An exact approach for aggregated formulations

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THE PROGRAM
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.

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 Weisseneburger

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 prices. 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.
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 murmers 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.
PLENARY AND SEMI-PLENARY LECTURES: Monday

**Plenary lecture**

**Mon.09:00.H0105**

Rakesh V. Vohra

**Polymatroids and auction theory**

Chair John Birge

A polymatroid is a polytope associated with a submodular function. Its 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 program-mer. 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.

**Semi-plenary lecture**

**Mon.17:00.H0105**

Dimitris Bertsimas

**A computationally tractable theory of performance analysis in stochastic systems**

Chair Friedrich Eisenbrand

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.
Semi-plenary lecture

Mon.17:00.H0104

Katya Scheinberg

Using randomized models in black-box and derivative free optimization
Chair Luís Nunes Vicente

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 SI OPT.

Tuesday

Tue.09:00.H0105

Robin Thomas

A new look at excluding a non-planar graph
Chair Gérard Cornuéjols

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**

**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**

**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 nonnegative 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 Hiderabad. 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.

This talk deals with algorithms and complexity results about the minimization of convex functions over integer points in convex regions. We begin with a survey about the current state of art. Then we discuss results about to the speed of convergence of a black box algorithm that iteratively solves special quadratic integer subproblems with a constant approximation factor. Despite the generality of the underlying problem we prove that we can detect efficiently w.r.t. our assumptions regarding the encoding of the problem a feasible solution whose objective function value is close to the optimal value. We also show that this proximity result is best possible up to a polynomial factor. Next we discuss a new “cone-shrinking algorithm” that allows us to prove that integer convex optimization with a constant number of variables is polynomial time solvable. Parts of our results are based on joint work with M. Baes, A. del Pia, Y. Nesterov, S. Onn. The other part is based on joint work with M. Baes, T. Oertel, C. Wagner.

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.
Thursday

**Plenary lecture**

**Thu.09:00.H0105**

Richard G. Baraniuk

**Compressive signal processing**

Chair Luís Nunes Vicente

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 fromEta 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.

**Semi-plenary lecture**

**Thu.17:00.H0104**

Michael P. Friedlander

**Data fitting and optimization with randomized sampling**

Chair Luís Nunes Vicente

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 Hirosaki 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 $L_1$ 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.
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.

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.

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**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. Valparaiso, 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
Thursday

Historical lecture Thu.17:00.H1012

Jürgen Sprekels
Karl Weierstrass and optimization
Chair Richard Cottle

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.

Historical lecture Thu.17:30.H1012

Martin Grötschel
Hermann Minkowski and convexity
Chair Richard Cottle

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: Jörg 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
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The exhibit area is located in the ‘Lichthof’ of the Main Building. The exhibition is open Monday, August 20, to Friday, August 24, 9:00–17:00.

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CAMPUS MAP

- Math Building
- Main Building
- Mensa
- Ernst-Reuter-Platz
- Underground Station 'Ernst-Reuter-Platz'

- Straße des 17. Juni
- Straßenbergstraße
- Steinplatz
- Harzburgerstraße
- Fasanenstraße
- Einsiedlustraße

- 'Ernst-Reuter-Platz' Station
- Urban Rail Station 'Tiergarten'
- Train Station
- Bus 245, M45, X9

- 5 min walk to Urban Rail Station 'Tiergarten'
- 5 min walk to Train Station/Zoologischer Garten
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# Daily events and sessions

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<td>Coffee Break</td>
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<tr>
<td>15:15–16:45</td>
<td>Technical Sessions (Thu.3)</td>
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<td>15:15–16:45</td>
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<td>Historical Lecture: Jürgen Sprekels</td>
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<td>Lunch Break (on your own)</td>
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<td>13:15–14:45</td>
<td>Technical Sessions (Fri.2)</td>
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<td>14:45–15:15</td>
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Organizer: Daniel Ralph (p. 74)  
Tucker awards ceremony  
Presentation by Tucker Prize Finalist |
| 10:45 | **Combinatorial optimization: Rational convex programs and combinatorial algorithms**  
Organizer: Lionel Pournin (p. 74)  
H 3004  
Julia Brandt  
A primal-dual Lagrange optimization for VLSI global placement  
(Conference)  
Sylvia Boyd  
A primal-dual Lagrange optimization for VLSI global placement  
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Markus Struzyna  
Quadratic and constrained placement in chip design  
(Conference)  
Ulrich Brenner  
A primal-dual Lagrange optimization for VLSI global placement  
(Conference)  |
| 11:00 | **Combinatorial optimization: Matching**  
Organizer: Michael Kapralov (p. 75)  
H 3012  
Sigrid Knust  
Scheduling sports tournaments on a single court based on special 2-factorizations  
(Conference)  
Mizuyo Takamatsu  
Matching problems with delta-matroid constraints  
(Conference)  
Michael Kapralov  
A primal-dual Lagrange optimization for VLSI global placement  
(Conference)  |
| 11:15 | **Combinatorial optimization: Matching**  
Organizer: Ralf Borndörfer (p. 75)  
H 3013  
Jun Imaizumi  
A column generation approach for crew rostering problem in a freight railway company in Japan  
(Conference)  
Thomas Schlechte  
Recent developments in railway track allocation  
(Conference)  
Steffen Weider  
A rapid branching method for the vehicle rotation planning problem  
(Conference)  |
| 11:30 | **Combinatorial optimization: Matching**  
Organizer: Nikhil Bansal (p. 76)  
H 3021  
Kirk Pruhs  
Online primal-dual for non-linear optimization with applications to speed scaling  
(Conference)  
Ola Svensson  
On the hardness of scheduling with precedence constraints to minimize makespan  
(Conference)  
Cliff Stein  
How to schedule when you have to buy your energy  
(Conference)  |
| 11:45 | **Combinatorial optimization: Matching**  
Organizer: Gabor Pataki (p. 76)  
H 2036  
Hayato Waki  
Computation of facial reduction algorithm  
(Conference)  
Vera Roshchina  
Partition and complementarity in multifold conic systems  
(Conference)  
Osman Guler  
Efficient first-order methods for convex programming  
(Conference)  |
| 12:00 | **Combinatorial optimization: Matching**  
Organizer: Petr Vilím (p. 77)  
H 3003A  
Andre Cire  
MDD propagation for disjunctive scheduling  
(Conference)  
Philippe Laborie  
Conditional interval variables: A powerful concept for modeling and solving complex scheduling problems  
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| 12:15 | **Combinatorial optimization: Matching**  
Organizer: Giorgio Consigli (p. 77)  
H 3027  
Andrea Consiglio  
Convex lower bounding to generate multi-asset, arbitrage-free, scenario trees  
(Conference)  
Nalan Gulpinar  
Robust investment decisions for asset liability management  
(Conference)  
Giorgio Consigli  
Institutional asset-liability management for a large P&C insurance company  
(Conference)  |
| 12:30 | **Combinatorial optimization: Matching**  
Organizer: Konstantinos Bimpikis (p. 78)  
MA 043  
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Network games under strategic complementarities  
(Conference)  
Matthew Elliott  
A network centrality approach to coalitional stability  
(Conference)  
Konstantinos Bimpikis  
A network centrality approach to coalitional stability  
(Conference)  |
| 12:45 | **Combinatorial optimization: Matching**  
Organizer: Miguel Anjos (p. 77)  
H 2038  
Henry Wolkowicz  
Taking advantage of degeneracy in cone optimization with applications to sensor network localization and molecular conformation  
(Conference)  
Philipp Hungerländer  
Semidefinite optimization approaches to some facility layout problems  
(Conference)  
Manuel Vieira  
Relationships between minimal unsatisfiable subformulas and semidefinite certificates of infeasibility  
(Conference)  |
### Monday 13:15–14:45

**Nonsmooth optimization: Iterative methods for variational analysis**  
-Celia Jean-Alexis: The second order generalized derivative and generalized equations  
- Robert Baier: Set-valued Newton’s method for computing convex invariant sets  
- Elza Farkhi: The directed subdifferential and applications

**Optimization in energy systems: Optimization models to manage risk and uncertainty in power systems operations**  
-Alexandre Street: Energy and reserve scheduling under a joint GT $n-K$ security criterion: An adjustable robust optimization approach  
- Jinye Zhao: Adaptive robust optimization for the security constrained unit commitment problem  
- Robert Baier: Set-valued Newton’s method for computing convex invariant sets

**Optimization in energy systems: Unit commitment and inventory problems**  
-Ali Koc: Parallel branch-cut-price for solving multistage stochastic unit commitment problems  
- Kin Keung Lai: A stochastic approach to power inventory optimization

**PDE-constrained optimization and multi-level/multi-grid methods**  
-Rene Pinnau: Exploiting model hierarchies in space mapping optimization  
-Michael Ulbrich: An adaptive semismooth Newton-CG method for constrained parameter identification in seismic tomography

**Robust optimization: Extensions of robust optimization models**  
-Michael Todd: A robust robust (sic) optimization result  
- Frank Pfeuffer: An extension of the controlled robustness model of Bertsimas and Sim

**Sparse optimization and compressed sensing: New models and algorithms in sparse optimization**  
-Nicolas Boumal: Riemannian algorithms and estimation bounds for synchronization of rotations  
- Mark Davenport: A simple framework for analog compressive sensing  
- Benjamin Recht: Atomic norm denoising with applications to spectrum estimation and system identification

**Stochastic optimization: Advances in stochastic optimization**  
-David Brown: Optimal sequential exploration: Bandits, clairvoyants, and wildcats  
- Ciamac Moallemi: Pathwise optimization for linear convex systems  
- Constantine Caramanis: Optimization at all levels: Probabilistic Envelope Constraints

