out that, after a more detailed analysis, the quasidifferential calculus is a kind of Fréchet-differentiations whose gradients are elements of a suitable Minkowski–Rådström–Hörmander space. Since the elements of the Minkowski–Rådström–Hörmander space are not uniquely determined, we mainly focused our attention to smallest possible representations of quasidifferentials, i.e. to minimal representations.

Adil Bagirov, University of Ballarat (with Ali A. Nuamah, Napsu Karmita, Nargi Sultanova)

Subgradient methods in nonconvex nonsmooth optimization

The subgradient method is known to be the simplest method in non-smooth optimization. This method requires only one subgradient and function evaluation at each iteration and it does not use a line search procedure. The simplicity of the subgradient method makes it very attractive. This method was studied for only convex problems. In this talk we will present new versions of the subgradient method for solving non-smooth nonconvex optimization problems. These methods are easy to implement. The efficiency of the proposed algorithms will be demonstrated by applying them to the well known nonsmooth optimization test problems.

Vladimir Goncharov, Universidad de Eova (with Giovanni Colombo, Boris Mordukhovich)

Well-posedness of minimal time problem with constant convex dynamics via differential properties of the value function

We consider a general minimal time problem with a constant convex dynamics in a reflexive Banach space, which can be seen as a mathematical programming problem. First, we obtain a general formula for the minimal time projection onto a closed set in terms of the dual mapping associated with the dynamics. Based on this formula we deduce then necessary and sufficient conditions of existence and uniqueness of a minimizer in terms of either dualityrotundity(equivalent to weak uniform rotundity of the dual space). In this work we extend the class of functions being rotund to a broad class of functions that are not necessarily rotund.

Gabriela Argiroffo, Universidad Nacional de Rosario (with Silvia Bianchi, Annegret Wagler)

The identifying code polyhedron of cycles

A subset \( C \) of vertices of a graph \( G \) is an identifying code of \( G \) if \( C \) intersects the closed neighbourhood of the vertices of \( G \) in different sets. The problem of finding minimum identifying codes arises from natural applications (fault detection in networks, fire detection and group tests, etc.). A complex and its study was introduced by Charbit, Habib and Levitin [1998]. We define the identifying code polyhedron of \( G \) as the convex hull of the integer solutions of \( M(G)x \geq 1 \), where \( M(G) \) is the matrix whose rows are the incidence vectors of the closed neighborhood of the vertices of \( G \) and their symmetric differences. In this work we present some results on the polyhedral structure of the identifying code polyhedron of a graph. In particular, this approach allows us to find a lower bound for the minimum cardinality of an identifying code of a graph that is tight for even paths and even cycles. We identify valid inequalities for the identifying code polyhedron of an arbitrary graph \( G \).
Finally, we study the identifying code polyhedron of cycles. In particular we identify their \{0, 1, 2\} facet defining inequalities.

Petru Valicov, LaBRI, University of Bordeaux (with Florent Foucaud, Sylvain Gravier, Reza Naserasr, Aline Parreau)

Complexity of identifying codes in some subclasses of perfect graphs

An identifying code \( C \) of a graph \( G = (V, E) \) is a subset of vertices of \( G \) such that it is a dominating set and every vertex of \( G \) is identified within \( C \). Formally speaking, let \( N(x) \) be the closed neighbourhood of a vertex \( x \) then \( u \in N(x) \) and \( v \in E \), \( N(u) \cap C \neq N(v) \cap C \). The concept of identifying codes was introduced by Karpovskiy et al. in 1998 and since then became a well-studied one.

Determining the size of a minimum identifying code of a graph \( G \) (denoted \( y^G \)) was previously proved to be \( \text{NP}\)-complete even for restricted classes of graphs. We prove that the edge-identifying code problem (i.e. identifying code problem in line graphs) is \( \text{NP}\)-complete even for the class of planar bipartite graphs of maximum degree 3 and arbitrarily large girth while the problem can be solved in linear time for graphs of bounded tree-width. As a corollary of this result we derive that the identifying code problem is \( \text{NP}\)-complete in a restricted subclass of perfect planar graphs. Moreover, for another family of perfect graphs - split graphs, the problem of computing the size of a minimum identifying code remains \( \text{NP}\)-complete.

Vishnu Narayanam, Indian Institute of Technology Bombay

Some properties of integer hulls of convex sets

We study properties of integer hulls of (unbounded) closed convex sets. We examine existence of facets, dimensions of faces and their properties, and derive results on representation of integer hulls using well studied sets. We derive necessary and sufficient conditions for semidefinite representation of these integer hulls.

Enrico Bartolini, University of Bologna (with Roberto Baldacci, Aristide Mingozzi)

The single-vehicle dial-a-ride problem

The single-vehicle dial-a-ride problem (SV-DARP) is a generalization of the traveling salesman problem with pickup and delivery (TSPPD) where the travel time between the visit of each pickup and the corresponding delivery cannot exceed a maximum ride time. The SV-DARP has several applications, e.g., in door-to-door transportation services for elderly or disabled people. We propose an exact algorithm that is based on a new mathematical formulation of the SV-DARP involving an exponential number of variables that correspond to the possible paths for each pickup-delivery pair. A valid lower bound is computed by a cut-and-column generation procedure that solves the LP relaxation of the mathematical formulation strengthened by valid inequalities. The resulting lower bound and the corresponding dual solution are used to generate all paths having reduced cost not greater than the gap between the lower bound computed and a known upper bound. The resulting integer problem is solved by means of an integer programming solver. We report on preliminary computational experiments over a large set of SV-DARP instances derived from the main TSPPD benchmark sets.

Rafael Martinielli, Pontificia Universidad Catolica do Rio de Janeiro (PUC-Rio) (with Diego Pecin, Marcus Poggi)

Efficient restricted non-elementary route pricing for routing problems

Column generation is present in the current most efficient approaches to routing problems. Set partitioning formulations model routing problems by considering all possible routes and selecting a subset of that visits all customers. This formulation often produces tight linear relaxation lower bounds and requires column generation for its pricing step. Recently the ng-routes were proposed as a compromise between elementary and non-elementary routes. The ng-routes are non-elementary routes with the restriction that following a customer it is not allowed to visit one that was visited before, if it belongs to a dynamically computed ng-set associated with this first customer. The larger the size of the ng-sets, the closer the ng-route is to an elementary route. This work presents an efficient pricing algorithm for ng-routes, which combines Decremental State-Space Relaxation (DSSR) technique with completion bounds. This allows strengthening the domination rule, drastically reducing the total number of labels. Experimental results are presented for the OVRP and CVRP. We report for the first time experimental results with ng-set sizes up to sixty-four obtaining several new best lower bounds.

Bartosz Rybicki, University of Wroclaw (with Jaroslaw Byrka)

Improved LP-rounding approximation algorithm for \( k \)-level uncapped facility location

We study the \( k \)-level uncapped facility location problem, where clients need to be connected with paths crossing open facilities of \( k \) types (levels). In this paper we give an approximation algorithm that for any constant \( k \), in polynomial time, delivers solutions of cost at most \( a_k \) times \( OPT \), where \( a_k \) is an increasing function of \( k \), with \( \lim_{k \to \infty} a_k = 3 \).

We improve the approximation ratio for \( k \)-UFL for all \( k \geq 3 \), in particular we obtain the ratio equal \( 2.02, 2.14, \) and \( 2.24 \) for \( k = 3, 4, \) and \( 5 \).

Sara Ahmadian, University of Waterloo (with Chaitanya Swamy)

Improved approximation guarantees for lower-bounded facility location

We consider the lower-bounded facility location (LBFL) problem, which is a generalization of uncapacitated facility location (UFL), where each open facility is required to serve a minimum amount of demand. More formally, an instance \( I \) of LBFL is specified by a set \( F \) of facilities with facility-opening costs \( \{c_f\} \), a set \( D \) of clients, a lower-bound \( M \), and connection costs \( \{c_{ij}\} \) specifying the cost of assigning a client \( j \) to a facility \( i \). The goal is to open a subset of facilities and assign each client to an open facility, so that each open facility serves at least \( M \) clients, in a cost-efficient manner.

We improve the current best approximation ratio for LBFL [550 by Switkina] to 83. Our improvement comes from a variety of ideas in algorithm design and analysis. Our chief algorithmic novelty is to reduce the more-structured LBFL instance to a problem we introduce, called
capacity-discounted UFL (CDUFL). CDUFL is a special case of capacitated facility location (CFL) where facilities are either uncapacitated, or have finite capacity and zero opening costs. We give a simple local-search algorithm for CDUFL that achieves the approximation ratio of $1 + \sqrt{2}$.

Complementarity & variational inequalities

Fri 2, MA 312

Variational inequality problems: Analysis and computation
Organizer/Chair: Vinayak Shanbhag, University of Illinois at Urbana-Champaign • Invited Session

Vinayak Shanbhag, University of Illinois at Urbana-Champaign (with Uma Ravat)

On the analysis and solution of stochastic variational inequalities

We consider the stochastic variational inequality problem in which the mappings contain expectations over a possibly general measure space and associated sets may be unbounded. In this talk, we consider two-stage problems. First, we provide tractable verifiable conditions for showing existence that do not necessitate integration. Important such conditions are provided for quasi-variational inequalities and complementarity problems and can further accommodate multi-valued maps and nonconvex sets. Second, we discuss some stochastic approximation schemes for monotone stochastic variational inequalities that incorporate regularization and allow for adaptive modifications of steplengths.

Che-Lin Su, University of Chicago Booth School of Business (with Yu-Ching Lee, Jong-Shi Pang)

Estimation of pure characteristics demand models with pricing

A pure characteristics model is a class of discrete-choice random-coefficients demand models in which there is no idiosyncratic logit error term. A consumer utility is a function of the attributes of the products. The absence of the logit error term leads to a nonsmooth formulation of the predicted market share equations. As a result, inverting the market share equations for the unobserved product characteristics and estimating the model by using the nested fixed-point approach as proposed in the existing econometrics literature becomes computationally intractable. We introduce lotteries for consumers’ purchase decisions, which are then characterized by a system of complementarity constraints. This reformulation leads to smooth market share equations. Based on this reformulation, we then cast the generalized method of moments (GMM) estimation of a pure characteristics model as a quadartic program with nonlinear complementarity constraints. We present numerical results to demonstrate the effectiveness of our approach.

Huifu Xu, University of Southampton (with Yongchao Liu, Werner Römisch)

Quantitative stability analysis of stochastic generalized equations and applications

We consider a stochastic generalized equation (SGE) where the underlying function is the expected value of a random set-valued mapping. SGE has many applications such as characterizing optimality conditions of a nonsmooth stochastic optimization problem and a stochastic equilibrium problem. We derive quantitative continuity of expected value of the set-valued mapping with respect to the variation of the underlying probability measure in a metric space. This leads to the subsequent qualitative and quantitative stability analysis of solution set mappings of the SGE. Under some metric regularity conditions, we derive Aubin’s property of the solution set mapping with respect to the change of probability measure. The approach is applied to study stability analysis of stationary points of classical one stage and two stage stochastic minimization problems, two stage stochastic mathematical programs with equilibrium constraints and stochastic programs with second order dominance constraints.

Fri 2, H 2038

Warmstarting interior point methods
Organizer/Chair: Jacek Gondzio, University of Edinburgh • Invited Session

Anders Skajaa, Technical University of Denmark (with Erling Andersen, Yinyu Ye)

Warmstarting the homogeneous and self-dual interior point method for linear and conic quadratic problems

We present two strategies for warmstarting primal-dual interior point methods for the homogeneous self-dual model when applied to mixed linear and quadratic conic optimization problems. Common to both strategies is their use of only the final (optimal) iterate of the initial problem and their negligible computational cost. This is a major advantage when comparing to previously suggested strategies that require a pool of iterates from the solution process of the initial problem. Consequently our strategies are better suited for users who use optimization algorithms as black-box routines which usually only output the final solution. Our two strategies differ in that one assumes knowledge only of the final primal solution while the other assumes the availability of both primal and dual solutions. We present extensive computational results showing work reductions when warmstarting compared to cold-starting in the range 30 to 75 percent depending on the problem class and magnitude of the problem perturbation. The computational experiments thus substantiate that the warmstarting strategies are useful in practice.

E. Alper Yildirim, Koc University

Warm-start strategies: What matters more?

The problem of solving a sequence of closely related optimization problems arises frequently in sequential optimization algorithms and branch-and-bound-like schemes. The information gained during the solution of an optimization problem can in principle be used to solve a closely related optimization problem with less computational effort. The proper use of this information constitutes warm-start techniques.
In this talk, our goal is to focus on the criteria in the design of warm-start strategies and to identify which ones are more closely related to the success in practice.

Pablo González-Breis, University of Edinburgh (with Jacek Gondzio)
A new warm-starting strategy for the primal-dual generation method

In this presentation a new warm-starting technique in the context of a primal-dual generation method application to solve a particular class of combinatorial optimization problems will be addressed. The technique relies on calculating an initial point and on solving auxiliary linear optimization problems to determine the step direction needed to fully restore primal and dual feasibilities after new columns arrive. Conditions on the maximum size of the cuts from the dual perspective and on a suitable initial point will be discussed. This strategy ensures that the duality gap of the warm-start is bounded by the old duality gap and a constant, which depends on the relation between the old and modified problems. Additionally, computational experience using this strategy will be reported.

Derivative-free & simulation-based opt.

Fr.i.R. 3802J
Multiple objectives in derivative-free optimization
Organizers/Chairs: Stefan Wild, Argonne National Laboratory; Luis Nunes Vicente, University of Coimbra - Invited Session

Fr.i.R. 3803A
Efficient cardinality/mean-variance portfolios
Luis Nunes Vicente, University of Coimbra (with Rui Pedro Brito)

We propose a novel approach to handle cardinality in portfolio selection, by means of a biobjective cardinality/mean-variance problem, allowing the investor to analyze the efficient tradeoff between return-risk and number of active positions. Recent progress in multibjective optimization without derivatives allows us to robustly compute (in-sample) the whole cardinality/mean-variance efficient frontier, for a variety of data and mean-variance risk measures. Our results show that a significant number of efficient cardinality/mean-variance portfolios can overcome out-of-sample the naive strategy, while keeping transaction costs relatively low.

Efficient cardinality/mean-variance portfolios

Ana Luisa Custodio, Universidade Nova de Lisboa (with Jose Aguiar Madeira, A. Ismael F. Vaz, Luis Nunes Vicente)

Direct MultiSearch: A robust and efficient approach to multibjective derivative-free optimization

In practical applications it is common to have several conflicting objective functions to optimize. Frequently, these functions exhibit non-differentiables, are subject to numerical noise or are of black-box type, requiring the use of derivative-free optimization techniques.

In 2011 we proposed a multibjective derivative-free methodology, called Direct MultiSearch (DMS), suited for this type of applications, which generalizes to multibjective optimization all direct-search methods of directional type. DMS is based on the search/poll framework, but uses the concept of Pareto dominance to maintain a list of nondominated points and to define a successful iteration. Under the common assumptions used in direct-search for single objective optimization, and without considering any aggregation function for the several objectives involved in the problem definition, we proved that at least one limit point of the sequence of iterates generated by DMS lies in the convex hull of the Pareto front. Extensive computational experience has shown, however, that DMS has an impressive capability of generating the whole Pareto front.

Risk management under probability model misspecification
Organizers/Chairs: Apostolos Fertis, ETH Zurich; Victor Demiguel, London Business School - Invited Session

David Wobis, Technische Universität München

Robustifying convex risk measures: A non-parametric approach

We introduce a framework for robustifying portfolio selection problems with respect to ambiguity in the distribution of the random asset losses. In particular, we are interested in convex, version independent risk measures. We use an ambiguity set which is defined as a neighborhood around a reference probability measure which represents the investors beliefs about the distribution of asset losses. The robustified risk measures are defined as the worst case portfolio risk over the ambiguity set of loss distributions. We demonstrate that under mild conditions, the infinite dimensional optimization problem of finding the worst case risk can be solved analytically and consequently closed form expressions for the robust risk measures are obtained. We use these results to derive robustified versions for several examples of risk measures. The resulting robust policies are computationally of the same complexity as their non-robust counterparts. We conclude with a numerical study that shows that in most instances the robustified risk measures perform significantly better out-of-sample than their non-robust variants in terms of risk, expected losses as well as turnover.