**Stochastic optimization: Optimization of physical systems under uncertainty**  
-Victor Zavala: Stochastic optimization: Impacts on electricity markets and operations  
- Jim Luedtke: Branch-and-cut approaches for chance-constrained formulations of reliable network design problems  
- Bernardo Pagnoncelli: The optimal harvesting problem under risk aversion

**Stochastic optimization: Decisions policies and estimation techniques in a stochastic environment**  
-Alwin Haensel: A SP approach for decision-dependent uncertainty in production planning under non-compliance risk  
- Fabian Bastin: On the combination of Hessian approximations for data estimation  
- Xinan Yang: Approximate dynamic programming with Bézier curves/surfaces for top-percentile traffic routing

**Telecommunications and networks: Optical access networks**  
-Cédric Hervet: Robust optimization of optical fiber access networks deployments  
- Maria João Lopes: Modelling the minimum cost PON access network design problem  
- Olaf Maurer: Lagrangian approaches to a two-level FTTX network design problem

**Variational analysis: Nonsmooth phenomena in optimal control**  
-Christian Meyer: Boundary control of the obstacle problem  
- Matthais Gerdes: Globalized semi-smooth Newton methods in optimal control problems with DAEs  
- Frank Schmidt: Properties of the optimal value function and application to worst-case robust optimal control problems

**Variational analysis: Equilibrium problems and related topics**  
-Orizon Ferreira: Local convergence of Newton’s method under majorant condition in Riemannian manifolds  
- Susana Scheimberg: A reflection-projection method for equilibrium problems  
- Luis Drummond: New strategies for vector optimization problems

**Monday 13:15–14:45**

**Approximation and online algorithms: Real-time scheduling**  
-Martin Niemeier: Scheduling with an orthogonal resource constraint  
- Suzanne van der Ster: Mixed-criticality scheduling of sporadic task systems on a single machine  
- Jian-Jia Chen: Resource augmentation in real-time systems
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### Optimization in energy systems: Network operation under failures and losses

- **Richard Chen**: Survivability-constrained generation unit commitment with post-contingency corrective recourse
- **Jose Canto dos Santos**: New genetic algorithms for contingencies selection in electric power systems
- **Maicon Evaldi**: Optimal allocation of equipment for monitoring and identification of commercial losses in distribution networks

### PDE-constrained optimization and multi-level/multi-grid methods

- **Pavel Zhlobich**: Multilevel quasiseparable matrices in PDE-constrained optimization
- **Gregor Krnet**: Covariance matrix computation for parameter estimation in nonlinear models solved by iterative linear algebra methods
- **Lutz Lehmann**: Optimal sequencing of primal, adjoint and design steps

### Robust optimization: Robust nonlinear optimization

- **Hans Pirnay**: An algorithm for robust optimization of nonlinear dynamic optimization problems
- **Daniel Fleischman**: On the trade-off between robustness and value

### Sparse optimization and compressed sensing: Sparse optimization and generalized sparsity models

- **Rayan Saab**: Recovering compressively sampled signals using partial support information
- **Emmanuel Candés**: PhaseLift: Exact phase retrieval via convex programming
- **Gitta Kutyniok**: Clustered sparsity

### Stochastic optimization: Applications in natural resources

- **Gankhuyag Danzan**: Regional economical mathematical models considering ecological factors
- **Ralf Lenz**: Optimization of water network operation under uncertainties
- **Adriana Piazza**: The optimal harvesting problem under price uncertainty

### Stochastic optimization: Production, inventory and project management

- **Ali Randa**: Static-dynamic uncertainty strategy for a single-item stochastic inventory control problem
- **Takashi Hasuike**: Risk control approach to critical path method in mathematical programming under uncertainty

### Stochastic optimization: Stochastic mixed-integer programming

- **Wen-Lung Huang**: Optimal aggregate production planning with fuzzy data
- **Simge Kucukyavuz**: Decomposition algorithms with Gomory cuts for two-stage stochastic integer programs

### Telecommunications and networks: Wireless networks

- **Asutosh Nigam**: A Lagrangian heuristic for delay constrained relay node placement problem in wireless sensor networks
- **Tatiana Tchemisova**: On a constructive approach to optimality conditions for convex SIP problems with polyhedral index sets

### Variational analysis: Eigenvalue and semi-infinite optimization

- **Tatiana Tchemisova**: On a constructive approach to optimality conditions for convex SIP problems with polyhedral index sets
- **Julia Eaton**: On the subdifferential regularity of functions of roots of polynomials

### Variational analysis: Variational analysis and economic equilibrium

- **Abderrahim Jourani**: A characterization of the free disposal condition for nonconvex economies on infinite-dimensional commodity spaces
- **Alejandro Jofrè**: The robust stability of every equilibrium in economic models of exchange even under relaxed standard conditions

### Monday 15:15–16:45

#### Approximation and online algorithms: Location and routing problems

- **Tim Nonner**: Polynomial-time approximation schemes for shortest path with alternatives
- **Adria Bock**: The school bus problem
- **Artem Panin**: On approximability some location and pricing problems

#### Combinatorial optimization: Interactions between optimization and game theory in scheduling

- **Marc Uetz**: Mechanism design for single machine scheduling by ILP
- **Ruben Hoeksma**: Price of anarchy for minsum related machine scheduling
- **Neil Olver**: Approximation algorithms for scheduling via coordination mechanisms

#### Combinatorial optimization: Exact and approximation algorithms on graphs

- **Denis Cornaz**: Strengthening Lovász bound for coloring with a new graph transformation
- **Frédéric Meunier**: A routing problem raised by self-service bike hiring systems
- **Henning Bruhn**: Clique or hole in claw-free graphs
### Combinatorial optimization: Distances in graphs
- **Monday:** 15:15–16:45
- **Room:** H 3008
- **Organizers:** Christian Wulff-Nilsen and Glencora Borradaile

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### Combinatorial optimization: Scheduling II
- **Monday:** 15:15–16:45
- **Room:** H 3012
- **Organizer:** Peter Gritzmann

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### Combinatorial optimization: Constrained clustering
- **Monday:** 15:15–16:45
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- **Organizer:** Britta Peis

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- **Room:** H 3021
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### Complementarity and variational inequalities: Analysis and learning in variational inequalities
- **Monday:** 15:15–16:45
- **Room:** MA 041
- **Organizer:** Shu Lui

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- **Monday:** 15:15–16:45
- **Room:** MA 043
- **Organizer:** Christian Kanzow and Michael Ulbrich

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### Conic programming: Semidefinite programming applications
- **Monday:** 15:15–16:45
- **Room:** H 2036
- **Organizer:** Defeng Sun

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### Conic programming: Matrix optimization
- **Monday:** 15:15–16:45
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- **Organizer:** Defeng Sun

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- **Monday:** 15:15–16:45
- **Room:** H 3003A
- **Organizer:** Narendra Jussien

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- **Monday:** 15:15–16:45
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- **Organizer:** Rudolf Müller

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- **Organizer:** Jeff Linderoth

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- **Monday:** 15:15–16:45
- **Room:** H 1058
- **Organizer:** Thorsten Koch

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<td>Yuan Shen: New augmented lagrangian-based proximal point algorithms for convex optimization with equality constraint</td>
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<td>Mehiddin Al-Baali: Hybrid damped-BFGS/Gauss-Newton methods for nonlinear least-squares</td>
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<td>Masoud Ahookhosh: An improved nonmonotone technique for both line search and trust-region frameworks</td>
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Michael Romer: Linear optimization with variable parameters: Robust and generalized linear programming and their relations
Mohammad Mehdi Nasrabadi: A fuzzy programming approach to robust optimization

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Sebastian Stiller: Robust network flows
David Adjishvili: Fault-tolerant shortest paths – Beyond the uniform failure model
Ebrahim Nasrabadi: On the power of randomization in robust optimization

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Sumit Kunnumkal: Randomization approaches for network RM with choice behavior
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Cong Shi: Revenue management of reusable resources with advanced reservations

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Brigitte Jaumard: Path vs. cutset column generation models for the design of IP-over-WDM optical networks
Jørgen Haahr: Heuristic planning of shared backup path protection
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  - Ronald Hoppe: Adaptive space-time finite element approximations of parabolic optimal control problems
  - [Organizer: Stefan Ulbrich] [p. 125]
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  - Maximum flows with minimum quantities
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  - [Organizer: Andreas Griewank] [p. 127]
  - Sabrina Fiege: An exploratory line-search for piecewise smooth functions

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  - [Organizer: Sylvia Boyd and David Shmoys] [p. 128]
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- **Fabio Furini**: Heuristic and exact algorithms for the interval min-max regret knapsack problem

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- **Gunnar Kliaou**: Charge group partitioning in biomolecular simulation
- **Rumen Andonov**: Optimal DALI protein structure alignment

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- **Vinícius Armentano**: Tabu search for the hub covering problem
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- **Tamás Terlaky**: Conic representation of the convex hull of disjunctions of convex sets and conic cuts for mixed integer second order cone optimization
- **Sarah Drewes**: Cover inequalities and outer-approximation for mixed-01 SOCPs
- **Antonio Morsi**: Solving MINLPs on loosely coupled networks

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- **Emil Gustavsson**: Primal convergence from dual subgradient methods for convex optimization

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- **Simon Stingelin**: Applications of optimal control in electromagnetic flow measurement
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### Sparse optimization and compressed sensing: Algorithms for sparse optimization II
- **Kimon Fountoulakis:** Matrix-free interior point method for compressed sensing problems
- **Xiangfeng Wang:** Linearized alternating direction methods for Dantzig selector
- **Sergey Voronin:** Iteratively reweighted least squares methods for structured sparse regularization

### Stochastic optimization: Algorithms for stochastic optimization and approximation
- **Vaclav Kozmik:** Risk-averse stochastic dual dynamic programming
- **Jens Hubner:** Structure-exploiting parallel interior point method for multistage stochastic programs
- **Anthony Man-Cho So:** Chance-constrained linear matrix inequalities with dependent perturbations: A safe tractable approximation approach

### Stochastic optimization: Scheduling, control and moment problems
- **Meggie von Haartman:** Probabilistic realization resource scheduler with active learning
- **Regina Hildenbrandt:** Partitions-requirements-matrices as optimal Markov kernels of special stochastic dynamic distance optimal partitioning problems
- **Mariya Naumova:** Univariate discrete moment problem for new classes of objective function and its applications

### Stochastic optimization: Risk aversion in stochastic combinatorial optimization
- **Jian Li:** Maximizing expected utility for stochastic combinatorial optimization problems
- **Chaitanya Swamy:** Risk-averse stochastic optimization: Probabilistically-constrained models and algorithms for black-box distributions
- **Abraham Othman:** Inventory-based versus prior-based options trading agents

### Telecommunications and networks: Network flows and network design
- **Tue Christensen:** Solving the piecewise linear network flow problem by branch-cut-and-price
- **Bernard Fortz:** The hop-constrained survivable network design problem with reliable edges
- **Edoardo Amaldi:** Network routing subject to max-min fair flow allocation

### Variational analysis: Nonsmooth variational inequalities: Theory and algorithms
- **Russell Luke:** Constraint qualifications for nonconvex feasibility problems
- **Charitha Cherugondi:** A descent method for solving an equilibrium problem based on generalized D-gap function

### Variational analysis: Quadratic and polynomial optimization
- **Gwi Soo Kim:** On ε-saddle point theorems for robust convex optimization problems
- **Jeya Jeyakumar:** Sum of squares representations and optimization over convex semialgebraic sets
- **Guoyin Li:** Error bound for classes of polynomial systems and its applications: A variational analysis approach

### Wednesday 13:15–14:45

#### Approximation and online algorithms:
- **Jose Soto:** The traveling salesmen problem in cubic graphs
- **Jose Verschae:** The power of recourse for online MST and TSP
- **Claudio Tetha:** The jump number (maximum independent set) of two-directional orthogonal-ray graphs

#### Combinatorial optimization:
- **Hans Raj Tiwary:** Extended formulations for polygon
- **Eranda Dragoti-Cela:** On the x-and-y axes travelling salesman problem
- **Rafael Barbosa:** Algorithms for the restricted strip cover problem

#### Combinatorial optimization: Assignment problems
- **Geir Dahl:** Generalized Birkhoff polytopes and majorization
- **Olga Heismann:** The hypergraph assignment problem

#### Combinatorial optimization:
- **Bernd Gärtner:** Abstract optimization problems revisited
- **Marco Di Summa:** A new bound on the diameter of polyhedra
- **Edward Kim:** Subset partition graphs and an approach to the linear Hirsch conjecture

#### Combinatorial optimization: Heuristics II
- **Salim Bouamama:** A population-based iterated greedy algorithm for the minimum weight vertex cover problem
- **Abderrezak Djadoun:** Random synchronized prospecting: A new metaheuristic for combinatorial optimization

#### Combinatorial optimization: Heuristics II
- **Olga Heismann:** The hypergraph assignment problem
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<td>Fabio Racić: On generalized Nash equilibrium problems: The Lagrange multipliers approach</td>
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Jorge Vera: Improving consistency of tactical and operational planning using robust optimization
Florian Bruns: Robust load planning of trains in intermodal transportation
Pierre-Louis Poirion: Robust optimal sizing of a hybrid energy stand-alone system

Sparse optimization and compressed sensing: Efficient first-order methods for sparse optimization and its applications
Zhaoqiang Lu: Sparse approximation via penalty decomposition methods
Donald Goldfarb: An accelerated linearized Bregman method

Stochastic optimization: Scenario generation in stochastic optimization
Jorge Vera: Improving consistency of tactical and operational planning using robust optimization
Florian Bruns: Robust load planning of trains in intermodal transportation
Pierre-Louis Poirion: Robust optimal sizing of a hybrid energy stand-alone system

Stochastic optimization: Large-scale stochastic programming
David Papp: Generating moment matching scenarios using optimization techniques
Mihai Anitescu: Parallel and distributed solution methods for two-stage stochastic MILPs

Telecommunications and networks: Length bounded trees
Ivana Ljubic: Layered graph models for hop constrained trees with multiple roots
Markus Leitner: New models for the diameter constrained steiner tree problem

Variational analysis: Structural properties in variational analysis
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
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

Wednesday 15:15–16:45

Approximation and online algorithms: Randomized rounding algorithms in mathematical programming
Viswanath Nagarajan: Thresholded covering algorithms for robust and max-min optimization
Barna Saha: The constructive aspects of the Lovasz Local Lemma: finding needles in a haystack

Combinatorial optimization: Knapsack and bin packing
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
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
Vladimir Beresnev: Algorithms for discrete competitive facility location problem
Yury Kochetov: A local search algorithm for the $l_{1}/p_{l}$-centroid problem on the plane
Marta Pascoalo: Path based method for multicriteria metro location

Combinatorial optimization: Heuristics III
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 warehouses

Combinatorial optimization: Polyhedra in combinatorial optimization
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 relationship between the capacitated location polytope and its knapsack and single-node flow relaxations
Combinatorial optimization: Routing in road networks [Organizer: Andrew Goldberg] [p. 185]
Peter Sanders: Advance route planning using contraction hierarchies
Andrew Goldberg: The hub labeling algorithm
Daniel Delling: Realistic route planning in road networks

Complementarity and variational inequalities: Applications of complementarity [p. 185]
Jong-Shi Pang: On differential linear-quadratic Nash games with mixed state-control constraints
Vadim Shmyrev: A polyhedral complementarity algorithm for searching an equilibrium in the linear production-exchange model.
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  - David Williamson: A dual-fitting \( \frac{3}{2} \)-approximation algorithm for some minimum-cost graph problems
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### Combinatorial optimization: Optimization and enumeration
- [Organizers: Jaroslav Nesetril and Martin Loebl] [p. 197]
  - 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
- [Organizer: Michael Juenger] [p. 197]
  - Manuel Kutschka: Robust metric inequalities for network design under demand uncertainty
  - Daniel Schmidt: Single commodity robust network design: Models and algorithms
  - Laura Sanità: Steiner tree approximation via iterative randomized rounding

### Combinatorial optimization: Resource placement in networks
- [Organizer: David Johnson] [p. 197]
  - 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
- [Organizer: Réal Carbonneau] [p. 198]
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  - Marzena 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 II
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  - Ronny Hansmann: Minimal shunting operations for freight train composition
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Tucker session
Organizer/Chair: Daniel Ralph, University of Cambridge - Invited Session

Daniel Ralph, University of Cambridge
Tucker awards ceremony

In this session, the Tucker Prize for an outstanding doctoral thesis will be awarded, followed by presentations by the three finalists.

Approximation & online algorithms

Mon. 1. H 3004
Approximation in routing and others
Organizers/Chairs: Sylvia Boyd, University of Ottawa; David Smeets, Cornell University - Invited Session

Hyung-Chan An, EPFL (with Robert Kleinberg, David Smeets)
Improving Christofides’ algorithm for the s-t path TSP

We present a deterministic \( \frac{14}{13} \)-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 chooses the initial spanning tree based on an optimal solution to the Held-Karp relaxation rather than a minimum spanning tree; we prove this simple but crucial modification leads to a solution of cost at most twice the optimal cost, and then show how this can be extended to yield, for any \( \epsilon > 0 \), a \((2 + \epsilon)\)-approximation algorithm for this problem. Furthermore, we generalize this result to allow the machine’s speed to vary over time arbitrarily, for which no previous constant-factor approximation algorithm was known.

Frans Schalekamp, The College of William and Mary (with Jiawei Qian, Anke van Zuylen, David Williamson)
On the integrality gap of the subtour LP for the 1,2-TSP

We study the integrality gap of the subtour LP relaxation for the traveling salesman problem in the special case when all edge costs are either 1 or 2. For the general case of symmetric costs that obey triangle inequality, a famous conjecture is that the integrality gap is \( \frac{5}{3} \). Little progress towards resolving this conjecture has been made in thirty years, even though there has very recently been exciting progress with new approximation algorithms for such cases of the TSP, as well as for related problems. We conjecture that all edge costs \( \epsilon_j \in \{1, 2\} \), the integrality gap is \( \frac{19}{12} \). We show that this conjecture is true when the optimal subtour LP solution has a certain structure: Under a weaker assumption, which is an analog of a recent conjecture by Schalekamp, Williamson and van Zuylen, we show that the integrality gap is at most \( \frac{2}{3} \). When we do not make any assumptions on the structure of the optimal subtour LP solution, we can show that integrality gap is at most \( \frac{19}{12} \approx 1.267 < 4/3 \), this is the first bound on the integrality gap of the subtour LP strictly less than 4/3 known for an interesting special case of the TSP.