Victor Demiguel, London Business School (with Francisco Nogales, Raman Uppal)

Stock return serial dependence and out-of-sample portfolio performance

We study whether investors can exploit stock return serial dependence to improve the out-of-sample performance of their portfolios. To do this, we first show that a vector autoregressive (VAR) model captures daily stock return serial dependence in a statistically significant manner. Second, we characterize [analytically and empirically] the expected return of an arbitrage (zero-cost) portfolio based on the VAR model, and show that it compares favorably to that of other arbitrage portfolios in the literature. Third, we evaluate the performance of three investment (positive-cost) portfolios: a conditional mean-variance myopic portfolio obtained using the linear VAR model; a conditional mean-variance portfolio using a nonparametric autoregressive (NAR) model; and, a portfolio that is dynamic rather than myopic in its use of the VAR model. We show that, subject to a suitable norm constraint, all three investment portfolios substantially outperform the traditional (unconditional) portfolios, even in the presence of transaction costs of up to 10 basis points.

Risk management under probability model misspecification

Fr.i.R. 3802A

Generalized Nash equilibrium problems
Organizer/Chair: Kenneth Judd, Hoover Institution - Invited Session

Philipp Romer, Universität Zürich (with Eftihios Coutsoulas)

Computing generalized Nash equilibria by polynomial programming

We present a new way to solve generalized Nash equilibrium problems. We assume the feasible set to be closed and compact. Furthermore all functions are assumed to be rational. However we do not need any convexity assumptions on either the utility functions or the action sets using a nonparametric autoregressive (NAR) model; and, a portfolio that is dynamic rather than myopic in its use of the VAR model. We show that, subject to a suitable norm constraint, all three investment portfolios substantially outperform the traditional (unconditional) portfolios, even in the presence of transaction costs of up to 10 basis points.

Testing rationality: algorithms and complexity

Frits Spieksma, KU Leuven (with Bart Smolders)

Microeconomic theory offers non-parametric tests that show whether observed data are consistent with a model of utility maximization. For instance, it is well-known that, given a dataset, it can be efficiently tested whether the generalized axiom of revealed preference (GARP) holds. The outcome of such a test is binary: data either satisfy GARP or they don’t. An implication of such an approach is that when the data do not pass the test, there is no indication concerning the severity or the amount of violations. A number of approaches have been proposed in the literature to express how close a dataset is to satisfying rationality. One popular approach is Afriat’s efficiency-index. Several alternative measures have been proposed, amongst others by Houthan and Maks, and by Varian. For the latter two indices, it is empirically recognized in the literature that finding these measures is computationally intensive. We show that computing these maximum efficiency-indices is an NP-hard problem. We also show that no constant-factor approximation algorithm exists for the Houthan-Maks index unless P = NP.

Testing rationality: algorithms and complexity

Fr.i.R. 3801

Finance & economics

Finance & economics
Finally, we give an exact polynomial time algorithm for finding the Aflati index.

Eleftherios Cazanavos, Universität Zürich

Finding well generalized Nash equilibria

Often a generalized Nash equilibrium problem has infinitely many solutions and commonly the solution set isn’t connected. The current method is then to only compute the normalized equilibrium in which the Lagrange multipliers are equal. This is only one solution out of a continuum of Nash equilibria which is a subset of the solution set. For problems with linear constraints an approach is shown where all solutions are given as a union of sets. For this a modified simplex algorithm is used to yield a vertex representation of the equilibrium subsets. The implementation is then used to compute some popular examples.

Fernando Ordonez, Universidad de Chile (with Tomas Spencer)

A mean-risk model for the stochastic traffic assignment problem

We embark on an agenda to investigate how stochastic travel times and risk aversion transform the traditional traffic assignment problem and its corresponding equilibrium concepts. Moving from deterministic to stochastic travel times with risk-averse users introduces non-convexities that make the problem more difficult to analyze. For example, even computing a best response of a user to the environment is still of unknown complexity. This paper focuses on equilibrium existence and characterization in the different settings of infinitesimal (non-atomic) vs. atomic users and fixed [exogenous] vs. congestion-dependent (endogenous) variability of travel times. Because cost functions are non-additive, solutions need to be represented as path flows. Nevertheless, we show that succinct representations of equilibria and optimal solutions always exist. We also obtain that exogenous variability of travel times, the worst-case inefficiency of equilibria (the price of anarchy) is exactly the same as when travel time functions are deterministic, meaning that in this case risk-aversion under stochastic travel times does not further degrade a system in the worst-case.

Nicolas Stier-Moses, Columbia University (with You Gu)

The competitive facility location problem in a duopoly: Advances beyond trees

We consider a competitive facility location game on a network where consumers located on vertices wish to connect to the nearest facility. Knowing this, competitors place facilities on vertices to maximize market share. Focusing in the two-player case, we study conditions that guarantee the existence of pure-strategy Nash equilibria for progressively more complicated networks. The case of trees, which extends the classic Hotelling model, is well-studied: equilibria are characterized by centroids of the tree. We find that cycles admit equilibria when there are vertices with sufficiently big demands. For a general graph, we construct a tree of maximal bi-connected components and apply the results for trees and cycles to get sufficient conditions for equilibrium existence. This provides a complete and efficient characterization of equilibria for networks where the central bi-connected component is a vertex or a cycle. We quantify the maximum inefficiency of equilibria with bounds that depend on topological parameters of the network. These bounds rely on trees, which are worst instances because for these games removing an edge from a graph always increases consumer cost.

Fernando Ordonez, Universidad de Chile (with Tomas Spencer)

Stackelberg security games on networks

Stackelberg games have recently been used in security applications to decide optimal patrolling strategies in the presence of strategic adversaries that can monitor the security actions prior to deciding on how and where to attack. By using column generation and other decomposition methods we have been able to solve large enough problems to consider interesting real world situations.

These methods, however, break down as the number of adversarial actions grows. In this work we consider the problem of patrolling a network where we decide the optimal location of fixed guards and the adversaries select a feasible path to attack. We develop decomposition algorithms to solve this problem and study the conditions for this algorithm to be exact. In particular we show that in the non zero-sum case this standard decomposition method can get stuck on a sub-optimal solution.

Leandro Prudêncio, State University of Campinas (with Estevão Bingis, José Mario Martínez)

An augmented Lagrangian method with finite termination

We will present a new algorithm based on the Powell-Hestenes-Rockafellar Augmented Lagrangian approach for constrained global optimization. Possible infeasibility will be detected in finite time. Further, we will introduce a practical stopping criterion that guarantees that, at the approximate solution provided by the algorithm, feasibility holds up to some prescribed tolerance and the objective function value is the optimal one up to tolerance ε. At first, in this algorithm, each sub-problem is solved with a precision ε that tends to zero. An adaptive modification in which optimality subproblem tolerances depend on current feasibility and complementarity will also be given. The adaptive algorithm allows one to detect possible infeasibility without requiring to solve suproblems with increasing precision. In this way, we aim rapid...
detection of infeasibility, without solving expensive subproblems with unreliable precision.

Luís Felipe Bene, University of Sao Paulo (with Ernesto Birgin, Natasa Krajčić, José Maria Martínez)

Low order-value approach for solving VaR-constrained optimization problems

In low order-value optimization (LOVO) problems the sum of the r smallest values of a finite sequence of q functions is involved as the objective to be minimized or as a constraint. The latter case is considered in the present paper. Portfolio optimization problems with a constraint on the admissible value-at-risk (VaR) can be modeled in terms of LOVO-constrained minimization. Different algorithms for practical solution of this problem will be presented. Global optimization properties of both the problem and the presented algorithms will be discussed. Using these techniques, portfolio optimization problems with transaction costs will be solved.

Marina Andretta, University of Sao Paulo (with Ernesto Birgin)

Deterministic and stochastic global optimization techniques for planar covering with ellipses problems

We are interested in the problem of planar covering of points with ellipses: we have a set of n demand points in the plane (with weights associated to them), a set of m ellipses (with costs associated to their allocation) and we want to allocate k of these ellipses and cover some demand points to get the maximum profit. The profit is measured by summing the weight of the covered demand points and subtracting the costs of the allocated ellipses. Ellipses can have a fixed angle or each of them can be freely rotated. We present deterministic global optimization methods for both cases, while a stochastic version of the method will also be presented for large instances of the latter case. Numerical results show the effectiveness and efficiency of the proposed methods are presented.

Global optimization

Fri. 2.H 2013

Advances in global optimization V
Chair Zulfiya Gabidullina, Kazan (Volga Region) Federal University

Giancarlo Bigi, Università di Pisa (with Antonio Frangioni, Qinghua Zhang)

Beyond canonical DC programs: The single reverse polar problem

We introduce the single reverse polar problem as a novel generalization of the canonical DC problem (CDC), and we extend to the former the outer approximation algorithms based on an approximated oracle, which have been previously proposed for the latter. In particular, we focus on the polyhedral case (PSRP), in which the problem amounts to a linear program in a single bilinear constraint which renders it nonconvex. Several important classes of nonconvex optimization problems (e.g., bilevel linear, integer and linear complementarity problems) can be easily formulated as PSRPs. In principle, this is true also for CDC, as most nonconvex programs have a DC representation, but the formulation as a DC program is substantially more difficult to derive. Furthermore, the outer approximation algorithms for PSRP do away with some of the core assumptions required by the algorithms for the CDC case: These assumptions are not trivial to satisfy in practice and indeed cannot hold for some important classes of problems.

Simon Kanz coc, Universität Wien (with Arnold Neumaier)

Numerical enclosures of solution manifolds at near singular points

This work considers nonlinear real parameter-dependent equations for global optimization. By using interval analysis rigorous enclosures of solution paths dependent on a parameter are determined. Especially the method provides enclosures of (near) singular points of the solution manifold. The method uses an augmentation of the original problem to correct the singularities. Then a low-dimensional problem is deduced of the augmented problem which reflects locally the behaviour of the original problem. In particular the singular behaviour is reflected. The application of the method is illustrated with some numerical results to show the efficiency and robustness of the method.

Zulfiya Gabidullina, Kazan (Volga Region) Federal University

Universal measure of the thickness of separator or pseudo-separator for sets of Euclidean space

At present, different approaches to linear separation of the sets in a finite-dimensional Euclidean space are effectively used in medical diagnostics, discriminant analysis, pattern recognition etc. These approaches represent a particular interest from both theoretical and practical points of view.

In this contributed talk we define a separator and pseudo-separator (the margin of unseparated points of sets) for the sets of Euclidean space by help of generalized supporting hyperplanes. We introduce new universal measure for estimation of the thickness of separator (when the sets are disjoint) as well as of pseudo-separator (when the sets are inseparable). The optimization problem maximizing the thickness of the separator and minimizing the thickness of the pseudo-separator is considered.

Implementations & software

Conic linear programming
Organizer/Chair Christoph Helmberg, TU Chemnitz - Invited Session

Christoph Helmberg, TU Chemnitz (with Kim-Chuan Toh)

Speeding up the spectral bundle method by solving the quadratic semidefinite subproblems with a PSQMR approach

The spectral bundle method is tuned to solving semidefinite programs (SDP) with large semidefinite matrix variables having constant or bounded trace. It exploits that these can be formulated equivalently as problems of minimizing the maximum eigenvalue of affine matrix functions and uses repeated eigenvalue computations to form a semidefinite model of the objective function. The next candidate point is determined as the minimizer of the model plus a quadratic augmenting term. Solving this quadratic semidefinite subproblem by interior point methods formed the bottleneck whenever bundle sizes increased. We report on our experience with a preconditioned symmetric quasi minimal residual (PSQMR) approach for computing the Newton step in this interior point method like in the package QSDP. On our test instances this results in significant savings. Indeed, the cost of the interior point method is then negligible in comparison to the cost of computing the eigenvalues and the cost matrices of the quadratic semidefinite subproblem. In combination with cutting plane approaches, however, results are less favorable and better preconditioning techniques still need to be developed.

Florian Jarre, Universität Düsseldorf (with Thomas Davi)

Solving large scale problems over the doubly nonnegative cone

We consider large scale problems over the doubly nonnegative cone. Under suitable assumptions, regularity of the standard reformulation splitting the doubly nonnegative variable into a semidefinite and a nonnegative part can be established. The application of first order methods to this reformulation of problems over the doubly nonnegative cone is motivated by the fact that the cost per iteration does not increase by adding nonnegativity constraints. Preliminary numerical experiments illustrate that even for large scale problems highly accurate numerical solutions can be obtained.

Kim-Chuan Toh, National University of Singapore (with Kaileng Jiang, Defeng Sun)

An inexact accelerated proximal gradient method for large scale convex quadratic SDP

The accelerated proximal gradient (APG) method has proven to be highly efficient in solving some large scale structured convex optimization (possibly nonsmooth) problems, including nuclear norm minimization. The method has superior worst-case iteration complexity over the classical projected gradient method, and usually has good practical performance on problems with appropriate structures. Here, we extend the APG method to the inexact setting where the subproblems are only solved approximately, and show that it enjoys the same worst-case iteration complexity as the exact counterpart if the subproblems are progressively solved to sufficient accuracy. We apply our inexact APG method to solve convex quadratic SDP (QSDP) problems of the form: \[
\min \left\{ \frac{1}{2} x^T Q x + c^T x \mid A(x) = b, x \geq 0 \right\}
\]
where \(A\) in each iteration is solved by a semismooth Newton-CG (SSNCG) method with warm-start using the iterate from the previous iteration. Our APG-SSNCG method is demonstrated to be efficient for QSDP problems whose positive semidefinite linear maps \(Q\) are highly ill-conditioned.

Trends in integer programming
Organizer/Chair Jan Lee, University of Michigan - Invited Session

Amitabh Basu, University of California, Davis (with Robertilde Hildebrand, Matthias Koeppe, Marco Molinaro)

\(A(\cdot) - 1\)-slope theorem for the \(k\)-dimensional infinite group relaxation

We prove that any minimal valid function for the \(k\)-dimensional infinite group relaxation that is piecewise linear with at most \(k + 1\) slopes and does not factor through a linear map with non-trivial kernel is ex-
treme. This generalizes a theorem of Gomory and Johnson for \( k = 1 \), and Corneljols and Molinaro for \( k = 2 \).

Siyuan Shen, University of Michigan

Bilevel interdiction and risk-and-return tradeoffs in probabilistic programs with single or multiple chance constraints

Chance-constrained programs (CCP) measure value-at-risk of uncertain events, and impose a pre-given tolerance as an upper bound for such a risk. This paper focuses on problems with discretely distributed right-hand-sides in the chance constraints, and trades off risk and cost by also treating risk tolerances as decision variables. We first consider a problem with a single chance constraint in a bilevel interdiction setting, in which a leader decides a risk tolerance, to maximize a follower’s objective of a minimization CCP. We show that only a finite number of possible constraint thresholds matter to the follower’s CCP, and interpret the risk tolerance variable as SOS1 binary variables. The bilevel program is then transformed into a deterministic IP. Similar results are used for solving a minimization problem with multiple chance constraints, where each has a risk tolerance variable and the summation of all tolerances is no more than a fixed budget. We develop an IP reformulation with multiple SOS1 binary variables, and solve it via decomposition and modified Bender’s cuts.

Christopher Ryan, University of Chicago (with Albert Xin Jiang, Kevin Leyton-Brown)
Computing pure Nash equilibria in symmetric games

We analyze the complexity of computing pure strategy Nash equilibria (PSNE) in symmetric games with a fixed number of actions. We restrict ourselves to “compact” representations, meaning that the number of players can be exponential in the representation size. We give polynomial-time algorithms for finding a sample PSNE and counting the number of PSNEs.