David Smeets, Cornell University (with Maurice Chang)
A primal-dual approximation algorithm for min-sum single-machine scheduling problems

We consider the following single-machine scheduling problem, which is often denoted \( \min \sum f_j \), we are given \( n \) jobs to be scheduled on a single machine, where each job \( j \) has an integral processing time \( p_j \), and there is a nondecreasing, nonnegative cost function \( f_j(C_j) \) that specifies the cost of finishing \( j \) at time \( C_j \); the objective is to minimize \( \sum_{j=1}^{n} f_j(C_j) \). Bansal & Pruhs recently gave the first constant approximation algorithm and we improve on their 16-approximation algorithm, by giving a primal-dual pseudo-polynomial-time algorithm that finds a solution of cost at most twice the optimal cost, and then show how this can be extended to yield, for any \( \epsilon > 0 \), a \((2 + \epsilon)\)-approximation algorithm for this problem. Furthermore, we generalize this result to allow the machine’s speed to vary over time arbitrarily, for which no previous constant-factor approximation algorithm was known.

Combinatorial optimization

Mon. 1. H 3004
Combinatorial optimization in chip design I
Organizer/Chair: Stephan Held, University of Bonn - Invited Session

Igor Markov, University of Michigan [with 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 sub-problems. 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.

Markus Shpungin, 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 movebounds. The key 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.

Uli Bremner, University of Bonn
Fractional versus integral flows: A new approach to VLSI legalization

In VLSI placement legalization, a large set of rectangular cells with the same height is given. The cells are spread over a rectangular area but may still overlap, and the task is to rearrange them overlap-free into rows such that the cells’ movement is minimized. If 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.

Triangulations
Organizer/Chair: Lionel Pournin, EFREI - Invited Session

Lionel Pournin, EFREI
The flip-graph of the 4-dimensional cube is connected

Flip-graph connectedness is established for the vertex set of the 4-
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 Schmid, 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 subspaces 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 per-unit willingness to pay to the model of main lines of the Fisher market with PLC utilities is unlikely to be in \( \mathcal{P} \), since it is PPAD-complete.

Gagan Goel, Google Research (with Vijay Vazirani)
A perfect price discrimination market model, and a rational convex program for it
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 are 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.

Sigrid Knust, University of Osnabrück
Scheduling sports tournaments on a single court based on special 2-factorizations
We consider a sports tournament for an odd number of teams where every team plays exactly two matches in each round and all matches have to be scheduled consecutively on a single court. We construct schedules for any number of teams minimizing waiting times by using special 2-factorizations of the complete graph (Hamiltonian 2-factorizations, solutions to special cases of the Oberwolfach problem).

Michael Kapralov, Stanford University (with Ashish Goel, Sanjeev Khanna)
On the communication and streaming complexity of maximum bipartite matching
Consider the following communication problem. Alice and Bob are given a bipartite graph \( G \) with \( 2n \) nodes whose edges are partitioned adversarially into two sets. Alice holds the first set, and Bob holds the second set. Alice sends Bob a message that depends only on her part of the graph, after which Bob must output a matching in \( G \). What is the minimum size of the message that allows Bob to recover a matching of size at least \( (1 - \varepsilon) \) times the maximum matching in \( G \), as a function of \( n \)? The minimum message size is the one-round communication complexity of approximating bipartite matching, which is also a lower bound on the space needed by a one-pass streaming algorithm to obtain a \( (1 - \varepsilon) \)-approximation. In this talk we are interested in the best approximation one can obtain with linear communication and space. Prior to our work, only the trivial \( 1/2 \) approximation was known. We show that Alice and Bob can achieve a \( 2/3 \)-approximation with a message of linear size, and then build on our techniques to design a deterministic streaming \( 1 - 1/e \) approximation in a single pass for the case of vertex arrivals. Finally, we show that both results are best possible.

Jun Imazumi, Toyoo University (with Kosuke Hasuike, Susumu Morito, Eiki Shigeta)
A column generation approach for crew rostering problem in a freight railway company in Japan
We consider the Crew Rostering Problem (CRP) in a freight railway company in Japan, “Japan Freight Railway Company” (JR-F). JR-F belongs to “JR Group” including six passenger railway companies and operates freight trains on the lines owned by these passenger railway companies. JR-F covers most of main lines of the passenger railway companies and has to manage their depots of the drivers all over Japan. CRP in this paper is to find rosters of a certain depot provided a set of “pairing”, which is a sequence of minimum job units called “trip”, is given for the depot. The pairings are sequenced into rosters satisfying various constraints. The objective function is to minimize the number of drivers for performing the pairings. We formulate this problem into the Set Partitioning Problem and demonstrate an application of the column generation method to it. As the exact approach to column generation sub-problems needs much computation effort, we employ an alterna-
tive approach consisting of four steps. We show results of numerical experiments for instances based on the timetable.

Thomas Schlechte, Zuse Institute Berlin (with Ralf Böndörf, Steven Harrod)
Recent developments in railway track allocation
This talk is about mathematical optimization for the efficient use of railway infrastructure. We address the optimal allocation of the available railway track capacity. This track allocation problem is a major challenge for any railway company. Planning and operating railway transport systems is extremely hard due to the complexity of the underlying discrete optimization problems, the technical intricacies, and the immense sizes of the problem instances. We tackle this challenge by developing novel mathematical models and associated innovative algorithmic solution methods for large scale instances. We present two main features – a novel modeling approach for the macroscopic track allocation problem and algorithmic improvements. Finally, we provide computational studies for real world instances, i.e., the Simpilon corridor in Switzerland, and various instances from the literature.

Steffen Weider, Zuse Institute Berlin (with Ralf Böndörf, Markus Reuther, Thomas Schlechte)
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 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 heuristic 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

Kirk Pruhs, University of Pittsburgh (with Anupam Gupta, Ravishankar Krishnaswamy)
Online primal-dual for non-linear optimization with applications to speed scaling
We give a principled method to design online algorithms (for potentially non-linear problems) using a mathematical programming formulation of the problem, and also to analyze the competitiveness of the resulting algorithm using the dual program. This method can be viewed as an extension of the online primal-dual method for linear programming problems, to nonlinear programs. We show the application of this method to two online speed scaling problems: one involving scheduling jobs on a speed scalar processor so as to minimize energy plus an arbitrary sum scheduling objective, and one involving routing virtual circuit connection requests in a network of speed scalable routers so as to minimize the aggregate power or energy used by the routers. This analysis shows that competitive algorithms exist for problems that had resisted analysis using the dominant potential function approach in the speed scaling literature, and provides alternate cleaner analysis for other known results. This presents another step towards a principled design and analysis of primal-dual algorithms for online problems.

Ola Svensson, EPFL
On the hardness of scheduling with precedence constraints to minimize makespan
We will talk about the recently established reductions from a bipartite (and 4-partite) ordering problem to two classical scheduling problems, the scheduling problem with precedence constraints on identical machines to minimize makespan \( |\text{prece} |_{\text{Cmax}} \) and scheduling with precedence constraints on related machines to minimize makespan \( |\text{prece} |_{\text{Cmax}} \).

Combining our reduction from the bipartite ordering problem with a recent result by Bansal & Khot shows that it is NP-hard to improve upon the classical 2-approximation by Graham & for identical machines, assuming a variant of the unique games conjecture.

For related machines, we show that if a generalized version of the bipartite [namely k-partite] ordering problem is hard then \( |\text{prece} |_{\text{Cmax}} \) does not admit a constant factor approximation algorithm. However, the hardness of the k-partite ordering problem remains open even if we assume the unique games conjecture.

Cliff Stein, Columbia University (with Kirk Pruhs)
How to schedule when you have to buy your energy
We consider a situation where jobs arrive over time at data centers, 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.

Mon.1.H 3021
Scheduling algorithms I
Organizer/Chair: Nishtil Bansal, Endowment University of Technology - Invited Session

Hayato Waki, Kyushu University (with Masakazu Muramatsu)
Geometry and duality in convex programming
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.

Mon.1.A 313
Optimization and equilibrium models in energy systems
Organizer/Chair: Jong-Shi Pang, University of Illinois at Urbana-Champaign - Invited Session

Steven Gabriel, University of Maryland (with Saitul Sididik)
A new method for MPECs with a natural gas application
We present a new method for solving MPECs based on SOS1 variables and a reformulation of the complementarity terms. We show two forms of the transformed MPECs: one using SOS1 variables and the other a penalty term. We present some theoretical results as well as numerical tests on a small energy production problem and a large-scale one for natural gas.

Yuehue Fan, University of California, Davis (with Roger Wets)
A stochastic variational inequality model for estimating traffic demand based on random link flow observations
In this talk, we will discuss a problem of estimating travel demand of a network based on observations of link flow. First, we will show how the estimation problem can be formulated as a stochastic programming problem. The objective is to minimize the expected estimation error, subjected to physical and behavior assumptions of network flow. Next, we will extend the estimation problem to a sensor resource allocation problem, in which the goal is to identify the best sensor deployment strategy to maximize the benefit of information gained from the sensors. The design of numerical solution algorithms will also be discussed. The proposed modeling framework demonstrates a clear linkage between statistical estimation and optimization. From the engineering perspective, this work has the potential to improve the utilization of information technologies.

Xiaofeng Yang, University of Illinois at Urbana-Champaign (with Yun Bai, Jong-Shi Pang)
Biofuel supply chain design under competitive agricultural land use and feedstock market equilibrium
The rapid expansion of the U.S. biofuel industry diverts a large amount of agricultural crops as energy feedstocks, and in turn affects farm land allocation, food market equilibrium, and agricultural economy. We present game-theoretic models that incorporate farmers’ decisions on land use and market choice into the biofuel manufacturers’ supply chain design problem (i.e., number and locations of biofinerries, resource procurement prices). A noncooperative bi-level Stackelberg game model and a cooperative game model are developed respectively to address possible business partnership scenarios between feedstock suppliers and biofuel manufacturers. Spatial market equilibrium is utilized to model crop supply and demand and the associated market price variations. We transform the bilevel model into a mixed integer quadratic program, and explore adaptive implementation of linear program relaxation and Lagrangian relaxation. The proposed methodology is illustrated using an empirical case study of the Illinois State, and the computation results reveal interesting insights into optimal land use strategies and supply chain design for the emerging “biofuel economy.”

Mon.1.C 2036

Hayato Waki, Kyushu University (with Masakazu Muramatsu)
Computation of 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 Roschina, University of Ballarat (with Javier Peña)

Partition and complementarity in multifield conic systems

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

Roman Golub, 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-Nemirovski, 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.
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 Montiglia, Davide Mustielli, Angoia Ustunel)  
**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 multivariate 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. Liabilities 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 stability.

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.

Daniel Cremers, TU Munich (with Antonin Chambolle, Bastian Goldlücke, Kalin Kolev, Thomas Pock, Evgeny Strekalovskiy)  
**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, Jia Xu)  
**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.

Yann Bramouille, Laval University (with Mohamed Belhaouari, Frederic Deniau)  
**Network games under strategic complementarities**

In this paper, we study network games with strategic complementarities. Agents are embedded in a fixed network and interact with their network neighbors. They play a game characterized by positive interactions and linear best-replies. We assume that actions are continuous but bounded from above. This means that our game is supermodular. We show that this game always possesses a unique equilibrium. We derive comparative statics, provide a fast algorithm to compute the equilibrium and we characterize the equilibrium explicitly for important families of graphs. We show that action may not be aligned with Bonacich centrality and that interdependence may be broken in the presence of bridges. Overall, we find that the presence of an upper bound on actions strongly affects the outcomes of the game.

Matthew Elliott, Microsoft Research (with Ben Golub)  
**A network centrality approach to coalitional stability**

We study games in which each player simultaneously exerts costly effort that provides different benefits to some of the other players. The goal is to find and describe effort profiles that are immune to coordinated coalitional deviations when such a game is played repeatedly. Formally, these effort profiles are the ones that can be sustained in a strong Nash equilibrium of the repeated game. First we show, under some assumptions (mainly concavity of utility functions), that an effort profile is Pareto efficient if and only if the spectral radius of an induced 'benefits' matrix is one. This 'benefits' matrix is a function of the action profile and measures the marginal benefits each agent can confer on each other per unit of marginal cost they incur. Our second result shows that if the right eigenvector of the benefits matrix also corresponds to the action profile, then the action profile is sustainable in a coalitionally robust equilibrium of the repeated game. These results are obtained without parametric assumptions, using the theory of general equilibrium and its relation to the core, along with the Perron-Frobenius spectral theory of nonnegative matrices.

Konstantinos Bimpikis, Stanford University (with Asuman Ozdaglar, Ercan Yildiz)  
**Competitive marketing strategies over social networks**

Recent advances in information technology have allowed firms to gather vast amounts of data regarding consumers' preferences and the structure and intensity of their social interactions. This paper examines a game-theoretic model of competition between firms, which can target their marketing budgets to individuals embedded in a social network. We provide a sharp characterization of the optimal targeted marketing strategies and highlight their dependence on the consumers' preferences as well as on the underlying social network structure. In particular, firms find it optimal to allocate their marketing budgets to consumers in proportion to their "network centrality", a measure of social influence. Moreover, we identify network structures for which targeted advertising is more beneficial for the firms and, finally, we show how the difference in the initial budgets affect the outcome of the marketing competition between the firms.
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 Cesia and Schaerf (2011). A discussion on several branching strategies to integrate the lower bound solution is also provided.

Implementations & software

Mon.1 H 1058

Testing environments for machine learning and compressed sensing

Organizer/Chair Katya Scheinberg, Lehigh University - Invited Session

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 representation 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.

Katya 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 step parameter 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 onto convex sets and also by linear programming method. The method have been implemented in a MATLAB package L1TestPack.

Katya Scheinberg, Lehigh University

Mon.1 H 2013

Column generation and decomposition

Chair Richard Lusby, Department of Management Engineering, Technical University of Denmark

Ozgur Ozpeyneci, I斯坦 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 Jesper Larsen, Trøels Range)

A column generation approach for solving the patient admission scheduling problem

The PatientAdmission 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 Demester 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 Cesar and Schaerf (2011). A discussion on several branching strategies to integrate the lower bound solution is also provided.

Mon.1 H 2022

Integer & mixed-integer programming

Mon.1.MA 004

Advances in integer programming

Organizer/Chair Shmuel Onn, Technion – Israel Institute of Technology - Invited Session

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

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 measures is the simplicial depth of $p$, 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 of a point $p$ 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 Homlensen et al. and our strengthening of these. We provide a new lower bound for the colourful simplicial depth improving the earlier bounds of Bárány & Matoušek and of Stephen & Thomas. Computational approaches for small dimension and the colourful 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 [Calvet and Mateos (1998), De la Croce et al. (1999), Lee (1992), Nickel and Puerto (2005), Puerto and Tamir (2005), Punnen and Anjela (1996, 2004), Turner and Hamacher (2011), Turner et al. (2011)]. We study the common framework that underlines those models, present different formulations as integer programs and study their relationships and reinforcements. This approach leads to a branch and cut algorithm applicable to he 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.

Matthias 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. Barvnik [2006] and continued by Baldo, 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 $d$, we integrate a given polynomial function $f$ over all lattice slices of the polytope $P$ parallel to the subspace $d$ and use the integral in the algorithm.

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 cross cuts from the important 2-row and basic relaxations and resolve cuts. We present a theoretical comparison of the strength of the cross-proving oversplit cuts, we study their most natural generalization, cross-ern heuristics can essentially harness their full power. Aiming at im-

A new paradigm for generating cuts in mixed integer programs

We settle a conjecture of Li and Richards on $t$-branch split cuts, and show that there are mixed-integer programs with $n + 1$ variables which are unsolvable by $(n − 1)$-branch split cuts, thus extending the well-known 3-variable example of Cook, Kannan and Schrijver which is unsolvable by split cuts.

Egon Balas, Carnegie Mellon University (with Francois Margot, Selvaraju Naraduraj)

Cut generating points on the boundary of a lattice-free convex set

A new paradigm for generating cuts in mixed integer program-
mics (Balas and Margot, 2011) identifies a set $O$ of boundary points of a lattice-free convex set $S$, such that the reverse polar of $O$ provides valid cuts. We discuss ways of generating such boundary points, and the properties of the resulting sets. We compare the cuts generated from such sets, which we call generalized or look-ahead intersection cuts, to cuts belonging to known families. In particular, we show that this paradigm offers a way to generate in a non-recursive fashion deep cuts that can otherwise be generated only through several iterations of one of the standard procedures. Finally, we discuss implementation aspects and some preliminary computational experience.
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 stochastic $p$-median problem is developed by considering the splitting variable representation of the static Deterministic Equivalent Model (DEM) of the stochastic model. 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.

Vincius Xavier, Federal University of Rio de Janeiro (with Felipe Frana, Priscila Lima, Addison Xavier)

**Solving the Weber-Location problem by the hyperbolic smoothing approach**

The Weber Location 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 its 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 characteristic 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.

Haldu Sural, METU Ankara (with Hooyin 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 problem, new 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.

Haldun Sural, METU Ankara (with Hooyin Guden)

**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 store 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 Romeros Morales, University of Oxford (with H. Edwin Romeijn, Wilco van den 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 production decisions, the planning horizon will 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 interested in measuring the pollution in each of the planning periods, or across all periods, or more generally, across subsets of periods. We assume fixed-charged 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 Shriki, 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 $z$ whose demand to satisfy as well as a corresponding overall order quantity $Q$. The supplier faces costs associated with satisfying demands, underage and overage 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 optimal solution and (ii) sampling from the generated distribution to estimate 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.

Igor Kravanja

Mon.1 81

**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 assess the performance of the method by solving to global optimality engineering design test problems.

Milosl Bogataj, Faculty of Chemistry and Chemical Engineering, University of Maribor (with Zdravko Kranjcar)

**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- and overestimators defined over domains of one or both complicating variables. The domains are partitioned over at least two levels with the finest grid density determined such that 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- and 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.

 taboo Westerlund, Åbo Akademi University (with Anders Lindberg)

**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 CS²-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.

An interactive approach for multi-objective optimization with integer variables
An interactive approach for multi-objective optimization with integer variables is introduced. In each iteration, the decision maker (DM) is asked to give a reference point [new aspiration levels]. Subsequent Pareto optimal point is the reference point projected into the set of feasible objective vectors using a suitable scalarizing function. Thereby, the procedure solves a sequence of optimization problems with integer variables. In such process, the DM provides preference information via pair-wise comparisons of Pareto-optimal points identified. Using such preference information and assuming a quasi-concave utility function of the DM we restrict the set of admissible objective vectors by excluding subsets, which cannot improve over the solutions already found. Infeasibility is overcame by linear approximations and the best Pareto point found is an optimal solution. We also propose a procedure to test whether or not a solution is a supported Pareto point (optimal under some linear value function). Our reference point optimization procedure runs in AMPL/MOSEK. Numerical tests with multi-criteria facility location models and knapsack problems indicate reasonably fast convergence.