Gennadiy Averkov, University of Magdeburg (with Christian Wagner, Robert Weismantel)

Continuous evolution of lattice polytopes

The sets of lattice points in normal polytopes, a.k.a. the homogenized Hilbert bases, model (continuous) convex polytopes. The concept of a normal polytope does not reduce to simpler properties — known attempts include unimodular triangulation and integral Carathéodory properties. To put it in other words, normal polytopes are the monads of quantization of convex shapes. Much work went into understanding special classes of normal polytopes, mostly from combinatorial commutative algebra, toric algebraic geometry, integer programming. In this talk we define a space of all normal polytopes. It is generated by certain dynamics, supported by these polytopes. The corresponding evolution process of normal polytopes was used back in the late 1990s to explain the high-resolution protein structures determination from biophysical methods. The triangle closure is a polyhedron and has been a standing open problem to decide whether the closures associated with certain families of lattice-free sets are polyhedra. For a long time, the only result known was the celebrated theorem of Cook, Kannan and Schrijver who showed that the split closure is a polyhedron. Although some fairly general results were obtained by Andersen, Louveaux and Weismantel “An analysis of mixed integer linear sets based on lattice point free convex sets” (2010), some basic questions have remained unresolved. For example, maximal lattice-free triangles are the natural family to study beyond the family of splits and it has been a standing open problem to decide whether the triangle closure is a polyhedron. We resolve this question by showing that the triangle closure is indeed a polyhedron, and its number of facets can be bounded by a polynomial in the size of the input data.

Robert Hildebrand, University of California, Davis (with Amitabh Basu, Matthias Köppe)

The triangle closure is a polyhedron

Recently, cutting planes derived from maximal lattice-free convex sets have been studied intensively by the integer programming community. An important question in this research area has been to decide whether the closures associated with certain families of lattice-free sets are polyhedra. For a long time, the only result known was the celebrated theorem of Cook, Kannan and Schrijver who showed that the split closure is a polyhedron. Although some fairly general results were obtained by Andersen, Louveaux and Weismantel “An analysis of mixed integer linear sets based on lattice point free convex sets” (2010), some basic questions have remained unresolved. For example, maximal lattice-free triangles are the natural family to study beyond the family of splits and it has been a standing open problem to decide whether the triangle closure is a polyhedron. We resolve this question by showing that the triangle closure is indeed a polyhedron, and its number of facets can be bounded by a polynomial in the size of the input data.
problem arises in the interpretation of live cell video data. We give approximation algorithms and hardness for the problem. Our algorithm is based on the fractional local ratio technique. In order to obtain a good approximation ratio we uncover and exploit properties of the extreme points of a linear program formulation for our problem.

Sandro Andreatta, FUL Berlin (with Gunter Klia, Knut Reiner)

De novo peptide sequencing with mathematical programming

Peptide sequencing from mass spectrometry data is a key step in proteome research. Especially de novo sequencing, the identification of a peptide from its spectrum alone, is still a challenging problem. We developed a fast and flexible algorithm based on mathematical programming. It builds on the widely used spectrum graph model and can be combined with a variety of scoring schemes. In the graph theoretical formulation the problem corresponds to the longest antisymmetric path problem in a directed acyclic graph. Other algorithms like PepNovo or NovoHMM can solve this problem only for the special case where conflicting node-pairs are non-interleaving. We combine Lagrangian relaxation with an adaptation of Yen’s k-shortest paths algorithm to compute suboptimal solutions. This approach shows a significant improvement in running time compared to mixed integer optimization approach with previous solutions being cut off using additional constraints and performed at the same speed like existing de novo sequencing tools. Furthermore we implement a generic probabilistic scoring scheme that can be trained for a dataset of annotated spectra and is independent of the mass spectrometer type.

Arnaud den Boer, Centrum Wiskunde & Informatica (with Bert Zwart)

Simultaneously learning and optimizing in dynamic pricing and revenue management

‘Dynamic pricing’ refers to practices where the selling price of a product is not a fixed quantity, but can easily be adjusted over time and adapted to changing circumstances. In an online sales channel, the availability of digital sales data enables firms to continuously learn about consumer behavior, and optimize pricing decisions accordingly. As a result, estimation and optimization can be considered simultaneously; the problem then is not only to optimize profit, but also to optimize the ‘learning process’. A key question in these problems is whether a learning-by-doing approach - always choosing the optimal price w.r.t. current estimates - has a good performance, or whether the decision maker should actively experiment in order to improve his/her knowledge on consumer behavior.

We show that when finite inventory is sold during finite selling seasons, learning-by-doing performs well, and give a bound on the regret which quantifies the cost for learning. In contrast, in a setting with no inventory restrictions, active experimentation is necessary for optimal learning. We offer an explanation why in these two models, the cost for learning behaves differently.

James Davis, Cornell ORIE (with Guillermo Gallego, Husayn Topaloglu)

Assortment optimization under variants of the nested logit model

We study a class of assortment optimization problems where customers choose among the offered products according to the nested logit model. There is a fixed revenue associated with each product. The objective is to find an assortment of products to offer that maximizes the expected revenue per customer. There are several variants of the nested logit model and the tractability of the optimization problem depends on which variant is used. The problem is solvable when the range of the nest dissimilarity parameters are between zero and one, and nests do not contain a no purchase option. By removing either of these restrictions the problem becomes NP-hard. However, in these other variants we are able to develop algorithms with desirable worst-case performance guarantees. Of particular note is a data independent approximation algorithm when the nest dissimilarity parameters are restricted to be between zero and one. The algorithms we propose across all variants perform well in computational experiments, generating solutions within a fraction of a percent of optimal.

James Davis, Cornell ORIE (with Guillermo Gallego, Huseyin Topaloglu)

Assortment optimization under variants of the nested logit model

The objective is to find an assortment of products to offer that maximizes the expected revenue per customer. There are several variants of the nested logit model. There is a fixed revenue associated with each product. The optimization problem depends on the fractional local ratio technique. In order to obtain a good approximation ratio we uncover and exploit properties of the extreme points of a linear program formulation for our problem.
Due to the difficulty of solving these problems directly, most approaches in the literature focus on approximations or relaxations. In our research we aim at solving them to global optimality. The solver used in the computational test implements a spatial branch and bound algorithm to find global optimality for tractable MINLPs.

Concerning nonconvexities and integrality as well as the size of networks and time horizon, the general-purpose solver cannot find a primal solution within 24 hours. In this talk, we present several primal heuristics creating fully feasible solutions.

Harald Held, Siemens AG

Challenges and requirements for MINLPs in industrial applications

Practitioners often face the question how to operate, e.g., a plant, a network, or a manufacturing process. In many cases, modeling this as a mathematical optimization problem supports the operator to find a good, ideally best, operating decision. Since there are many well developed mixed-integer linear programming (MILP) solvers, this is what has so far typically been used to provide an operator with good decisions in reasonable time.

However, in many industrial applications, describing a system’s physical behavior involves non-linear functions. In these cases, simplification to an MILP could mean a significant loss of accuracy. As a matter of fact, the algorithm solves a very simple separable convex programming problem with multiple CVaR constraints. In each step, the algorithm solves a very simple separable convex quadratic program. The algorithm extends to the case where the objective is a utility function with mean return and a weighted combination of a set of spectral risk constraints, or maximum of a set of spectral risk functions. We report numerical results that show that our proposed algorithm is very efficient, and is at least two orders of magnitude faster than the state of the art general purpose solver for all practical instances.

Carlos Abad, Columbia University (with Garud Iyengar)

Portfolio selection with multiple spectral risk constraints

We propose an iterative algorithm to efficiently solve the portfolio selection problem with multiple CVaR constraints. In each step, the algorithm solves a very simple separable convex quadratic program. The algorithm extends to the case where the objective is a utility function with mean return and a weighted combination of a set of spectral risk constraints, or maximum of a set of spectral risk functions. We report numerical results that show that our proposed algorithm is very efficient, and is at least two orders of magnitude faster than the state of the art general purpose solver for all practical instances.

Carlos Abad, Columbia University (with Garud Iyengar)

Nonlinear programming

Optimality conditions I

Chair Andrei Dmitruk, Russian Academy of Sciences

Feyzullah Abmetov, Giresun University

Necessary conditions for a convex programming problem in Banach spaces partially ordered by a cone with empty interior

The existence of saddle point of the Lagrange function for a convex programming problem in Banach spaces ordered by a cone with empty interior is established under strong stationarity condition. As a consequence the Kuhn-Tucker conditions are derived. It is shown that the Slater and the strong stationarity conditions are equivalent if the cone determining the partial order has an interior.

Kalpana Shukla, Banaras Hindu University, Varanasi, India (with Shashi Mishra)

Global parametric sufficient optimality conditions for semi-finite discrete minimax fractional programming involving generalized \( V_{p,q} \)-invex functions

In this paper, we have considered semi-finite discrete minimax fractional programming problems

\[
\text{Minimize } \frac{f(x)}{g(x)} \\
\text{Subject to } G_j(x,t) \leq 0, \forall t \in T_j, \quad j \in I_p, \quad H_k(x,s) = 0, \forall s \in S_k, \quad k \in I_q, \quad x \in X,
\]

where \( p, q \) and \( r \) are positive integers, \( X \) is an open convex subset of \( R^n \) (n-dimensional Euclidean space), for each \( j \in I_p \), \( q \) and \( r \) are real-valued functions defined on \( X \),\( k \in I_q \), and \( g \) is a real-valued function defined on \( X \), for each \( j \in I_p \), \( q \) and \( r \) are real-valued functions defined on \( X \),\( k \in I_q \), and \( g \) is a real-valued function defined on \( X \) for all \( s \in S_k \) for each \( x \) and \( s \) for each

Andrei Dmitruk, Russian Academy of Sciences (with Nikolai Osmdnovskii)

Conditions for a weak minimality in optimal control problems with integral equations of Volterra type

On a time interval \([0, T]\) consider the problem

\[
x(t) = x(0) + \int_0^t f(t,s,x(s),u(s))ds,
\]

\[
\eta_j(p) = 0, \quad j = 1, \ldots, m, \quad \psi_i(p) \leq 0, \quad i = 1, \ldots, \nu, \quad J = \psi(p) \to \min
\]

where \( p = (x(0),x(T),x) \in R^n, \quad u \in R^u \). Theorem 1 (First order necessary conditions). Let a process \( \hat{w} = (\hat{k}(t), \hat{u}(t)) \) provide a weak minimum. Then

\[
\exists (\alpha_0, \ldots, \alpha_\nu) \geq...
\]
0, \( (\beta_1, \ldots, \beta_n) \) not all zero, and \( n \)–vector function \( \psi(t) \) satisfying the conditions:
\[
\psi(s) = \int_t^s \left( \dot{\psi}(t) f_s(t, s, \dot{x}(s), \ddot{x}(s)) dt - \psi(T) f_s(T, s, \dot{x}(s), \ddot{x}(s)) \right),
\]
where
\[
\psi(0) = \lambda_0, \quad \psi(t) = \lambda_t,
\]
where
\[
l(\rho) = \sum_i \alpha_i \phi_i(\rho) + \sum_j \beta_j \eta_j(\rho).
\]
We also give second order necessary and sufficient conditions.

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**Nonlinear programming**

Fast gradient methods for nonlinear optimization and applications I
Organizer/Chair William Hager, University of Florida - Invited Session
Zhang Hongchao, Louisiana State University (with William Hager)
An adaptive preconditioned nonlinear conjugate gradient method with limited memory
An adaptive preconditioner is developed for the conjugate gradient method based on a limited memory BFOS matrix. The preconditioner is only used when the iterates lie in an ill-conditioned subspace, otherwise, the usual conjugate gradient algorithm is applied. The resulting algorithm uses less memory and has lower computational complexity than the standard L-BFGS algorithm, but performs significantly better than either the conjugate gradient method or the L-BFGS quasi-Newton method for the CUTEr test problems.

A sequential quadratic programming method without a penalty function or a filter for general nonlinear constrained optimization
We present a primal–dual interior-point method without using a penalty function or a filter for solving the constrained optimization with general equality and inequality constraints. The method combines the interior-point approach with a sequential quadratic programming without using a penalty function or a filter. The algorithm is terminated with an approximate KKT point or is stopped with a singular stationary point or an infeasible stationary point. We adopt several numerical techniques for solving subproblems and updating strategy to ensure the algorithm suitable for large scale problems. The numerical experiments with CUTEr collection show that the algorithm is efficient.

Gerardo Toraldo, University of Naples Federico II (with Roberta de Asmundis, Daniela di Serafino)
On the use of spectral properties of the steepest descent method
In the last two decades the innovative approach of Barzilai and Borwein (BB) has stimulated the design of faster gradient methods for function minimization, which have shown to be effective in applications such as image restoration. The surprising behaviour of these methods has been partially justified, mostly in terms of the spectrum of the Hessian matrix. On the other hand the well known ability of the Cauchy Steepest Descent (SD) to reveal second order information about the problem has been little exploited to modify the method in order to design more effective gradient methods. In this work we show that, for convex quadratic problems, second order information provided by SD can be exploited to improve the usually poor practical behaviour of this method, achieving computational results comparable with those of BB, with the further advantage of monotonic behaviour. Our analysis also provides insight into the relaxed gradient method by Raydan and Svaiter.

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**Non-smooth optimization**

Non-smooth optimization and applications
Organizer/Chair Dominikus Noll, Université de Toulouse - Invited Session
Dominikus Noll, Université de Toulouse
Non-convex bundle algorithm with inexact sub-gradient and function values
We discuss a non-convex bundle method where function values and subgradients are available only up to an error \( \epsilon \), which remains unknown to the user. We show that even in that situation one can still assure (under practical hypotheses) that every accumulation point \( x^* \) of the sequence \( x^\nu \) of serious iterates is approximate critical in the sense that
\[
\theta \in \partial \psi(x^\nu) + \epsilon \partial B,
\]
where \( B \) is the unit ball, and where the final precision \( \epsilon \) depends on the error precision \( \epsilon \) of function and subgradient values. In the realm of convex bundle results of this flavor have been pioneered by Hintermüller and Kiwiel. The principal new difficulty in non-convex bundling it to provide a substrate for the convex cutting plane mechanism, and this problem was solved by the author for a large class of problems including all instances of practical interest. Here we discuss the more specific case of downshifted tangents, an oracle which we used successfully in a variety of applications in automatic control.

Frank Fischer, Chemnitz University of Technology (with Christoph Helmberg)
An asynchronous parallel bundle method for Lagrangian relaxation
Lagrangian relaxation is frequently used for decomposing discrete optimization problems and the standard parallel approach would solve these problems in parallel. Here we propose a different approach that optimizes, asynchronously in parallel, subspaces of multipliers that are selected dynamically. The algorithm starts several parallel processes and in a kind of parallel coordinated descent each process selects a subspace with large predicted decrease. Then each process optimizes the associated multipliers independently until a certain improvement level has been achieved and writes its solution back to the global data. Because this improvement may lead to increased violation of other constraints, the algorithm automatically detects and tracks these dependencies and respects them in future subspace selections ensuring global convergence. Preliminary computational results show that the presented approach may be turned into a viable alternative for applications of practical relevance.

Endre Bjøndal, NHH Norwegian School of Economics (with Mette Bjøndal)
Congestion management in the Nordic electricity market
Presently in the Nordic day-ahead market, zonal pricing or market splitting is used for congestions between a predetermined set of price areas. Intra-zonal congestion is resolved by counter trading or redscheduling in the regulation market. We study aggregation choices when simplifying nodal prices into zonal or area prices. We discuss two different aggregation concepts, which we call economic and physical aggregation, and their relation to optimal nodal prices. In a model of the Nordic electricity market we consider an hourly case from winter 2010 and present analyses of the effects of different congestion management methods on prices, quantities, surpluses and network utilization.