Mohammad Alī Yaghoobi, Shahid Bahonar University of Kerman (with Alireza Dehmiry)
Reference point method for multi-criteria optimization with integer variables
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 reduce to trivial problems of finding the minima of finite sets. The geometric duality of multi-objective linear programming furthermore allows us to identify all efficient DMUs without solving a linear programme for every DMU using the dual outer approximation algorithm. Moreover the primal outer approximation algorithm directly finds all hyperplanes defining the efficient frontier of the production possibility set. We demonstrate the efficiency of our algorithm on a number of standard DEA reference problems.

Mohammad Alī Yaghoobi, Shahid Bahonar University of Kerman (with Alireza Dehmiry)
Using ball center of a polytope to solve a multiobjective linear programming problem
Recently, ball center of a polytope as the center of a largest ball inside the polytope is applied to solve a single objective linear programming problem. The current research aims to develop an algorithm for solving a multiobjective linear programming problem based on approximating ball center of some polytopes obtained from the feasible region. In fact, the proposed algorithm asks a weight vector from a decision maker and then tries to solve the problem iteratively. It is proved that the algorithm converges to an epsilon efficient solution after a finite number of iterations. Moreover, the well performance of it in comparison with the well known weighted sum method is discussed. Furthermore, numerical examples and a simulation study are used to illustrate the validity and strengths of the recommended algorithm.
propose a new algorithm, contrasting this method with established approaches. We report numerical results on large scale machine learning applications.

Stefan Scholze, Northwestern University (with Richard Byrd, Jorge Nocedal)

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.

Mon.1 H 1012
Iterative methods for variational analysis
Organizers/Chair Alan Pietsch, Université des Antilles et de la Guyane - Invited Session
Celia Jean-Alexis, Universite des Antilles et de la Guyane (with Michel Genrfray, Alain Pietsch)
The second order generalized derivative and generalized equations

We consider a generalized equation of the form $0 \in f(x) + G(x)$ where $f : R^n \rightarrow R^n$ is a $C^{1,1}$ function such that its Fréchet-derivative $F$ is subanalytic and $G : R^n \rightarrow 2^{R^n}$ 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 Baier, 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 $X \subset R^n$ 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 $R^n$ 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 usually non-convex subsets of $R^n$ is available.

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 Baier, Vera Roschina)
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 Rubinov subdifferential is compared with other well-known subdifferentials.

Mon.1 MA 547
Optimization models to manage risk and uncertainty in power systems operations
Organizers/Chairs Raphael Chabri, PSR; Luiz Barroso, PSR - Invited Session
Alexandra Street, Pontifical Catholic University of Rio de Janeiro (PUC-Rio) (with Arroyo Jose, Alexandre Moreira)

Energy and reserve scheduling under a joint GT - K security criterion: An adjustable robust optimization approach

This presentation shows a new approach for energy and reserve scheduling in electricity markets under a general $g - K$ 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.

Jinhe Zhu, 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

Nonlinear programming

Mon.1.0012
Algorithms for optimal control I
Chair Carsten Gräser, Freie Universität Berlin / MATHEON
Dennis Janka, Heidelberg University (with Hans-Georg Bock, Stefan Körkel, Sebastian Sager)

Separable formulations of optimum experimental design problems

We consider optimal control problems coming from nonlinear optimum experimental design. These problems are non-standard in the sense that the objective function is not of Bolza type. In a straightforward direct solution approach one discretizes the controls and regards the states as dependent variables. However, this often leads to poor convergence properties of the resulting NLP. We propose a reformulation of the problem to a standard optimal control problem by introducing additional variables. It is then possible to attack this problem with direct state-of-the-art methods for optimal control with better convergence properties, e.g., multiple shooting. The reformulation gives rise to a highly structured NLP due to the multiple shooting discretization as well as due to the peculiarities of the optimum experimental design problem. We highlight some of these structures in the constraints, the objective function, and the Hessian matrix of the Lagrangian, and present ways to exploit them leading to efficient SQP methods tailored to optimum experimental design problems. Numerical results are presented comparing the new separable formulations to an existing implementation.

Kathrin Hatz, Otto-von-Guericke-Universität Magdeburg (with Hans-Georg Bock, Johannes Schlöder)
Hierarchical dynamic optimization - Numerical methods and computational results for estimating parameters in optimal control problems

We are interested in numerical methods for hierarchical dynamic optimization problems with a least-squares objective on the upper level and a optimal control problem (OCP) with mixed path-control constraints on the lower level. The OCP can be considered as a model for so-called optimal control models that describes optimal control processes in nature, such as the gait of cerebral palsy patients. The optimal control model includes unknown parameters that have to be determined from measurements. We present an efficient direct all-at once approach for solving this class of problems. The main idea is to discretize the infinite dimensional Bilevel problem, replace the lower level nonlinear program (NLP) by its first order necessary conditions (KKT conditions), and solve the resulting complex NLP with a tailored sequential quadratic programming (SQP) method. The performance of our method is discussed and compared with the one of alternative approaches. Furthermore, we present an optimal control model for a cerebral palsy patient which has been identified from real-world motion capture data that has been provided by the Motion Laboratory of the University Hospital Heidelberg.

Carsten Gräser, Freie Universität Berlin / MATHEON
Truncated nonsmooth newton multigrid methods for nonsmooth minimization

The combination of well-known primal–dual active-set methods for quadratic obstacle problems with linear multigrid solvers leads to algorithms that sometimes converge very fast, but fail to converge in general. In contrast nonlinear multilevel relaxation converges globally but exposes suboptimal convergence speed and complexity. Combining nonlinear relaxation and active-set ideas we derive the globally convergent “truncated nonsmooth Newton multigrid” (TNNMG) method. While its complexity is comparable to linear multigrid its convergence in general much faster than multilevel relaxation. Combined with nested iteration it turns out to be essentially as fast as multigrid for related linear problems. The generalization to more nonlinear objectives, nonsmooth energies is straightforward.

Optimization in energy systems

Nonsmooth optimization

Iterative methods for variational analysis
Organizers/Chair Alan Pietsch, Université des Antilles et de la Guyane - Invited Session
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demonstrate the economic and operational advantages of our model over the traditional reserve adjustment approach.

Anthony Papavasiliou, University of California at Berkeley (with Shmuel 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 for 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 duality gap on the number of scenarios in the model and relate our results to theoretical bounds provided in the literature. We finally report results regarding speedup and efficiency.

Optimization in energy systems

Mon.1, MA 550

Unit commitment and inventory problems

Chair Tim Schulze, The University of Edinburgh

Ali Koc, IBM TJ Watson Research Center (with Jayant Kalagnanam)

Parallel branch-cut-price for solving multistage stochastic unit commitment problems

Unit commitment (UC) lies in the heart of future smart grid. Independent system operators and utilities aim to solve various forms of the problem that handle such contemporary concepts as renewable generation, energy storage, power purchase agreements, future power markets, demand response, etc. These concepts induce various forms of uncertainty into the problem. We use multistage stochastic programming framework to incorporate these uncertainties, and present a parallel decomposition algorithm based on a branch-cut-price framework. We bring together several advancements in the UC literature, stochastic programming, mixed integer programming, large-scale optimization, and parallel computing. We develop a new weighting scheme and a lower bounding method to improve the decomposition algorithm, and a constructive heuristic method to restore near-optimal solutions. The serial algorithm solves problem instances as efficient as highly sophisticated commercial solvers, and the parallel algorithm solves large-scale nonlinear stochastic UC problem instances with up to 3000 generators, 24 hours, and 200 scenarios on a 32-processor cluster, obtaining almost linear speedups.

Kin Keung Lai, City University of Hong Kong (with Dang Wang, Qian Zhang)

A stochastic approach to power inventory optimization

Rooted in the airline industry, inventory management systems have been applied for 40 years since the first paper by Beckham. This involves application of information systems and pricing strategies to allocate the right capacity to the right customer at the right price at the right time. Also there are some salient differences between airlines and power plants. For example: (i) electric power has to be generated, transmitted and consumed at the same time; and (ii) safety of power grid is also an important factor to be considered, implying more strict requirements for cancellations, no-shows and overbooking problems. Also, unlike the airline industry, orders for electricity power usually last for a period of time such as one day, one week, and one month and even one year, and the price varies with quantity and time periods. Advance bookings are encouraged even one day or even half-an-hour in advance in order to guarantee safety and efficiency of the power grid and the power plant. This study is developed on the basis of power plants facing stochastic demands with varied prices. A network optimization model is proposed for power plant inventory management under an uncertain environment.

Tim Schulze, The University of Edinburgh (with Andreas Grothey, Kenneth McKinnon)

Decomposition methods for stochastic unit commitments

In recent years the expansion of energy supplies from volatile renewable sources has triggered an increased interest in stochastic optimization models for generation unit commitment. Several studies have modelled the problem as a stochastic mixed-integer linear program. Solving this problem directly is computationally intractable for large instances and many alternative approaches have been proposed. However, few of them exploit the structure of the multi-stage formulation. In this talk we outline how decomposition and combination 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.
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 \( \mathbf{R}_{ij} \). 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 \( \{\text{Absil et al.}, \text{Optimization Algorithms on Matrix Manifolds, Princeton Univ. Press, 2008}\} \) 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.

Often motivated as an alternative to 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 Budhika Bhaskar, Parikshit Shah, Gongguo 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 estimate a variety of other objects and structures beyond sparse signals and images.

To demonstrate the wide applicability of atomic norm denoising, I will specialize the abstract formulation to two applications of practical interest. First, I will present a convex approach to superresolution, estimating the frequencies and phases of a mixture of complex exponentials. In this formulation, we propose a new algorithm for identification of linear systems from incomplete measurements. In both cases, atomic norm denoising efficiently achieves comparable or better error compared to state-of-the-art heuristics without any priori knowledge of system parameters such as model order.

Constantine Caramanis, The 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 \( \rho \% \) of the time. But what happens if \( \rho \) is very small? Current methodology fails to provide any guarantees on these bad events.

In this talk, I will present a computational tractable framework to design optimization solutions that have performance guarantees at all levels of uncertainty reliably realized. We call these probabilistic envelope constraints, and, as we show, they have a surprising connection to an extension of robust optimization.

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 of power plants and power plant operations. 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 Tingting 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 the \( s-t \) cuts 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 will be presented that demonstrate that the approaches can solve large instances. We also show how our results can be applied to more general connectivity requirements.

Bernardo Pagnoncelli, University of Adolfo Ibáñez (with Adriana Piazza)

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.

Advances in stochastic optimization
Organizer/Chair: David Brown, Duke University - Invited Session
David Brown, Duke University

Optimal sequential exploration: Bandits, clairvoyants, and wildcats
This paper was motivated by the problem of developing an optimal strategy for exploring a large oil and gas field in the North Sea.

We study a problem of optimal sequential exploration when the price is uncertain and two important cases are considered: geometric Brownian motion and a mean-reverting Ornstein-Uhlenbeck process.

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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.

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.

Mon.1 MA 374

Decisions policies and estimation techniques in a stochastic environment

Organizer/Chair Fabian Bastin, University of Montreal - Limited Session

Avin Haansel, VU University Amsterdam (with Marco Laumanns)

A SP approach for decision-dependent uncertainty in production planning under non-compliance risk

Governmental regulation pressure on production quality and standards is increasing in many areas, especially in the chemical, food and pharmaceutical industries. Therefore, a production plan needs to consider the risks of failing the quality inspection by the authority agency. Inspection realizations are clearly dependent on the previous production planning decisions. Normally stochastic programs assume the random process to be independent of the optimization decision. This dependency increases the complexity of the underlying problem significantly. The uncertain inspection realizations are modelled by scenarios, which are generated according given product-site hazards. We propose a general MILP model-based stochastic programming approach and start initially with a risk-neutral model maximizing the expected revenue. The model is extended to account for more risk-averse attitudes of the decision maker by introducing probabilistic constraints. The main focus is on a direct CVaR (conditional value-at-risk) optimization formulation.

Fabian Bastin, University of Montreal (with Ath Tien Mai, Michel Toulouse)

On the combination of Hessian approximations for data estimation

Data estimation is increasingly more computing intensive as more data becomes available, and as it is used with always more complex models. Typical estimation procedures have however very specific structures, even when the models are nonlinear, and we aim to exploit them, but this may compromise convergence when we get close to the solution. In particular, we revisit optimization techniques relying on multiple Hessian approximation update schemes, with a specific focus on maximum likelihood techniques involving expensive objective functions. Such functions can for instance be constructed as Monte Carlo samples on some population and some inner expectations, as considered in fields like discrete choice theory. Using a trust-region approach, we show that combinations of standard secant updates (SR1 and BFGS) and statistical approximations (here the BBHH update), can dramatically decrease the time required to converge to the solution, and that it is possible to further scale up and start from rather simple random walk methods.

Numerical experiments on real data are presented in order to demonstrate the approach potential.

Xinan Yang, Lancaster University (with Andreas Grothey)

Approximate dynamic programming with Bézier curves/surfaces for top-percentage traffic routing

Multi-homing is used by Internet Service Providers to connect to the Internet via different network providers. This study develops a routing strategy under multi-homing in the case where network providers are ISPs according to top-percentage pricing (i.e. based on the 8-th highest volume of traffic). We call this problem the Top-percentage Traffic Routing Problem (TTRP).

To overcome the curse of dimensionality in Stochastic Dynamic Programming, in previous work we have suggested to use Approximate Dynamic Programming (ADP) to construct value function approximations, which allow us to work in continuous state space. The resulting ADP model produces well performing policies already for medium sized instances. In this work we extend the ADP model, by using Bézier Curves/Surfaces to obtain continuous-time approximations of the time-dependent ADP parameters. This modification reduces the number of regression parameters to estimate and thus accelerates the efficiency of parameter training in the solution of the ADP model, which makes realistically sized TTRP instances tractable. We argue that our routing strategy is near optimal by giving bounds.

Xinan Yang, Lancaster University (with Andreas Grothey)

Optimal access networks

Organizer/Chair Andreas Bley, TU Berlin - Limited Session

Cédric Hervet, Orange Labs / CNAM (with Matthieu Chardy, Marie-Christine Costa, Alain Faye, Stanislas Franchort)

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 Amares de Sousa, Luis 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 became 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.

Olad Mauer, TU Berlin (with Andreas Bley, Ivara Ljubic)

Lagrangian approaches to a two-level FTTX 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-charge costs 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 different formulations of the Lagrangian approach to the direct approach via an integrated MILP model.

Xinan Yang, Lancaster University (with Andreas Grothey)

Approximate dynamic programming with Bézier curves/surfaces for top-percentage traffic routing

Organizer/Chair Roland Herzog, TU Chemnitz - Limited 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 Gerdes, 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 semielliptic partial differential equations.

Mon. 1–Mon. 2

Equilibrium problems and related topics

Organizer/Chair Alfredo Iusem, Instituto de Matemática Pura e Aplicada - Invited Session

Ozcan Fennia, Federal University of Goias (with Roberto Silva)

Local convergence of Newton's method under majorant condition in Riemannian manifolds

A local convergence analysis of Newton's method for finding a singularity of a differentiable vector field defined on a complete Riemannian manifold, based on majorant principle, is presented in this paper. This analysis provides a clear relationship between the majorant function, which relaxes the Lipschitz continuity of the derivative, and the vector field under consideration. It also allows us to obtain the optimal convergence radius, the biggest range for the uniqueness of the solution, and to unify some previous unrelated results.

Susana Scheiner, UFRJ-Universidade Federal do Rio de Janeiro (with Paulo Santos)

A reflection-projection method for equilibrium problems

We consider an implementable algorithm for solving nonsmooth equilibrium problems in finite-dimensional spaces. The algorithm combines the strategy of generating a feasible point, by using reflections related to hyperplanes, and the projected-subgradient method where the projection is done onto a suitable half-space. The algorithm has a low computational cost per iteration. Computational experience is reported and comparative analysis with other algorithms is also given.

Luis Drummond, UFRJ - Universidade Federal do Rio de Janeiro (with E. Fukuda)

New strategies for vector optimization problems

Under partial orders derived from arbitrary closed convex pointed cones with nonempty interior, we propose extensions of scalar optimization procedures to the vector setting. For constrained vector-valued optimization problems, we seek efficient/weakly efficient points by adopting classical real-valued strategies. Assuming reasonable hypotheses, we establish some convergence results to optimal points.

Mon. 1–Mon. 2 3014

Combinatorial optimization

Organizer/Chair Ulrich Brenner, University of Bonn - Invited Session

Uliete Suhl, Research Institute for Discrete Mathematics University of Bonn (with Stephan Held)

Lagrangian relaxation and quadratic minimum cost flows for gate sizing

One of the key problems during the physical design of a computer chip is to choose a physical realization (gate size) for each gate/translator on the chip from a discrete set. Available sizes for a gate differ in their power and area usage, and influence the time it takes electrical signals to traverse the chip.

We present a Gate Sizing algorithm based on Lagrangian Relaxation minimizing overall circuit power, while fulfilling constraints imposed on the speed of electrical signals.

We restrict gate sizes to the discrete sets available in practice, and solve a discretized primal problem to avoid a rounding step in the end. Instances are modified appropriately to guarantee the existence of a finite dual solution.

Lagrangian Multiplier have to be projected to the flow space, which can be formulated as a Quadratic Minimum Cost Flow Problem.

Constraints on the area usage of gates in specified regions on the chip can be incorporated directly into the framework, and we show convergence for the continuous case.

Christoph Bartoschek, University of Bonn (with Stephan Held, Jens Vagn)

Fast buffering of repeater trees

The optimization of electrical interconnections is a critical task in the design of modern VLSI chips. A popular approach is to divide the problem into a Steiner tree computation and a buffering step that inserts repeaters, which some-times would only be required for preserving Boolean parity. We present
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 cen-
tral problem is the construction of Steiner trees with delay constraints.
They are used for optimizing electrical interconnections and symmetric
Boolean functions. We provide a bicriterion algorithm for tree
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 prob-
lems 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 em-
plored for increasing the clock frequency by 18% of an upcoming mi-
croprocessor.

Mon.2.H 3005
Combinatorial optimization

Organizator/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-minors relations of graphs which are
defined in terms of local complementation and pivot operations, respec-
tively, on graphs. Many theorems on graph minors can be extended to
vertex- and pivot-minors. We will discuss various known aspects and
then talk about partial results towards some conjectures general-
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 minor graph \( H \) as a minor has the so-called
Erdős-Pósa property; namely, there exists a function \( f \) 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 \( |X| \leq f(k) \) such that \( G - X \) has
no \( H \)-minor. While the best function \( f \) currently known is super-exponen-
tial in \( k \), an \( O(k\log k) \) bound is known in the special case where \( H \) is a forest.
This is a consequence of a theorem of Bienstock, Robertson, Seymour, and
Thomas on the pathwidth of graphs with an excluded forest-minor.

Stephan Held, University of Bonn (with Ronny Hansmann, Uwe Zimmermann)
Pairs of disjoint cycles
We will describe a polynomial-time algorithm which determines
whether an input graph contains a pair of disjoint cycles with the given
property. In particular, it allows one to test whether a graph has two dis-
joint odd cycles, whether it has two disjoint cycles, one non-zero mod-
ulo 3 and the other non-zero modulo 5, whether a graph embedded in
a surface has two disjoint homologically non-trivial cycles, and whether
given embedding of a graph in 3-space is linkless.