Linda Rud, NHH Norwegian School of Economics (with Mette Bjøndal, Endre Bjøndal)
Nodal versus zonal pricing: Market power in day-ahead versus in balancing services
Presently in the Nordic day-ahead market, zonal pricing or market splitting is used for congestions between a predetermined set of price areas. Intra-zonal congestion is resolved by counter trading or redscheduling based on bids from the regulation power market. In a stylized model, we compare this joint model of handling congestions to the theoretically correct method of nodal pricing. Furthermore, we investigate the implications of both schemes for exercising market power in congested network scenarios.

Yves Smeers, Université Catholique de Louvain (with Danny Ralph)
Stochastic equilibrium in investment models: Capacity expansion in the power market
An investor in power generation assets faces unprecedented uncertainty on the evolution of the sector. The market equilibrium is hence one under uncertainty. Agents can be risk neutral or risk averse. We therefore insert risk functions in order to account for idiosyncratic risk (risk that is not priced by the CAPM) in investments. Adding a risk function on the cost in a standard (stochastic) capacity expansion planning model can be done and we retain a convex program but it poses questions on the interpretation. We structure the discussion the interpretation around market completeness: In a world of perfect risk trading we can derive a price vector for all instruments from a system risk function. The complete market can be represented in terms of stochastic programming. The assumption of perfect risk trading is however rather heroic for investments that last 20 to 30 years. We hence relax the assumption of perfect risk trading and allow for different stochastic discount factors. The interpretation becomes more difficult since the incomplete market is no longer amenable to a stochastic programming approach.
Optimization in energy systems

**Fr.2.MA 559**

**Generation and expansion problems**  
Chair Roman Cada, University of West Bohemia

Michael Lindahl, Technical University of Denmark  
(with Niels-Christian Fink Bagger)

Discrete optimization support system for the collection grid in large offshore wind parks

Offshore wind parks have in the recent years started to grow significantly in size making the task of deciding on how to build the cable collection grid a lot more complex. The goal is to connect all turbines down to a substation by using different types of cables. The objective is then to minimize the cost by minimizing the amount of cables, connection lengths and loss of power. The project is made in collaboration with DONG Energy which is market leader in building offshore wind parks. A mathematical representation of the problem is given which is turned into a MIP model by linear approximations of the quadratic power losses. It is shown how the problem is simplified by removing uninteresting connections. In order to solve the problem within a reasonable time the local branching framework is used. The considered test case is the Anholt Project which is a large offshore wind park including 111 wind turbines and 1 substation. It is shown how this can be used, not only to reduce cost, but also to easily explore different scenarios and see how the solution is affected if different constraints are added or other properties are changed.

Stefano Zoppi, University of Bergamo  
(with Marida Bertocchi, Laureano Escudero, Maria Teresa Vesperucci)

A multistage stochastic model for the electric power generation capacity expansion problem of a price-taker power producer in a multi-year horizon

We consider the optimal electric power generation capacity expansion problem over a multi-year time horizon of a price-taker power producer, who has to choose among different production technologies, while taking into account regulatory constraints on CO2 emissions, incentives to generation from renewable energy sources and risk due to uncertainties of prices and of market share. A multi-stage stochastic MILP model is developed for determining the evolution of the generation system along the time horizon, with the aim of maximizing the expected total profit, subject to a set of constraints to be satisfied for each scenario. Additionally, the maximization of the expected profit is subject, alternatively, to first-order stochastic dominance constraints (sdc), for a set of profiles given by pairs of threshold profit values and probability of not reaching them, and to second-order sdc, whose set of profiles is given by pairs of threshold profit values and bounds on the expected shortfall on reaching the thresholds. Provisional results are reported of a computational comparison between the following strategies: parameters’ expected value, risk neutral and first- and second-order sdc.

Roman Cada, University of West Bohemia

Optimizing nuclear fuel reload patterns

A nuclear reactor operates in cycles. At the end of every cycle a fraction of spent fuel assemblies is to be replaced by fresh ones. A new collection of fuel assemblies is to be distributed in the reactor core. It is necessary to meet all safety criteria and also minimize costs and maximize production of electrical energy.

We present several possible mathematical models which are suitable for attacking the problem. In general it is a multicriteria nonlinear combinatorial optimization problem. We will also discuss a problem of multicyle optimization in which several consecutive fuel cycles are to be optimized. Finally we present results obtained by the Athena code dedicated to nanoporous materials. Such materials have a broad range of engineering applications, including gas storage and filtration, electrical energy storage in batteries and capacitors, and catalysis. The method works well on moderate-sized problems, but it is clear that additional strategies would be required for the large problems of interest. In this talk, we discuss our use of domain decomposition (DD) to extend our MG/Opt work to larger problems. In particular, we adopt the point of view that DD and MG/Opt are both preconditioning strategies and we demonstrate an effective combination of MG/Opt and DD to solve these much larger problems. Numerical results will be presented.

Duy Luong, Imperial College London  
(with Panos Pardalos, Daniel Ruckert, Berc Rustem)

A multiresolution algorithm for large scale non-smooth convex optimization problems

We develop an algorithm based on multigrid concepts and apply it to nondifferentiable convex optimization problems. The approach utilizes the first order method and a hierarchy of models of different fidelity. The goal is to exploit the efficiency of the lower resolution model and propagate the information of the solution to the high resolution model. We discuss the convergence of the algorithm and show numerical results in a Computer Vision application. The convergence results apply to a broad class of non-smooth convex optimization problems.

Michelle Valtierra, University of the Philippines

**Optimal control of elliptic variational inequalities: A mesh-adaptive finite element solver**

A wide range of optimization problems arise originally in a non-discrete function space setting which has to be discretized in order to find an approximate solution. It is the idea behind mesh-adaption techniques, to find a discrete space that fits best to the unknown continuous solution. While adaptive methods are well-established in solvers for partial differential equations, only a few work has been done for optimal control problems.

We consider the optimal control of an elliptic variational inequality, a problem class with a challenging analytic and algorithmic background on the one hand, and a wide range of applications on the other hand. Moving on the border line between numerical analysis and computational optimization, we show the principle of goal oriented error estimation operating with the C-stationarity system in the continuous as well as the discrete setting, present a numerical solver for the mathematical model with equilibrium constraints (MPEC) and analyze the benefit of our adaptive solver compared to a method working on a uniformly refined mesh.

Caroline Löhndörfer, Humboldt-Universität zu Berlin  
(with Michael Hintermüller, Ronald Hoppe)

**Hierarchical methods for the design of nanoporous materials**

Organizer/Chair Robert Lewis, College of William and Mary - Invited Session

Paul Boggs, Sandia National Laboratories  
(with Julien Cortial, David Gay, Michael Lewis, Kevin Long, Stephen Nash)

Combining multi-grid and domain decomposition as preconditioners for a class of multi-level PDE-constrained optimization problems

Recently we developed a multi-grid optimization (MG/Opt) strategy for solving a class of multi-level, multi-physics problems that arise in the design of nanoporous materials. The method works well on moderate-sized problems, but it is clear that additional strategies would be required for the large problems of interest. In this talk, we discuss our use of domain decomposition (DD) to extend our MG/Opt work to larger problems. In particular, we adopt the point of view that DD and MG/Opt are both preconditioning strategies and we demonstrate an effective combination of MG/Opt and DD to solve these much larger problems. Numerical results will be presented.

David Gay, Ampl Optimization, Inc.  
(with Paul Boggs, Stewart Griffths, Robert Lewis, Kevin Long, Stephen Nash, Robert Nelson)

Optimization algorithms for hierarchical problems, with application to nanoporous materials

This talk concerns optimization algorithms for designing complex hierarchical systems, motivated by applications to the design of nanoporous materials. Such materials have a broad range of engineering applications, including gas storage and filtration, electrical energy storage in batteries and capacitors, and catalysis. The design of these materials involves modeling the material over many length scales, leading to a hierarchy of mathematical models. Our algorithms are also hierarchical in structure, with the goal of exploiting the model hierarchy to obtain solutions more rapidly. We discuss implementation issues and present some computational results.

Robert Lewis, College of William and Mary  
(with Stephen Nash)

Using inexact gradients in a multilevel optimization algorithm

Optimization algorithms typically require gradients of the objective and constraints, however, computing accurate gradients can be computationally expensive. We discuss the implications of using inexact gradients in the context of the multilevel optimization algorithm MG/Opt. MG/Opt recursively uses a hierarchy of models, of less fidelity but also less cost, to obtain search directions for finer-level models. However, MG/Opt requires the gradient on the fine level in order to define the recursion. We discuss the impact of gradient errors on the multilevel recursion in MG/Opt under various assumptions about the source of the error in the gradients. We illustrate these impacts both analytically and numerically for a number of model problems.
Structured matrix optimization

Organizer/Chair: Indrzej Dhillon, UT Austin - Invited Session

Ewout van den Berg, Stanford University (with Emmanuel Candès)

Phase-retrieval using explicit low-rank matrix factorization

Recently, Candès et al. proposed a novel methodology for phase retrieval from magnitude information by formulating it as a matrix completion problem. In this work we develop an algorithm aimed at solving large-scale instances of this problem. We take advantage of the fact that the desired solution is of rank one and use low-rank matrix factorization techniques to attain considerable speed-up over existing approaches. We consider phase recovery in both the noisy and noiseless setting and study how various design choices affect the performance and reliability of the algorithm.

Ziad Harchaoui, INRIA (with Minslao Dukdak, Jérôme Malick)

Lifted coordinate descent for learning with Gaussian regularization

We study learning problems with general sparsity-inducing matrix regularization penalties. We formulate the matrix regularizers as Gaussian functions, and, using their structure, we lift the optimization problem in a higher space where we propose to apply a coordinate descent algorithm. Our framework allows to efficiently tackle difficult matrix-regularized optimization problems, e.g., with a trace-norm, or a group trace-norm, regularization penalty. We present experimental results on synthetic datasets and on real-world large-scale computer vision datasets. Our algorithm is competitive and often outperforms existing approaches on large-scale problems.

Indrzej Dhillon, UT Austin (with Cho-Jui Hsieh, Padmini Ravikumar, Mathyas Sustik)

Sparse inverse covariance matrix estimation using quadratic approximation

The L1-regularized Gaussian maximum likelihood estimator has been shown to have strong statistical guarantees in recovering a sparse inverse covariance matrix, or alternatively the underlying graph structure of a Gaussian Markov Random Field, from very limited samples. We propose a new algorithm for solving the resulting optimization problem which is a regularized log-determinant program. In contrast to other state-of-the-art methods that largely use first order gradient information, our algorithm is based on Newton’s method and employs a quadratic approximation, but with some modifications that leverage the structure of the sparse Gaussian MLE problem. We present experimental results using synthetic and real application data that demonstrate the considerable improvements in performance of our method when compared to other state-of-the-art methods.

Target oriented optimization under uncertainty

Organizer/Chair: Metyn Sim, NUS Business School - Invited Session

Zhiwei Long, National University of Singapore (with Lucy Gongtao Chen, Metyn Sim)

Managing operational and financial decisions to meet consumption targets

We study dynamic operational decision problems where risky cash flows are resolved over a finite planning horizon. Financing decisions via lending and borrowing are available to smooth out consumptions over time, with the goal of achieving prescribed consumption targets. Our target-oriented decision criterion has salient properties of subadditivity, convexity and respecting second-order stochastic dominance. We show that if borrowing and lending are unrestricted, the optimal policy is to finance consumptions at the target levels for all periods except the last. Moreover, the optimal policy has the same control state as the optimal risk neutral policy and could be achieved with relatively modest computational effort. Under restricted financing, the optimal policies correspond to those that maximize expected additive-exponential utilities, and can be obtained by an efficient algorithm. We also analyze the optimal policies of joint inventory-pricing decision problems under the target-oriented criterion and provide optimal policy structures. With a numerical study, we report favorable computational results for using targets in regulating uncertain consumptions over time.

Mechyn Sim, NUS Business School (with Shao-Wai Lam, Tsan Sheng Ng, Jin-Hwa Song)

Multiple objective satisfying under uncertainty

We propose a class of functions, called multiple objective satisficing (MOS) criteria, for evaluating the level of compliance of a set of objectives in meeting their targets collectively under uncertainty. The MOS criteria include the targets’ achievement probability (success probability criterion) as a special case and also extend to situations when the probability distribution is not fully characterized. We focus on a class of MOS criteria that favors diversification, which has the potential to mitigate severe shortfalls in scenarios when an objective fails to achieve its target.

Jin Qi, National University of Singapore (with Patrick Jaillet, Melvyn Sim)

Routing optimization with deadlines under uncertainty

We study a routing problem with deadlines imposed at a given subset of nodes, and uncertain arc travel times characterized by distributions. Our model is static in the sense that the routing decision is made prior to the initialization of uncertain travel times. To find an optimal routing policy such that arrival times at the nodes “effectively” respect deadlines, we first introduce a new measure named Lateness Index to evaluate the performance of meeting deadlines. It is defined as the minimum risk tolerance parameter such that its worst-case certainty equivalent arrival time is no larger than the deadline prescribed at the corresponding node. Instead of specifying the exact probability distribution of the uncertain arc travel time, we assume its true distribution lies in a family of distributions, which is characterized by some descriptive statistics. We show that some special cases of our problem, such as when only one node has a deadline requirement, are polynomially solvable. And for the general case, we can develop computationally more “efficient” algorithms to find exact optimal routing policy by only solving a series of deterministic routing problems.

Stochastic algorithms

Chair: Nikolaus Hansen, INRIA, Research Centre Saclay, University Paris-Sud

Sang Luo, University of Tsukuba (with Makio Shigeno, Mingchao Zhang)

A nonadaptive probabilistic group testing algorithm for detecting consecutive positives of linear DNA library

Identifying and isolating clones containing a particular segment of a specific DNA sequence of interest play important roles in molecular biology. Group testing is one of useful techniques to reduce the number of nonadaptive tests and screening necessary for determining which clones contain the segment. A testing algorithm is proposed for a case where clones are placed in a linear order corresponding to their appearance in the linear DNA and where the DNA library is constructed by consecutive clones. The proposed algorithm, which is based on a computationally feasible stochastic model of consecutive positive clones, efficiently identifies the consecutive positives of a linear DNA library.

Stochastic optimization

Nikolaus Hansen, INRIA, Research Centre Saclay, University Paris-Sud (with Anne Auger, Tann Ollivier)

Information-geometric optimization

Given an arbitrary search space with an arbitrary objective function and a parametrized family of probability distributions on this search space, we derive in a generic way a stochastic search method. The derivation is based on invariance principles, keeping the number of arbitrary decisions to a minimum. If the parametrization of the probability distribution is a smooth manifold, we derive a canonical ODE and the related IGO flow that conducts a natural gradient ascent on the manifold. The ascent is based on a time-dependent transformation of the original objective function. Via discretization, a corresponding search algorithm can be derived. Depending on the given family of probability distributions, several well-known algorithms are recovered.

Madeleine Thiele, TU Berlin (with Timo Kötzing, Dirk Sudholt)

How crossover helps in pseudo-boolean optimization

Understanding the impact of crossover on performance is a major problem in the theory of genetic algorithms (GAs). In this talk I present new insights on working principles of crossover by analyzing the performance of crossover-based GAs on the simple functions OneMax and Jump. First, the potential speedup by crossover is assessed when combined with a fitness-invariant bit shuffling operator that simulates a lineage of independent evolution on a function of unitation. Theoretical and empirical results show drastic speedups for both functions. Second, a simple GA without shuffling is considered and the interplay of mutation and crossover on Jump is investigated. If the crossover probability is small, subsequent mutations create sufficient diversity, even for very small populations. Contrarily, with high crossover probabilities crossover tends to lose diversity quickly than mutation can create it. This has a drastic impact on the performance on Jump. The theoretical findings are complemented by Monte Carlo simulations on the population diversity.


**Telecommunications & networks**

**Fri.2, 3rd 1002**

**Game theoretic concepts in telecommunications**

Chair Fabian Medel, Universidad de Chile

Fabian Medel, Universidad de Chile (with Alejandro Jofré)

*Optimal regulation with non discriminatory prices in mobile two way access, with call externalities and heterogeneous congestion.*

The existence of congestion and exclusion in mobile markets, coupled with increased supply in the range of services to the costumers, has led regulators to confront a difficult problem in the search for tools to promote competition in this market. In this sense, there was an oligopolistic market modell where multiple wireless services, different types of users and the presence of a market regulator. The models used is nonlinear market equilibriums in the subgame perfect equilibriums among firms (MPEC). Strategic behavior of firms contemplates Nash equilibriums and predatory interactions, encompassing most models existing in the literature. The result was a detailed analysis of regulatory actions of the non-discriminatory call prices of the firms and the impact on social welfare. Obtaining the optimal strategy by the regulator would be through a substantial reduction of access charges, even below the marginal cost of service, facilitating the entry of new competitors by a fair use of the infrastructure of third parties.

Jonathan Krollkowski, Zuse Institute Berlin (ZIB) (with Anastasios Giovandis, Tobias Rahn)

*Game theoretic model for the downlink in cellular mobile networks: Nash equilibria and algorithmic concepts.*

In the downlink of multicell wireless networks, a number of mobile stations (MSs) should be assigned to a set of spatially distinct base stations (BSs). Two questions are addressed in our work: Which MS is served by which BS, and how much power it consumes. The aim is to provide the information of the BS signal-to-interference-noise-ratio (SINR) with constraints on the power emissions per BS. A central optimization of these parameters is costly. To this aim we propose a decentralized algorithm based on game theory, whose outcome is a pure-strategy Nash equilibrium (PNE). The MSs aim at non-cooperatively optimizing their payoff functions. All information necessary to each MS is its channel quality from all the BSs and the current strategy choices of the other MSs. This problem is more involved than already investigated models of uplink communication scenarios. We show that a PNE cannot be ensured even in small cases, when considering interference between all pairs of BSs and MSs. Simplification leads to versions of the problem as congestion games with player specific payoff functions, thereby showing the existence of PNEs.

Olivier Fercoq, INRIA Saclay and CMAP École Polytechnique

*Polychedral and ergodic control approaches to PageRank optimization and spam detection.*

We study the PageRank optimization problem, which consists in finding an optimal outlink strategy for a web site. In each page, some hyperlinks are controlled while the others are not. We show that the problem can be modeled by a Markov decision process with ergodic reward, in which the webmaster determines the transition probabilities of webusers. Although the number of actions may be exponential, we show that an associated polytope of transition measures has a concise representation, from which we deduce that the problem is solvable in polynomial time. Then we give an alternative application of PageRank optimization with the search engine’s point of view: link spam detection and demotion. From seeds of hand-picked trusted and spam pages, we define a PageRank optimization problem where the cost function penalizes known spam pages and hyperlink removals. The invariant measure, called MaxRank, is interpreted as a modified PageRank vector, used to rank web pages. We show that the bias vector of the associated ergodic control problem is a measure of the “spamicity” of each page. We introduce scalable algorithms that allowed us to perform numerical experiments on large datasets.

Arthur Gómez, University of Vaile do Rio das Sinas. (with Carlos Weisheimmer, Junia)

*Development of a hybrid algorithm based on the application of metaheuristics on an Internet Protocol Television platform using Tabu Search (TS) and Genetic Algorithm (GA).*

The technology internet protocol television (IPTV) is a strong factor impacting on society. She has been exploited, by different means of transmission, for multimedia content delivery service based on internet protocol (IP). Currently, IPTV is the subject of several studies, and it can bring many benefits to society such as support for interactivity and increased interoperability in home networks. This paper presents the development and implementation of a hybrid algorithm based on the application of metaheuristics on an IPTV platform using tabu search (TS) and genetic algorithm (GA). This algorithm makes it possible analysis and study of the following parameters: baud rate, audio quality, number of customers and bandwidth. The focus is find the best parameters setting for the transmission given the characteristics of the IPTV client. After validation of the algorithm were performed experiments that help understand the dynamics of the system and allow find a good solution that can be simulated by the network simulator 3 (NS3).

Cristobal Guzman, Georgia Institute of Technology (with Roberto Cominetti)

*Network congestion control with Markovian multipath routing.*

In this paper we consider an integrated model for TCP/IP protocols with multipath routing. The model combines a network utility maximization for rate control based on end-to-end queuing delays, with a Markovian traffic equilibrium for routing based on total expected delays. We prove the existence of a unique equilibrium state which is characterized as the solution of an unconstrained strictly convex program. A distributed algorithm for solving this optimization problem is proposed, with a brief discussion of how it can be implemented by adapting the current Internet protocols.

Chair Fabian Medel, Universidad de Chile (with Alejandro Jofré)

*Optimization in infinite dimensional spaces.*

Organizer/Chair Alexander Zaslavski, The Technion - Israel Institute of Technology - Invited Session

Joël Blot, Université Paris 1 Panthéon-Sorbonne

*Discrete-time Pontryagin principles and ordered Banach spaces.*

We provide new Pontryagin principles in infinite horizon and discrete time for systems governed by a difference inequality, $x_{n+1} \leq f(x_n, u_n)$, where the order is defined in a cone in an infinite-dimensional Banach space. To obtain our results, we use a method of reduction to finite horizon, and special properties of ordered Banach spaces.

Tamar Doncheva, University of Architecture and Civil Engineering (with Robert Bax, Qamar Oin)

*Runge-Kutta methods for differential equations with variable time of impulses.*

In the paper Runge-Kutta methods of order $p$ are used to approximate the solutions of differential equations with variable times of impulses in general form. We prove that under natural assumption these methods have order of approximation $O(p^2)$. Illustrative examples are provided. Several strategies to find the jump point of the approximate solution for order two and four Runge-Kutta methods are tested. The models studied can be applied in some control problems of population dynamics and mathematical economics.

Elena Resmerita, Alpen-Adria University (with Klaus Frick, Dirk Lorenz)

*A discrepancy principle for the augmented Lagrangian method.*

The augmented Lagrangian method received much attention recently (also under the name Bregman iteration), as an approach for regularizing inverse problems. This work shows convergence and convergence rates for this method when a special a posteriori rule, namely Morozov’s discrepancy principle, is chosen as a stopping criterion. As potential fields of application we study implications of these results for particular examples in imaging, that is total variation regularization as well as $l^p$ penalties with $q \in [1, 2]$.

**Variational analysis**

**Fri.2, 3rd 2025**

**Optimization in infinite dimensional spaces**

Organizer/Chair Alexander Zaslavski, The Technion - Israel Institute of Technology - Invited Session

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**Variational analysis**

**Fri.2, 3th 2025**

**Duality in convex optimization**

Organizer/Chair Rudo I. Bot, Chemnitz University of Technology - Invited Session

Ernst Cuijpers, Chemnitz University of Technology (with Rudo Bot)

*Conjugate duality and the control of linear discrete systems.*

We consider a constrained minimization problem, the function to be minimized being a convex one with values in the extended real line, and the set of constraints is governed by a set valued operator with convex graph. We attach a dual problem to it and we deliver regularity conditions guaranteeing the equality of the optimal objective values of the two problems and we discuss also the existence of optimal solutions. The results are applied to the control of linear discrete systems.

André Heinrich, Chemnitz University of Technology (with Rudo I. Bot, Gert Wanka)

*The support vector machines approach via Fenichel-type duality.*

Supervised learning methods are powerful techniques to learn a
Physarum can compute shortest paths

Vincenzo Bonifaci, IASI-CNR, Italy (with Varma Girish, Kurt Mehlhorn)
Organizer/Chair Nicole Megow, Technische Universität Berlin. Invited Session
Routing and shortest paths

We introduce a vector dual problem that successfully cures the trouble encountered by some classical vector duals to the classical linear vector optimization problem in finite-dimensional spaces. This new-old vector dual is based on a vector dual introduced by Boţ and Wanka for the case when the image space of the objective function of the primal problem is partially ordered by the corresponding nonnegative orthant, extending it for the framework where an arbitrary nontrivial pointed convex cone partially orders the mentioned space. The vector dual problem we propose has, different to other recent contributions to the field which are of set-valued nature, a vector objective function. Weak, strong, and converse duality for this vector dual problem are delivered and it is compared with other vector duals considered in the same framework in the literature. We also extend a well-known classical result by showing that the efficient solutions of the classical linear vector optimization problem coincide with its properly efficient solutions (in any sense) when the image space is partially ordered by a nontrivial pointed closed convex cone.

On the theta number of powers of cycle graphs

A main result of combinatorial optimization is that clique and chromatic number of a perfect graph are computable in polynomial time (Grotschel, Lovász and Schrijver 1981). We give a closed formula for Lovász’s theta number of the powers of cycle graphs $C_n^k$ and of their complements, the circular complete graphs $K_{n/k}$. As a consequence, we establish that the circular-chromatic number of a circular-perfect graph is computable in polynomial time, which extends the above result from the chromatic number to the circular-chromatic number, and from perfect graphs to the superclass of circular-perfect graphs.

The disjunctive rank of the stable set polytope of web graphs

We consider the behavior of the disjunctive operator defined by Balas, Ceria and Cornuéjols, over the clique relaxation of the stable set problem on webs. The disjunctive rank of a graph is the minimum number of steps of this procedure needed to obtain the convex hull of integer solutions in it. In this work we obtain the disjunctive rank of all webs, when starting from the clique relaxation. We find that almost every web $W_n$ attain the upper bound of its disjunctive rank, i.e., $k$, except for those of the form $W_{n,k+r}$ with $r = 0$ or $r = 1$, that requires $k + 2$ or $k + 1$ steps, respectively. Our results allow us to obtain bounds for the disjunctive rank of a larger class of graphs such as quasi-linear graphs and their complements, the near-bipartite graphs.

On the Chvátal-closure of the fractional set covering polyhedron of circulant matrices

The set covering polyhedron $Q(C)$ related to circulant 0,1-matrices has been the object of several recent studies. It has been conjectured that the Chvátal-rank of its fractional relaxation $Q(C)$ is equal to 1. In 2009, Argiroffo and Bianchi characterized all vertices of $Q(C)$. In this talk we present the results obtained so far for some classes of vertices. In particular, our construction yields a counterexample to a conjecture that all facets of $Q'(C')$ are given by boolean, nonnegative, and so-called minor inequalities having only coefficients in $\{0,1,2\}$. At the same time, we motivate why a weaker version of this conjecture might still hold.

Approximation & online algorithms

Approximation algorithms for capacitated location routing

Janik Matuschke, TU Berlin (with Tobias Harks, Felix König)

Location routing integrates the two classical optimization problems of facility location and vehicle routing, addressing both location decisions and tour planning in a single step. Given a graph whose vertex set consists of facilities and clients with given demands, the problem is to find a subset of facilities that have to be opened, and a set of tours originating from those facilities, serving all clients while at the same time respecting the (uniform) capacity limitation of the vehicles in use, and minimizing the incurred opening and connection costs.

We derive the first polynomial time constant factor approximation for capacitated location routing and some variants of the problem, including cross-docking, prize-collecting, and a group variant. Our results originate from combining algorithms and lower bounds for different relaxations of the original problem.

Finally, we present a computational study on popular benchmark instances from the literature and newly generated large-scale random instances. It turns out that, in practice, solutions of our algorithm are much closer to optimality than guaranteed by the theoretical approximation factor.

Combinatorial optimization

Packing, covering and domination II

Organizer/Chair AnneBright, University Blaise Pascal (Clermont-Ferrand II)/CNRS - Invited Session

Amna Zeit Ffather, Université de Bordeaux (with Christine Bachem, Alain Thiery)

On the theta number of powers of cycle graphs

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the quadratic version. We explain how this can be done, and present some extremely promising computational results.

Ruth Höbner, Georg-August-Universität Göttingen (with Christoph Buchheim, Anita Schöbel)
Ellipsoid bounds for convex quadratic integer programming
Solving unrestricted convex quadratic integer programs by a branch&bound approach requires lower bounds on the objective value. We are going to follow the approach by Buchheim, Caprara and Lodi (2011) and approximate the quadratic function by an “easier” quadratic function which underestimates the original one. Geometrically, we approximate the level set of the objective by an auxiliary ellipsoid for which we require that the corresponding quadratic integer problem can be solved by rounding its continuous optimal solution. In a first approach we are going to restrict the choice of the auxiliary ellipsoid to axis-parallel ellipsoids corresponding to the level sets of separable convex quadratic functions. Which one is the “best” auxiliary axis-parallel ellipsoid depends not only on the given objective function but also on the respective continuous optimal solution which changes in every node of the branching tree. As it is expensive to find a good auxiliary ellipsoid we want to decide on a single ellipsoid and use it for the whole algorithm. This raises the question on how to compare different ellipsoids. To this end, worst-case and average-case arguments are discussed.

Souour Elloumi, ENSIE
A unified view of linear and quadratic convex reformulation for binary quadratic programming
We consider binary quadratic programs (QP) having a quadratic objective function, linear constraints, and binary variables. Many classical solution methods of these problems are based on exact reformulation of QP into an equivalent mixed integer linear program. Several linearization methods were studied in the literature. More recent solution methods also build an exact reformulation but into a problem which objective function is quadratic and convex. A common point of the two approaches is that the continuous relaxation of the reformulated problem is a convex optimization problem that can be solved in polynomial time. This makes it possible to use a general branch-and-bound framework to solve the reformulated problem and even to rely on the strongness of standard solvers. In this paper, we show that several quadratic convex reformulation methods, as well as classical linearization, can be viewed within a unified framework. This shows the non-surprising result that linearization is a particular quadratic convex reformulation on the one hand. On the other hand, it allows to compare these methods from a theoretical point of view.

Combinatorial optimization
Fri,3 2017
Graph optimization problems in the streaming model
Organizer/Chair: Anand Srivastav, Christian-Albrechts-Universität zu Kiel - Invited Session
Christian Konrad, LIAGA – Université Paris Diderot (Paris 7)
On the order of graph streams
While classical graph algorithms assume random access to the input graph, a semi-streaming algorithm receives a sequence of edges of the input graph and processes them one-by-one in sequential order while using small memory. How important is the order in which the edges arrive? Are there problems that become easier if we assume that edges arrive in uniform random order instead of worst-case order? Are there other particular orders that make sense to consider? We address these questions via two concrete examples: the unweighted bipartite graph matching problem and the unweighted semi-matching problem: given a bipartite graph \((A,B,E)\), in the semi-streaming problem we aim to match all \(A\) vertices to \(B\) vertices such that the maximal degree of the \(A\) vertices is minimized. The talk concludes with a review on open problems in this area of research.

Laszlo Klimm, Christian-Albrechts-Universität zu Kiel (with Sebastian Eggert, Peter Munstermann, Anand Srivastav)
(1 + 1/4)-Approximate maximum matching in bipartite graph streams in \(O(k^2)\) passes and improvements
Two algorithms for the maximum matching problem in bipartite graph streams will be presented. RAM is restricted to \(O(n)\) edges at a time, \(n\) denoting the number of vertices. Given a parameter \(k\), we find a \((1 + 1/k)\) approximation. The number of passes is allowed to depend on \(k\). When the number of passes is independent of \(n\), we speak of a semi-streaming algorithm. However, on a large set of test instances it outperformed the first algorithm by an impressive margin: for a 90% approximation \((k = 9)\) the second algorithm never required more than 94 passes, while the first one required up to 32,000. But even those 32,000 are far away from the theoretical \(O(k^2)\) bound.

Mariano Zele, Goethe-Universität Frankfurt am Main
Algorithmic techniques for data stream computations
One major computation on today’s massive data, it is not unreasonable anymore to assume the existence of a main memory containing the whole input for fast random access. On such data streaming algorithms are appropriate for which fast random access to the input and even its complete storage are dispensable. In contrast, the input is processed in an online fashion using a main memory size that significantly falls below the input data size.
In this talk we present some basic techniques for streaming algorithms which provide the foundation for more elaborate approaches. We illustrate reservoir sampling to draw uniform random samples out of a stream of unknown length and sliding window sampling to exclude outdated input items from the sample. Moreover, we show how to approximate the frequency moments of a stream via the technique of AMS sampling and how to estimate the multiplicity of an item in the input stream by using the count-min sketch.
Combinatorial optimization

Flows, cuts, and sparsifiers
Organizer/Chair Lisa Fleischer, Dartmouth College - Invited Session

Nicholas Harvey, University of British Columbia

Graph sparsifiers

A sparsifier of a graph is a sparse, weighted subgraph for which every cut has approximately the same value as the original graph, up to a factor of $1 \pm \epsilon$. Sparsifiers were first studied by Benzer and Karger (1996). They have wide-ranging applications, including fast network flow algorithms, fast linear system solvers, etc.

We describe a new approach to constructing sparsifiers: by sampling each edge with probability inversely proportional to the edge-connectivity between $u$ and $v$. This results in a sparsifier with $O(n \log^2(n)/\epsilon^2)$ edges, answering a question of Benzer and Karger. A variant of this argument shows that one can obtain sparsifiers by sampling uniformly random spanning trees. Our proofs are based on extensions of Karger’s contraction algorithm which allow it to compute minimum “Steiner” cuts.

Jonathan Kelner, MIT (with Paul Christiano, Aleksander Madry, Gary Miller, Richard Peng, Daniel Spielman, Shanghua Teng)

Electrical flows, linear systems, and faster approximations of maximum flows, minimum $s$-$t$ cuts, and multicommodity flows in undirected graphs

In this talk, I’ll describe a new collection of techniques for approximately solving maximum flow, minimum $s$-$t$ cut, and multicommodity flow problems in capacitated, undirected graphs. Using these techniques, we obtain asymptotically faster algorithms for all three, breaking running time barriers that have stood for over 30 years.

For graphs with $v$ vertices and $e$ edges, I’ll show how to compute $(\epsilon, \epsilon)$-approximately maximum flows in time $\tilde{O}(m^{13/7} \text{poly}(1/\epsilon))$ and $(\epsilon, \epsilon)$-approximately minimum $s$-$t$ cuts in time $\tilde{O}(m + n^{13/7} \text{poly}(1/\epsilon))$. We do this by treating our graph as a network of resistors and solving a sequence of electrical flow problems with varying resistances on the edges. Each of these may be reduced to the solution of a system of linear equations in a Laplacian matrix, which can be solved in nearly-linear time.

I’ll then discuss why generalizing this approach to the multicommodity setting requires more general classes of linear systems and iterative methods. Using these, we find $(\epsilon, \epsilon)$-approximate solutions to the maximum concurrent flow problem with $k$ commodities in time $\tilde{O}(m^{13/7} \text{poly}(k, 1/\epsilon^{2}))$.

Christophe Weibel, Google Inc. (with Amit Chakrabarti, Lisa Fleischer)

When the cut condition is enough: Characterization of multiflow problems by forbidden minors

For a supply graph $G = (V, E)$ and a demand graph $H = (V, F)$, an assignment of capacities to the edges of $G$ and demands to the edges of $H$ is said to satisfy the cut condition if for any cut in the graph, the total demand crossing the cut is no more than the total capacity crossing it. The pair $(G, H)$ is called cut-sufficient if for any assignment of capacities and demands that satisfy the cut condition, the demands defined on $H$ can be routed within the network with capacities defined on $G$.

In this talk, I’ll state to contain another pair $(G’, H’)$ as a minor if it is possible to obtain $(G’, H’)$ from $(G, H)$ by contracting edges of $G$ and deleting edges of $G$ and $H$. We propose to characterize cut-sufficient pairs by forbidden minors.

In particular, we prove a previous conjecture giving the minimal set of forbidden minors for instances with a series-parallel supply graph, and propose a conjecture extending our results to planar supply graphs.

Complementarity & variational inequalities

Contraction methods for separable convex optimization in the frame of Vls
Organizer/Chair Bingsheng He, Nanjing University - Invited Session

Guoyong Gu, Nanjing University (with Bingsheng He, Xiaoming Yuan)

Customized proximal point algorithms: A unified approach

This talk takes a unified look at the customized applications of proximal point algorithms (PPA) to two classes of problems, namely, the linearly constrained convex problem with a generic or separable objective function and a saddle-point problem. We model these two classes of problems as mixed variational inequalities, and show how PPA with customized proximal parameters can yield favorable algorithms, which are able to exploit the structure of the models. Our customized PPA revisits turns out to be a unified approach in designing a number of efficient algorithms, which are competitive with, or even more efficient than some benchmark methods in the existing literature such as the augmented Lagrangian method, the alternating direction method and a class of primal–dual methods, etc. From the PPA perspective, the global convergence and the $O(1/t)$ convergence rate are established in a uniform way.

Min Tao, Nanjing University (with Sheng He, Ming Yuan)

A slightly changed alternating direction method of multipliers for separable convex programming

The classical alternating direction method of multipliers (ADMM) has been well studied in the context of linearly constrained convex programming and variational inequalities where the involved operator is formed as the sum of two individual functions without crossed variables. Recently, ADMM has found many novel applications in diversified aspects due to its image processing application statistics. However, it is still not clear whether ADMM can be extended to the case where the operator is the sum of more than two individual functions. In this paper, we present an ADMM with minor change for solving the linearly constrained separable convex optimization whose involved operator is separable into three individual functions. The $O(1/t)$ convergence rate of the proposed methods is demonstrated.

Xinglu Cai, Nanjing University (with Guoyong Gu, Bingsheng He, Xiaoming Yuan)

ADM based customized PPA for separable convex programming

The ADM is classical for solving a linearly constrained separable convex programming problem, and it is well known that ADM is essentially the application of a concrete form of the PPA to the corresponding dual problem. This paper shows that an efficient method competitive to ADM can be easily derived by applying PPA directly to the primal problem. More specifically, if the proximal parameters are chosen judiciously according to the separable structure of the primal problem, the resulting customized PPA takes a similar decomposition algorithmic framework as that of ADM. The customized PPA and ADM are equally effective to exploit the separable structure of the primal problem, equally efficient in numerical senses and equally easy to implement. Moreover, the customized PPA is ready to be accelerated by an over-relaxation step, yielding a relaxed customized PPA for the primal problem. We verify numerically the competitive efficiency of the customized PPA to ADM, and the effectiveness of the over-relaxation step. Furthermore, we provide a simple proof for the $O(1/t)$ convergence rate of the relaxed customized PPA.

Conic programming

Algebraic geometry and conic programming III
Organizer/Chairs Markus Schweighofer, Universität Konstanz; Lek-Heng Lim, University of Chicago - Invited Session

Caroline Uhler, IST Austria

Maximum likelihood estimation in Gaussian graphical models from the perspective of convex algebraic geometry

We study multivariate normal models that are described by linear constraints on the inverse of the covariance matrix. Maximum likelihood estimation for such models leads to the problem of maximizing the determinant function over a spectrahedron, and to the problem of characterizing the image of the positive definite cone under an arbitrary linear mapping. We examine these problems at the interface of statistics and conic optimization from the perspective of convex algebraic geometry.

Thorsten Theobald, Goethe University Frankfurt am Main (with Kai Kellner, Christian Trabandt)

Containment problems for polytopes and spectrahedra

Spectrahedra are the feasible regions of semidefinite programs. In this talk we study the computational question(s) whether a given polytope or spectrahedron $S_\alpha$ (as given by a linear matrix pencil $A(x)$) is contained in another one $S_\beta$.

Our results both concern the computational complexity (extending results on the polytope/polytope-case by Gritzmann and Klee) as well as sufficient conditions to certify containedness (whose study was initiated by Ben-Tal, Nemirovski and Helton, Klep, McCullough).

Fri.3 II 2020

Algebraic symmetry in semidefinite programming
Organizer/Chair Etienne de Klerk, Tilburg University - Invited Session

Etienne de Klerk, Tilburg University (with Dimitri Pasechnik)

Improved lower bounds on crossing numbers of graphs via semidefinite programming

The crossing number problem for graphs is to draw a graph in the plane with a minimum number of edge crossings. Crossing numbers...
are of interest for graph visualization, VLSI design, quantum dot cellular automata, RNA folding, and other applications. On the other hand, the problem is notoriously difficult. In 1973, Erdős and Guy wrote that: “Almost all questions that one can ask about crossing numbers remain unsolved.” For example, the crossing numbers of complete and complete bipartite graphs are still unknown in general. Moreover, even for cut-edge graphs, it is NP-hard to compute the crossing number. Different types of crossing numbers may be defined by restricting drawings; thus the two-page crossing number corresponds to drawings where all vertices are drawn on a circle, and all edges either inside or outside the circle. In this talk, we will survey some recent results, where improved lower bounds were obtained for (two-page) crossing numbers of complete and complete bipartite graphs via optimization.

Mariana Eisenberg-Nagy, CW Amsterdam (with Etiene de Klerk, Renata Sotirov, Uwe Tvershchak)
Symmetry in RLT cuts for the quadratic assignment and standard quadratic optimization problems

The reformulation-linearization technique (RLT), introduced in [W. P. Adams, H. D. Sherali, A tight linearization and an algorithm for zero-one quadratic programming problems, Management Science, 32(10): 1274—1290, 1986], provides a way to compute linear program bounds on the optimal values of NP-hard combinatorial optimization problems. This type of method has become known as a lift-and-project strategy; the “lifting” refers to the addition of new variables, and the “projection” to projecting the optimal values of the new variables to a feasible point of the original problem.

We study the RLT technique for two specific problems, namely the standard quadratic program and the quadratic assignment problem (QAP). We show how one may solve the second level: RLT relaxation with additional semidefinite programming constraints in the presence of suitable algebraic symmetry in the problem data. As a result we are able to compute the best known bounds for certain graph partitioning problems involving strongly regular graphs. These graph partitioning problems have QAP reformulations.

Dion Gijswijt, TU Delft
Symmetric semidefinite programs based on tuples

The independence number in graphs can be bounded using semidefinite programming. Symmetries of the graph can be used to reduce the size of the SDP. A dramatic example of this occurs in coding theory, where the Lovász theta number for exponentially large graphs reduces to a polynomial sized LP (Delartse bound) by virtue of the large symmetry group of the Hamming space.

Here we discuss stronger bounds, related to the Lasserre hierarchy, that involve tuples of vertices of the graph. We show efficient methods to apply symmetry reduction in this case. An explicit result (joint work with A. Schrijver and H. Mittelmann) gives improved bounds on binary codes using four-tuples, and shows that the quadruply shortened Golay code is optimal.

Juan Montoya, UC Merced
Derivative-free optimization methods for determining the surface structure of nanosystems

Many properties of nanosystems depend on the atomic configuration at the surface. One common technique used for determining this surface structure is based on the low energy electron diffraction (LEED) method, which uses a sophisticated physics model to compute the diffraction spectra. While this approach is highly effective, the computational cost of the simulations can be prohibitive for large systems. Here, we describe the use of pattern search methods and simplified physics surrogates for determining the surface structure of nanosystems. The pattern search methods have the property of being able to handle both continuous and categorical variables. This allows the simultaneous optimization of the atomic coordinates as well as the chemical identity.

Andrew Conn, T. J. Watson Research Center (with Sippe Douma, Li He, Hoi Hon, Eduardo Jimenez, Gis van Essen)
Simulation-based optimization: Integrating seismic and production data in history matching

We present two recent complementary approaches to mitigate the ill-posedness of this problem: Joint inversion – the development of a virtual sensing formulation for efficient and consistent assimilation of 4D time-lapse seismic data; Flow relevant geostatistical sampling – despite conscientious efforts to minimize the undeterminedness of the solution space, through joint inversion or through regularization, the distribution of the unknown parameters conditional on the historical data, often remains illusive. This is typically accounted for through extensive sampling. We propose a reduced space hierarchical clustering of flow-relevant indicators for determining representative characteristics of these samples. This allows us to identify model characteristics that affect the dynamics. The effectiveness of both methods are demonstrated both with synthetic and real field data. Time permitting we will discuss the ramifications for the optimization and the numerical linear algebra.

Marianna Terecan, University of Namur (FUNDP) (with Serge Gratton, Patrick Laaloua)
Derivative-free optimization for large-scale nonlinear data assimilation problems

Data assimilation consists in techniques to combine observations with a numerical prediction model. The goal is to produce the best estimate of the current state of the system. Two different approaches are used in data assimilation algorithms: the sequential one, based on the statistical estimation theory (Kalman filter) and the variational one, based on the optimal control theory. This last approach amounts to solve a very large nonlinear weighted least-squares problem called 4D-Var (four-dimensional variational problem). In both approaches, evaluating derivatives is challenging as one needs to compute the Jacobian of the model operator. The Ensemble Kalman Filter (EnKF) provides a suitable derivative-free alternative for the first approach by using a Monte-Carlo implementation on the Kalman filter equations. However, no derivative-free variant of the variational approach has been proposed so far. In this talk, we present such a variant, based on a technique to build and explore a sequence of appropriate low dimensional subspaces. Numerical illustration is shown on a shallow water data assimilation problem, including a comparison with the Ensemble Kalman Filter approach.

Annick Sarten, Chair: University of Namur (FUNDP)
changes in their feelings and their behavior as a result of interaction with other individuals. When individuals relate to each other, considering a heterogeneous population, behavior patterns allow groups formation. Studies of group behaviors inside a population have applications like preparation to marketing campaign for competitive products, tendencies analysis of voters in political campaigns and to simulate all situations where groups with antagonist ideas compete for new members. This work proposes the use of Lotka-Volterra differential equations to model the segmentation of a population into two groups, each one associated with concepts/choices competitors. In this scope, the coefficients of the Lotka-Volterra equations are defined from the average of the parameters of the individuals which are member of each group. Furthermore the model is dynamic. Model coefficients are updated as groups update their number of members. Individual parameters also continue to change due interactions. With this, the system modeling is replaced by stochastic component, becoming the linear stability analysis innocuous.

Deepak Kumar, Indian School of Business

Simultaneous optimization problems in gambling strategies

The optimization problem in portfolio management of meeting objectives with maximum probability and/or within minimum time uses continuous time Red & Black gambling strategies for answers to the problem of (a) minimizing the expected time of reaching a target. The problem of trying to maximize probability of reaching a target before hitting a low and (b) minimizing the expected time of reaching a target. The problem of trying to maximize probability of reaching a target before hitting a low when there is some deadline constraint makes the problem altogether different. The aim is to look into the mathematical structure of the problem in optimal control framework, try to have a discrete analogue of it and have a look into the theoretical issues related to such optimization problems.

José Gilberto Hernández Ramirez, Universidad Metropolitana [with María García G., Gilberto Hernández G.]

The amplitude model and regret model in decision making under uncertainty

Upon reinforcing the traditional methods for decisions making under uncertainty, especially Hurwicz and Laplace, the amplitude model (TAM) was created. TAM, among the parameters to choose the best alternative, takes into account the amplitude. Although it is created to reinforce other methods, TAM has taken own life. Besides TAM has extended to decisions making under risk, with the model of amplitude for risk and uncertainty [MARU]. Likewise has worked TAM together the regret model [Minimax]. The maximum repentance of Minimax has been used as parameter of TAM and the amplitude of the repentance to evaluate Minimax. In this work continues with this search, of there that the objective of the same one is to create a new model, based on the philosophy of the amplitude model, using simultaneously as parameters the amplitude of the payments and the maximum repentance of the same. To reach this objective will be used like methodology the scientific method for research operations. For the illustration and validation of the new model will be contrasted against the traditional methods and other variant of TAM, through problems created especially for it.

A gossip algorithm for aggregate equilibrium games on graphs

We consider a class of games, termed as aggregate games, being played over a distributed multi-agent networked system. In an aggregate game, an agent’s objective function is coupled through a function of the aggregate of all agents decisions. Every agent maintains an estimate of the aggregate and agents exchange this information over a connected network. We study the gossip-based distributed algorithm for information exchange and computation of equilibrium decisions of agents over the network. Our primary emphasis is on proving the convergence of the algorithm under an assumption of a diminishing (agent-specific) stepsize sequence. Under standard conditions, we establish the almost-sure convergence of the algorithm to an equilibrium point. Finally, we present numerical results to assess the performance of the gossip algorithm for aggregate games.

Tobias Harks, Maastricht University (with Max Klimm)

Decentralized mechanisms for throughput scheduling

Motivated by contribution scenarios in (social) networks, we analyze network contribution games in which each agent in a network has a budget of effort that he can contribute to different collaborative projects or relationships. Depending on the contribution of the involved agents a relationship will flourish or drown, and to measure success we use a reward function for each relationship. Every agent is trying to maximize the reward from all relationships that it is involved in. We consider pairwise equilibria of this game, and characterize the existence, computational complexity, and quality of equilibrium. Our results concern several natural classes of functions such as convex or concave rewards. We also discuss extensions towards altruistic behavior and different local reward sharing rules.

Jasper de Jong, University of Twente

Decentralized mechanisms for throughput scheduling

Motivated by the organization of decentralized service systems, we study new models for throughput scheduling. In throughput scheduling, we have a set of jobs $i$ with value $w_i$, processing requirement $p_i$, and deadline $d_i$, to be processed non-preemptively on a set of unrelated servers. The goal is to maximize the total value of jobs finished before their deadline. While several approximation algorithms with different performance guarantees exist for this and related models, we are interested in decentralized mechanisms where the servers act selfishly according to some given, simple protocol. We show by simple, combinatorial arguments that, when each server deploys an $\alpha$-approximation locally, any Nash equilibrium still yields an $(\alpha+1)$-approximation with respect to the global optimum. This bound is tight, even in the case of related machines, unit weights and unit processing times. For models with identical machines, the bound can be improved to $\frac{\alpha+1}{\alpha}$. Some of our results also extend to online models with corresponding competitive ratios.
Global optimization

Structural aspects of global optimization
Organizer/Chair: Oliver Stein, Karlsruhe Institute of Technology - Invited Session

Georg Still, University of Twente
Minimization of nonconvex quadratic functions on special feasible sets
We are interested in global minimization of general quadratic functions on a feasible set F. It is well-known that depending on the specific set F the problem is possibly tractable or hard. We are especially interested in the minimization on the unit simplex F. This problem is just the feasibility problem for copositive programming. The latter recently attracted much attention as it appeared that many hard integer problems can be represented exactly by copositive programs.

In our talk we firstly discuss some interesting properties of quadratic functions such as the number of components of the level sets and the number of global minimizers. We then consider copositive programming and give some recent results on the structure of this problem.

Tomas Babaj, Karlsruhe Institute of Technology
Nonsmooth versions of Sard’s theorem
We present a comparison between some versions of Sard’s Theorem which have been proven recently for special function classes with different definitions of critical points. The motivation for calling a given point a critical point of a function varies. Considering the class of C^1 functions, the motivation for the definition of critical point is the topological structure of the inverse image. Considering the class of set-valued definable mappings, the motivation for the definition of critical points is the property of metric regularity. We compare topological critical points and critical points defined via metric regularity in the class of min-type and min-max functions.

We illustrate the whole problematic by some examples.

Dominik Dorsch, RWTH Aachen University (with Hubertus Th. Jongen, Vladimir Shikhman)
Local models in equilibrium optimization
We study equilibrium optimization from a structural point of view. For that, we consider equilibrium optimization problems up to the smooth coordinate transformations locally at their solutions. The latter equivalence relation induces classes of equilibrium optimization problems. We focus on the stable classes corresponding to a dense set of data functions. We prove that these classes are unique and call them “basic classes”. Their representatives in the simplest form are called local models. For particular realizations of equilibrium optimization problems basic classes and their local models are elaborated. The latter include bivelop optimization, general semi-infinite programming and Nash optimization.

Advances in global optimization VI
Chair: Daniel Aloise, Universidade Federal do Rio Grande do Norte (with Sebastian Sager)
Global optimal control using direct multiple shooting
Motivated by state-of-the-art algorithms for mixed integer optimal control problems (MIOCP), where lower bounds on the solution are necessary, we developed a numerical method to combine direct multiple shooting with convex relaxation techniques for optimal control problems.

Embedded into an extended branch and bound framework and applied to a MIOCP with relaxed integer decisions, the lower bounds on the solutions allow to determine if the objective value of the resulting optimal control problem is, at least up to a desired epsilon accuracy, close to the global solution. Afterwards, we apply integer approximation methods like the Sum Up Rounding strategy to the relaxed solution in order to obtain arbitrarily close approximations of the global integer solution for a wide range of MIOCPs.

Finally, we present first numerical results on selected benchmark problems from the literature and new challenging problems including mixed integer decisions with relaxed problems that exhibit multiple local minima.

Daniel Aloise, Universidade Federal do Rio Grande do Norte (with Pierre Hansen, Caroline Rocha)
A column generation algorithm for semi-supervised clustering
Clustering is a powerful tool for automated analysis of data. It addresses the following problem: given a set of entities find subsets, called clusters, which are homogeneous and/or well separated. In addition to the entities themselves, in many applications, information is also available regarding their relations in the space. This work presents a column generation algorithm for minimum sum-of-squares clustering in the presence of must-link and cannot-link pairwise constraints. The computational results show that the proposed algorithm is faster than the current state-of-the-art method.

Parallel optimization software
Organizer/Chair: Jeff Linderoth, University of Wisconsin-Madison - Invited Session
Katsuki Fujisawa, Chuo University (with Toshio Aida, Satoshi Matsuoka, Hitoshi Sato, Makoto Yamashita)
High-performance general solver for extremely large-scale semidefinite programming problems
Semidefinite Program (SDP) is one of the most important problems in current research areas in optimization problems. It covers a wide range of applications such as combinatorial optimization, control theory, economics, quantum chemistry, sensor network location, data mining, etc. Solving extremely large-scale SDPs has a significant importance for the current and future applications of SDPs. In 1995, Fujisawa et al. started the SDPA Project aimed for solving large-scale SDPs with numerical stability and accuracy. It is one of pioneering general SDPs. The SDPARA is a parallel version of the SDPA on multiple processors and distributed memory, which replaces major bottleneck components of the SDPA by their parallel implementation. In particular, it has been successfully applied on quantum chemistry and combinatorial optimization, the SDPARA on a large-scale supercomputer called TSUBAME 2.0 in Tokyo Institute of Technology has succeeded to solve the largest SDP which has over one million constraints with high accuracy and make a new world record.

Yuji Shinano, Zuse Institute Berlin (with Tobias Achterberg, Timo Berthold, Stefan Heinz, Thorsten Koch, Stefan Vigerske, Michael Winkler)
ParaSCIP and FiberSCIP – Parallel extensions of SCIP
SCIP is a powerful Mixed Integer Linear and Non-Linear Programming (MILP/MINLP) solver. We will present the implementation of two parallel extensions of SCIP. One is ParaSCIP, which is intended to run on a large scale distributed memory computing environment and the other is FiberSCIP, intended to run in shared memory computing environments. ParaSCIP has successfully been run on the HLRN II supercomputer utilizing up to 7,168 cores to solve a single difficult MILP. It has also been tested on a Fujitsu PRIMERGY RX2000S using up to 512 cores. Even though ParaSCIP and FiberSCIP have different capabilities, they are realized using a single software: the Ubiquity Generator (UG) framework. The latest computational results using the both ParaSCIP and FiberSCIP will be presented.

Cynthia Phillips, Sandia National Laboratories (with Jonathan Eckstein, Ojas Parekh, John Siirola, Jean-Paul Watson)
PICO’s new hierarchical branch-and-bound system for massively parallel IP
We will discuss the design, implementation, and large-scale parallel computation techniques for PICO, Parallel Integer and Combinatorial Optimizer, a massively-parallel mixed-integer programming solver. We leverage the basic PICO ramp up system for automatic integer program decomposition and carefully manage runtime conditions to effectively run arbitrary black-box IP solvers on massively parallel systems. Our computational results use Sandia National Laboratories’ “Red Sky” system, which has more than 20,000 cores.

Symmetry issues in integer programming
Organizer/Chair: Volker Kaibel, Otto-von-Guericke-Universität Magdeburg - Invited Session
Matteo Fischetti, University of Padova (with Luc Liberti)
Orbital shrinking
Symmetry plays an important role in optimization. The usual approach to cope with symmetry in discrete optimization is to try to eliminate it by introducing artificial symmetry-breaking conditions into the problem, and/or by using an ad-hoc search strategy. In this paper we argue that symmetry is instead a beneficial feature that we should preserve and exploit as much as possible, breaking it only as a last resort. To this end, we outline a new approach, that we call orbital shrinking, where additional integer variables expressing variable sums within each symmetry orbit are introduces and used to encapsulate module symmetry. This leads to a discrete relaxation of the original problem, whose solution yields a bound on its optimal value. Encouraging preliminary
A computational comparison of symmetry handling methods in integer programming

During the past several years several methods to handle symmetries in integer programs have been introduced. This includes isomorphism pruning by Margot, orbital branching by Ostrowski et al., symmetry breaking constraints by Liberti, etc. In this talk we present a computational comparison of these different approaches in the framework SCIP. We discuss implementation issues like symmetry detection and the detection of interesting subgroups of the symmetry group as well as their exploitation during the solution process. The tests are run on the highly symmetric instances of Margot and on the CFP10B 2010. We discuss the results of these test runs, which, as can be expected, depend on the instances at hand. We also compare two different ways to detect symmetry via graph isomorphism.

Jim Ostrowski, University of Tennessee (with Jianhui Wang)

Dominance-strengthened symmetry breaking constraints in the unit commitment problem

Adding symmetry-breaking to a highly symmetric instance of a MILP problem can reduce the size of the problem’s feasible region considerably. The same can be said for good dominance constraints. In this talk we will examine the impact of using dominance arguments to strengthen symmetry breaking constraints for the Unit Commitment (UC) problem. It is present in [traditional formulations of the] UC problem when there are several generators of the same type. We show that by adding dominance strengthened cuts, the number of feasible solutions that need to be considered only grows polynomially as the number of generators increases (so long as the number of unique generators is fixed).

Benjamin Nill, Case Western Reserve University

Recent developments in the geometry of numbers of lattice polytopes

In this talk, I will give an overview about recent results in the geometry of numbers of lattice polytopes. All of these will deal with the question of what we know about lattice polytopes with a certain number of interior lattice points or none at all. I also hope to show how an invariant in Ehrrhart theory possibly allows a unifying view on these results.

Andreas Paffenholz, TU Darmstadt (with Barbara Baumeister, Christian Haase, Benjamin Nill)

Permutation polytopes

A permutation polytope is the convex hull of the permutation matrices of a subgroup of $S_n$. These polytopes are a special class of 0/1-polytopes. A well-known example is the Birkhoff polytope of all doubly-stochastic matrices defined by the symmetric group $S_2$. This is a well-studied polytope. Much less is known about general permutation polytopes. I will shortly discuss basic properties, combinatorial characterizations, lattice properties, and connections between the group and the polytope. A main focus of my presentation will be on recent results for cyclic groups. Their permutation polytopes correspond to marginal polytopes studied in algebraic statistics and optimization. In particular, I will present families of facet defying inequalities.

Alexander Kasprzyk, Imperial College London (with Satoru Higashispery)

Riemannian polytopes

Given a convex lattice polytope $P$, one can count the number of points in a dilation $mP$ via the Ehrhart polynomial $E(P)$. The roots of $E(P)$ (over $\mathbb{C}$) have recently been the subject of much study, with a particular focus on the distribution of the real parts. In particular, V. Golyshev conjectured, and the authors recently proved, that any smooth polytope of dimension at most five are so-called Riemannian polytopes; this is, conjectured, and the authors recently proved, that any smooth polytope.

Marc Pfetsch, TU Darmstadt (with Thomas Rehe)

Integer points in polytopes II

Organizers/Chairs Michael Jörgow, TU Darmstadt; Günther M. Ziegler, TU Berlin – Invited Session

Benjamin Nill, Case Western Reserve University

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the proposed algorithm is quite efficient. Finally, the advantage using commitments is formulated as the stochastic programming problem in which objectives of the problem are: (1) Minimization of the total expected cost, a function of inflation and time value of money where the inflation and rate of the long chain relative to full flexibility increases as the number of chain increases with system size, thus implying that the effectiveness of the long chain relative to full flexibility increases as the number of products decreases; (ii) a guillotine result implying that the fill rate of a long chain increases with the number of products, but this increase converges to zero exponentially fast.

Takayuki Shiina, Chiba Institute of Technology

Inventory distribution problem using both transshipment and emergency transshipment, have been studied separately in the inventory distribution problem. The transshipment in inventory distribution problem incorporates partial backlogging. The demand rate can be over the time horizon. In the real situation, some but not all customers that require goods in the warehouse of the time horizon. The ideal point approach has been proposed to formulate the model. Also, the numerical example has been provided for evaluation and validation of the theoretical results.

Stefan Walldenner, Universität Osnabrück

Two-stage order sequence planning in shelf-board production

In cooperation with a supplier of kitchen elements the production of storage boards is optimized. Because of the problem’s high complexity and the frequent changes of the order situation, the time horizon for the order sequence scheduling should cover at most two days. However, to assure the needed raw material in time for production, it is necessary to determine an appropriate production time within the two-day time horizon. Therefore we split the production scheduling into two stages: In a first coarse planning stage we relax the problem by dropping some constraints and consider it as a Min Cost Flow Problem to calculate a production time detailed to the day. This forms the basis for planning the pre-production of the needed raw material to assure their availability. In a second fine planning stage the exact sequence scheduling is carried out taking into account both, resource constraints and sequence-dependent setup- and production times.

Yehua Wei, Massachusetts Institute of Technology (with David Simchi-Levi)

Understanding the performance of the long chain and sparse designs in process flexibility

We study the expected sales of sparse flexibility designs, which are modeled by the expected objective value of a stochastic bipartite max-flow problem. In particular, we focus on the long chain design, a design that has been successfully applied by several industries. First, we uncover an interesting property of the long chain, supermodularity. Then, this property is used to show that the performance of the long chain is characterized by the difference between the expected sales of two simpler designs which leads to the optimality of the long chain among 2-flexibility designs. Finally, under IID demand, this characterization gives rise to three developments: (i) an effective algorithm to compute the expected sales of long chains using only matrix multiplications; (ii) a result that the gap between the fill rate of full flexibility and that of the long chain increases with system size, thus implying that the effectiveness of the long chain relative to full flexibility increases as the number of products decreases; (iii) a surprising result implying that the fill rate of a long chain increases with the number of products, but this increase converges to zero exponentially fast.

Chair Yehua Wei, Massachusetts Institute of Technology (with David Simchi-Levi)

Modelling, reformulation and solution of MINLPs

Organizer/Chair Leo Liberti, École Polytechnique - Invited Session

Mariana de Santis, Istituto di Analisi dei Sistemi e Informatica (with Stefano Lucidi)

A method for MINLP problems with simple constraints

We are concerned with the problem of minimizing a continuously differentiable function subject to simple constraints on the variables where some of the variables are restricted to take integer values. To tackle the problem we propose an approach based on a minimization of distributed type: an appropriate local search is performed depending on whether the variable is continuous or integer. The continuous local search is based on an active set method that combines ideas from projected and Newton-type algorithms. For the discrete local search a grid search along the discrete variables is performed.

Leo Liberti, École Polytechnique (with Pietro Belotti, Sonia Cafieri, Jan Lee)

On feasibility-based bounds tightening

Mathematical programming problems involving nonconvexities are usually solved to optimality using a spatial branch-and-bound (sBB) algorithm. Algorithmic efficiency depends on many factors, among which the widths of the bounding box for the problem variables at each branch-and-bound node naturally plays a critical role. The practically fastest box-tightening algorithm is known as FBBT (feasibility-based bounds tightening): an iterative procedure to tighten the variable ranges. Depending on the instance, FBBT may not converge finitely to its limit ranges, even in the case of linear constraints. Tolerance-based termination criteria yield finite termination, but not in worst-case polynomial time. We model FBBT by using fixed-point equations in terms of the variable bounding box, and we treat these equations as constraints of an auxiliary mathematical program. We demonstrate that the auxiliary mathematical program is a linear program, which can of course be
solved in polynomial time. We demonstrate the usefulness of our approach by improving the open-source SBB solver Couenne.

Claudia D’Ambrosio, CNRS Ecole Polytechnique (with Andrea Lodi, Riccardo Rovatti, Martello Silvano) Optimistic modeling of non-linear optimization problems by mixed-integer linear programming

We present a new piecewise linear approximation of non-linear optimization problems. It can be seen as a variant of classical triangulations that leaves more degrees of freedom to define any point as a convex combination of points from a finite number of polyhedra. In most cases, a hyper-rectangular subdomain is partitioned into hyper-rectangular subdomains through a grid defined by \( n_t \) points on the \( t \)-axis \((t = 1, \ldots, T)\), and the number of potential simplices is \( |T|^{\sum_{t=1}^T (n_t - 1)} \), and an MILP model incorporating it without complicated encoding strategies must have the same number of additional binary variables. In the proposed approach the choice of the simplices is optimistically guided by one between two approximating objective functions, and the number of additional binary variables needed by a straightforward implementation drops to only \( \sum_{t=1}^T (n_t - 1) \). The method allows the use of recent methods for representing such a partition with a logarithmic number of constraints and binary variables. We show theoretical properties of the approximating functions, and provide computational evidence of the impact of the method when embedded in MILP models.
algorithms compare favorably with solutions obtained from the channel matched beamforming or the leakage interference minimization.

William Rager, University of Florida (with Hongchao Zhang)

A primal-dual active set algorithm for nonlinear optimization with polyhedral constraints

A primal-dual active set algorithm is developed for nonlinear optimization with polyhedral constraints. The algorithm consists of a non-monotone gradient projection phase implemented by dual active set techniques, an unconstrained optimization phase in the subspace determined by the active set, and a set of rules for branching between the two phases. Global convergence to a stationary point is established. For a nondegenerate stationary point, the algorithm eventually reduces to an unconstrained optimization in a subspace without restarts. Similarly, for a degenerate stationary point where the strong second-order sufficient optimality condition holds, the algorithm eventually reduces to unconstrained optimization in a subspace. A specific implementation of the algorithm is given which exploits a new dual active set algorithm for the gradient projection step and the conjugate gradient algorithm CONDENSET for unconstrained optimization.

Yu-Hong Dai, Chinese Academy of Sciences

A perfect example for the BFGS method

Consider the BFGS quasi-Newton method applied to a general nonconvex function that has continuous second derivatives. This paper aims to construct a four-dimensional example such that the BFGS method need not converge. The example is perfect in the following sense: (a) All the stepsizes are exactly equal to one; (b) the unit stepsize can also be accepted by various line search schemes including the Wolfe line search and the Armijo line search; (b) The objective function is strongly convex along each search direction although it is not in itself. The unit stepsize is the unique minimizer of each line search function. Hence the example also applies to the global line search and the line search that always picks the first local minimizer; (c) The objective function is polynomial and hence is infinitely continuously differentiable. If relaxing the convexity requirement of the line search function; namely, (b), we are able to construct a relatively simple polynomial example.

Juan Pablo Luna, Instituto de Matemática Pura e Aplicada – IMPA (with Claudia Sagastizábal, Mikhail Solodov)

Finding equilibrium prices for energy markets with clearing conditions

Energy markets often involve a large number of agents, responsible for production, transportation, storing, or consumption of items such as generated power, distributed energy, stored gas. We analyze an equilibrium model for a market whose agents seek to maximize profits by selling items through a network at a price determined by market clearing. This type of market can be modelled as a large complementarity problem obtained by gathering the agents profit-maximization conditions together with the market-clearing relation. We consider an alternative model formulated as a generalized Nash equilibrium problem, with agents seeking to minimize costs instead of maximizing profits. Interestingly, this alternative formulation turns out to be equivalent to the more common complementarity model mentioned above. At the same time, it reduces substantially the size of the variational problem and is amenable to decomposition schemes, thus making it possible to consider more realistic situations dealing, for example, with uncertainty and risk for large gas or power networks.

Özge Ozdemir, ECN (with Gul Gurkan, Yves Smeers)

Risk averse long term capacity equilibria: An optimization formulation extending MARKAL

Linear Programming (LP) and other optimization models are standard & useful for long term capacity equilibria, eg, MARKAL for energy capacity equilibria. Such models:

- assume Perfect competition
- can handle uncertainty via risk neutral valuation, i.e., expectation with respect to given probability density.

Our main result is that risk aversion can be included in LP/optimization models for long term capacity equilibria:

- assuming Perfect competition
- where valuation of uncertain assets is modelled by Coherent Risk Measures
- by using financial securities which are traded in a Complete Risk Market.
A trust-region based adaptive stochastic collocation method for PDE constrained optimization with uncertain coefficients

Many optimization problems in engineering and science are governed by partial differential equations (PDEs) with uncertain parameters. Although such problems can be formulated as optimization problems in Banach spaces and derivative based optimization methods can in principle be applied, the numerical solution of these problems is more challenging than the solution of deterministic PDE constrained optimization problems. The difficulty is that the PDE solution is a random field and the numerical solution of the PDE requires a discretization of the PDE in space/time as well as in the random variables. As a consequence, these optimization problems are substantially larger than the already large deterministic PDE constrained optimization problems.

In this talk we discuss numerical solution of such optimization problems using stochastic collocation methods. We explore the structure of this method in gradient and Hessian computations. We use a trust-region framework to adapt the collocation points based on the progress of the algorithms and structure of the problem. Convergence results are presented. Numerical results demonstrate significant savings of our adaptive approach.

John Pearson, University of Oxford

Iterative solution techniques for Stokes and Navier-Stokes control problems

The development of efficient iterative methods for the solution of PDE-constrained optimization problems is an area of much recent interest in computational mathematics. In this talk, we discuss preconditioned iterative methods for the Stokes and Navier-Stokes control problems, two of the most important problems of this type in fluid dynamics. We focus on the Krylov subspace methods used to solve the matrix systems involved, develop the relevant preconditioners using the theory of saddle point matrices, and present analytical and numerical results to demonstrate the effectiveness of our proposed preconditioners in theory and practice.

John Pearson, University of Oxford (with XuanCan Ye)

Reduced order models in preconditioning techniques

The main effort of solving a PDE constrained optimization problem is devoted to solving the corresponding large scale linear system, which is usually sparse and ill conditioned. As a result, a suitable Krylov subspace solver is favorable, if a proper preconditioner is embedded. Other than the commonly used block preconditioners, we exploit knowledge of proper orthogonal decomposition (POD) for preconditioning and also some interesting features. Numerical results on nonlinear test problems are presented.

Ekkehard Sachs, University of Trier (with Xuancan Ye)

New results in scenario generation for stochastic optimization problems via the sparse grid method

We study the use of sparse grid methods for the scenario generation (or discretization) problem in stochastic optimization problems when the uncertainty is modulated using a continuous univariate distribution. We show that, under a regularity assumption on the random function, the sequence of optimal solutions of the sparse grid approximations converges to the true optimal solution as the number of scenarios increases. The rate of convergence is also established. An improvement is presented for stochastic programs in the case when the uncertainty is described using a linear transformation of a product of univariate distributions, such as joint normal distributions. We numerically compare the performance of sparse grid methods with quasi-Monte Carlo and Monte Carlo scenario generation. The results show that the sparse grid method is very efficient if the integrand is sufficiently smooth, and that the method is potentially scalable to thousands of random variables.

Sanjay Mehrotra, Northwestern University (with Michael Chen, David Papp)

Cut generation for serially dependent multistage stochastic optimization problems

Several variations of Monte Carlo methods for multistage stochastic programs rely on serial independence to obtain valid cuts (supporting hyperplanes) on a lower-bounding value function approximation. Many practical problems, however, have several forms of serial dependence. In particular, many financial models involve auto-regressive processes with significant auto-correlations. This talk will describe how to obtain valid cuts in this framework so that extensions of methods such as stochastic dual dynamic programming (SDDP), abridged nested decomposition (AND), and others can be extended to a more general environment.

Tito Homem-de-Mello, University Adolfo Ibáñez (with Víctor de Matos, Elion Finardi)

On scenario generation methods for a hydroelectric power system

We study a multi-stage stochastic programming model for hydrotidal energy planning in Brazil, where uncertainty is due to water inflows. We discuss some methods for generation of scenario trees.

John Birge, University of Chicago
that can be used by an optimization algorithm to solve the problem. Although the original input process is modeled with an periodic auto-regressive model, by making a transformation we can reduce the input process to one that is stage-wise independent. That in turn allows us to proceed with generating scenarios stage-by-stage following the approach in Mirkov and Pflug (2007). The algorithm we propose hinges on the stage-wise independence property and consists of two phases: first, we generate a scenario tree where the distribution in each stage is approximated by a discrete distribution with large number of points; then, we apply a reduction method to find a distribution with smaller support that minimizes the Wasserstein distance to that discrete distribution. We show how this minimization problem can be solved with a structured binary linear program. Some numerical results are presented to illustrate the ideas.

Stochastic optimization

PDE constrained stochastic optimization
Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen - Invited Session

Rüdiger Schultz, University of Duisburg-Essen (with Sergio Conti, Harald Held, Martin Pac, Martin Rumpf)

Shape optimization under uncertainty via stochastic optimization
- Shape optimization with linearized elasticity and stochastic loading is put into the framework of two-stage stochastic programming. Principal model setup is set, both risk neutral and risk averse, are discussed. Outlines of solution procedures and some computational experiments complete the talk.

Benedikt Gehre, Bonn University

A two-scale approach for risk averse shape optimization
We investigate macroscopic geometries with underlying periodic lattices of fine scale structures. These details are expected to be parametrized via a finite number of parameters over which we optimize. Risk averse stochastic cost functionals are taken into account. We employ a two-scale approach based on boundary elements for the elastic problem on the microscale and fine elements on the macroscale.

Tony Haschke, University of Heidelberg (with Sebastian Sager)

Solving stochastic optimal control problems by a polynomial chaos approach
In optimal control problems driven by stochastic differential equations, the detection of optimal (Markovian) decision rules is a very challenging task. Explicit solutions can be found in only very few cases by considering the corresponding Hamilton-Jacobi-Bellman equation. Thus numerical methods, e.g., based on Markov chains, have attracted great interest.

In this contribution, we introduce a new methodology for solving continuous finite-horizon stochastic optimal control problems. We utilize ideas for approximating stochastic differential equations within the framework of Polynomial Chaos and expand this to reformulate stochastic optimal control problems directly into deterministic ones. This allows us to use Bock’s direct multiple shooting method, a state of the art simultaneous method to solve optimization and simulation tasks at the same time. We implement different approaches to preserve the feedback character of the optimal decision rules. Numerical examples illustrate this new methodology and show the validity of the developed reformulations.

Telecommunications & networks

Robust vehicle routing problem with time windows
This work addresses the robust vehicle routing problem with time windows. We are motivated by a problem that arises in maritime transportation where delays are frequent and should be taken into account. Our model only allows routes that are feasible for all values of the travel times in a predetermined uncertainty polytope, which yields a robust optimization problem. We propose two new formulations for the robust problem, each based on a different robust approach. The first formulation extends the well-known resource inequalities formulation by employing robust programming with recourse. We propose two techniques, which, using the structure of the problem, allow to reduce significantly the number of extreme points of the uncertainty polytope. The second formulation generalizes a path inequalities formulation to the uncertain context. The uncertainty appears implicitly in this formulation, so that we develop a new cutting plane technique for robust combinatorial optimization problems with complicated constraints. In particular, efficient separation procedures are discussed. We compare the two formulations on maritime transportation instances.

Sara Martia, IASI-CNRS

The robust network loading problem
The Robust Network Loading (RNL) problem is a generalization of the well known Network Loading (NL) problem. Given a graph with capacity installation costs for the edges, the RNL problem consists of choosing minimum cost integer capacities to serve all the demands belonging to a given polyhedron of feasible traffic matrices. If the routing scheme must be the same for all the matrices, it is called static or oblivious; if it can be changed according to the matrix, it is called dynamic. If the point-to-point demand in the matrix must be routed over a single path, the flows are called unsplittable, otherwise they are said to be splittable. In this talk we present an algorithm for solving the RNL with dynamic routing and splittable flows and a preliminary comparison between the static and the dynamic approach.

Fabio D’Andreagiovanni, Zuse Institute Berlin (ZIB) (with Christina Büsing)

On the adoption of multi-band uncertainty in robust network design
Handling uncertainty in the design of telecommunication networks has become a key challenge for leading network operators. Uncertainty in Network Design has been mainly tackled by the Bertsimas-Sim model (BS). However, the central assumption of BS that the deviation band of each uncertain parameter is single may be too simplistic in practice. Our experience indeed suggests that relevant deviations also occur internally and asymmetrically over the band. Breaking the band into multiple sub-bands looks thus advisable.

In this work, we study the robust counterpart of an LP with uncertain coefficient matrix, when a multi-band uncertainty set is considered. We show that the robust counterpart corresponds to a compacted LP formulation and that separating robustness cuts corresponds to solving a mixed-cost flow problem. Finally, we assess the effectiveness of our approach on realistic instances of robust network design problems considered by our industrial partners.


Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen. Invited Session

Monotone operators
Organizer/Chair Radoi Ioan Bot, Chemnitz University of Technology - Invited Session

Radoi Ioan Bot, Chemnitz University of Technology (with Sorin-Mihai Grad)

Approximating the maximal monotonicity of bifunctions via representative functions
In this talk we provide an approach to maximal monotone bifunctions by means of the theory of representative functions. Thus we extend to nonreflexive Banach spaces recent results due to A.N. Iusem (Journal of Convex Analysis, 2011) and, respectively, N. Hadjisawas and H. Khatibzadeh (Optimization, 2010), where sufﬁcient conditions guaranteeing the maximal monotonicity of bifunctions were introduced.

Marco Rocca, Bank of Italy (with Juan Enrique Martínez-Legaz)

On a surjectivity-type property of maximal monotone operators
In this paper we carry on the inquiry into surjectivity and related properties of maximal monotone operators initiated in Martinez-Legaz, Some generalizations of Rockafellar’s surjectivity theorem (Pac. J. Optim., 2008) and Rocco and Martínez-Legaz, On surjectivity results for maximal monotone operators of type [D] (J. Convex Anal., 2011). Providing a correction to a previous result, we obtain a new generalization of the surjectivity theorem for maximal monotone operators.

Szilárd László, Babes-Bolyai University, Cluj-Napoca

Regularity conditions for the maximal monotonicity of the generalized parallel sum
We give several regularity conditions, both closedness and interior point type, that ensure the maximal monotonicity of the generalized parallel sum of two strongly representable maximal monotone operators, and we extend some recent results concerning on the same problem. Our results are based on the concepts of representable function and Fenchel conjugate, while the technique used to establish closedness type, respectively interior-point type regularity conditions, that ensure the maximal monotonicity of this generalized parallel sum, is stable strong duality. We give an useful application of the stable strong duality for the problem involving the function $f + A + g$, where $f$ and $g$ are proper, convex and lower semicontinuous functionals, and $A$ is a linear and continuous operator. We also introduce some new generalized infimal convolution formulas, and establish some results concerning on their Fenchel conjugate.
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