Jens Maassberg, University of Ulm (with Satoshi Fujishige)
Dual consistency and cardinality constrained polytopes
We introduce a concept of dual consistency of systems of linear in-
equalities with full generality. We show that a cardinality constrained
polytope is represented by a certain system of linear inequalities if and
only if the systems of linear inequalities associated with the cardinal-
ities are dual consistent. Typical dual consistent systems of inequali-
ties are those which describe polymatroids, generalized polymatroids,
and dual greedy polyhedra with certain choice functions. We show that
the systems of inequalities for cardinality-constrained ordinary bipartite
matching polytopes are not dual consistent in general, and give addi-
tional inequalities to make them dual consistent. Moreover, we show that
ordinary systems of inequalities for the cardinality-constrained
polymatroid intersection are not dual consistent, which disproves a
conjecture of Maurras, Spiegelberg, and Stephan about a linear rep-
resentation of the cardinality-constrained polymatroid intersection.

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
maximizing minimization of total completion time 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 all succeeding machines of a work cen-
ter. The two considered variants only differ in the implication of the lat-
ter 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 solu-
tion methods (heuristic and exact) and introduce a mixed integer lin-
ear programming model for both variants. Our exact methods are based
on a dedicated branch-and-bound-implementing using bounds gen-
erated 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 of 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 pre-
emption is not used. The situation with job-splitting is much less clear.
If a is very large, then splitting becomes too expensive and the problem
is solved by SPT again. If a is very small (say 0), then each job is split
over all machines and the jobs are scheduled in SPT order. To find out
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.

George Steiner, McMaster University

Scheduling and the traveling salesman problem on permuted monge
matrices

A variety of scheduling problems has been shown to be solv-
able as special cases of the Traveling Salesman Problem (TSP) on
permuted Monge matrices. Although the TSP on permuted Monge ma-
crates is known to be strongly NP-hard, polynomial-time solutions exist for
many of the special cases generated by the scheduling problems. Fur-
thermore, a simple subtour-patching heuristic is asymptotically optimal
for the TSP on permuted Monge matrices under some mild technical
conditions.

Christina Büsing, RWTH Aachen

k-distance recoverable robustness

Recoverable Robustness (RR) is a method to deal with uncertainties
in optimization problems extending the classical concept of robustness
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 lim-
lited by changing at most k elements of the previously fixed solution and
apply this method to various combinatorial optimization problems. For
the shortest path problem, we will see that small changes in the prob-
lem setting, e.g., choosing simple s, t-paths at the beginning instead of
any s, t-path, strongly influences the complexity status and combinatori-
alsoptimal structures of the optional solutions. I will conclude the talk with
an overview of current results on cutting planes for the recoverable robust
designed to have a constant speedup factor of

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

Column generation for the demand robust shortest path 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 traf-
fic 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 presenta-
tion.

Martin van den Akker, Utrecht University (with Paul Bouman, Han Hoogeveen, Denise Tonissen)

Game theoretic analysis and optimization for resource allocation in
communication systems

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

Nicole Megow, Technische Universität Berlin (with Julia Mestre)

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

Multi-value sequencing with an unknown covering or packing con-
straint appears as a core subproblem, e.g., when scheduling on an un-
reliable machine or when determining a universal knapsack solution. A
sequence is called \( \alpha \)-robust when, for any possible constraint, the max-
imal 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 ro-
bustness guarantees. We present an algorithm that constructs for each
instance a solution with a robustness factor arbitrarily close to opti-
mal. This implies nearly optimal solutions for universal knapsack and
scheduling on an unreliable machine. The crucial ingredient is an ap-
proximate feasibility test for multi-value sequencing with a given target
function. This result may be of independent interest. We show that de-
ciding exact feasibility is strongly NP-hard, and thus, our test is best
possible, unless \( P=NP \).

Combinatorial optimization

Mon.2.H 3013

Recoverable robust combinatorial optimization
Organizer/Chair Arie Koster, RWTH Aachen University - Invited Session

Christina Büsing, RWTH Aachen

k-distance recoverable robustness

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in optimization problems extending the classical concept of robustness
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the shortest path problem, we will see that small changes in the prob-
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any \( s, t \)-path, strongly influences the complexity status and combinatori-
alsoptimal structures of the optional solutions. I will conclude the talk with
an overview of current results on cutting planes for the recoverable robust
designed to have a constant speedup factor of

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

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 traf-
fic 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 presenta-
tion.

Martin van den Akker, Utrecht University (with Paul Bouman, Han Hoogeveen, Denise Tonissen)

Column generation for the demand robust shortest path problem

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tion.
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 non-differentiability.
Alexandra Schwartz, University of Würzburg (with Jörg Franke, Christian Kanzow, Wolfgang Leisinger) 
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. We analyze how 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.
Michael Ferris, University of Wisconsin 
Stochastic variational inequalities and MOPEC
We describe some recent extensions of the extended mathematical programming (EMP) framework that enable the modeling of stochastic variational inequalities and link these to the notion of multiple optimization problems with equilibrium constraints (MOPEC). We show how to incorporate stochastic information into these systems, including notions of hedging and dynamics, and give examples of their use and their possible extensions to hierarchical modeling. We contrast these approaches to existing modeling formats such as complementarity problems and mathematical programs with equilibrium constraints, and show how this relates to decentralized operations. We demonstrate this mechanism in the context of energy and environmental planning problems, specifically for capacity expansion, hydro operation, water pricing and load shedding.
Zhi-Quan (Tom) Luo, University of Minnesota (with Mingyi Hong, Razaviyayn Meisam, Sun Ruoyu) 
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. Finally, we develop 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.
Gesualdi Scutari, State University of New York at Buffalo (with Francesco Facchine, 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 new 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.
Qingna Li, AMSS, Chinese Academy of Sciences (with Houduo Qi) 
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.
Yu 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.
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 are unspecified, and for the case of unspecified non-diagonal entries.

Peter Dickinson, Johan Bernoulili Institute, University of Groningen (with Kurt Anstreicher, Samuel Burer, Lukas Gibon)

Considering the complexity of complete positivity using the Ellipsoid method

Copositive programming has become a useful tool in dealing with all sorts of 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, Griessmayer 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 Pelleau)

Octagonal domains for constraint programming

Continuous Constraint Programming relies on interval representations of the variables 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 initial constraint problem into an semantically equivalent 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.

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 Raisinger, 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 strategy of American options. While convergence of the penalised 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 a 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.
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 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.

Dario Bauso, Università di Palermo (with Giuseppe Notastefano, Raffaele Penta)

**Time-averaged consensus and distributed approachability in large multi-agent networks**

We consider a doubly slower 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, i) all agents reach consensus on time-averaged estimates, and ii) 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 Zhengming 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.

Oleg Prokopyev, University of Pittsburgh (with Osman Qazilbash, Andrew Schaefer)

**Optimal design of the annual influenza vaccine with autonomous manufacturers**

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.

Olesya Zhupanska, University of Iowa (with Paolo Kokkinos, Yana Morenko)

**A nonlinear semidefinite programming approach to design of materials**

We consider a problem of design of composite materials that consist of multiple phases of ‘matrix’ with randomly oriented ‘inclusions’. It is assumed that spatial orientation of inclusions is prescribed by an orientation distribution function. Our approach allows for constructing lower and upper bounds on the tensor of elastic moduli of the resulting composite material by formulating the corresponding nonlinear semidefinite programming problems. A solution algorithm and computational studies are presented.

Stefan Theußl, WU Wien (with Kurt Hornik, David Meyer)

**ROI – R Optimization Infrastructure package**

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.

Stefan Theußl, WU Wien (with Kurt Hornik, David Meyer)

**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.
optimal priority list policy can be identified by formulating constrained Markov decision processes as mixed integer programming models.

Silvio de Araujo, UNESP/Brasil (with Diego Furtado)

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 releases, is developed to generate feasible solutions (upper bounds). Computational experiments are presented on data sets available from the literature.

Daniel Bienstock, Columbia University (with Alexander Michalka)

Strong dual for conic mixed-integer programs

Generated by a finite number of split disjunctions, but is not necessarily quadratic sets and show that the split closure of a strictly convex set is quadratic cost depending on the distances and flows. The Minimum Linear Arrangement (MinLA) is a special case of (QAP) where $d_{kl} = \|k - l\|$. It has been proposed for MinLA 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 $d$ defines a metric, as the grid graphs in QAPLIB instances. Adding valid inequalities linking $D$ and $x$, we have tested this model. The result shows a competitive average relative gap of 10.7% with a minimum of 3.4%.


Hier hy Williams, London School of Economics (with John Hooker)

The general solution of a mixed integer programme

We give general formulae for the optimal objective value and solution values of a Mixed Integer Programme (MIP) as a function of the coefficients, objective matrix and RHS. In order to do this we project out all the variables giving an (attainable) bound on the optimal objective value. This results in the optimal objective value expressed as a finite disjunction of inequalities and linear congruences. While the method is not computationally viable for practical sized MIPs it reveals a lot about their mathematical structure. It also provides a finite method of proving optimality. Hopefully the resultant ‘dual’ solution also provides useful economic interpretations.

Sérgine Gueye and her collaborators

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 $d_{kl}$ between facilities $k$ and $l$, and flows. The Minimum Linear Arrangement (MinLA) is a special case of (QAP) where $d_{kl} = \|k - l\|$. It has been proposed for MinLA 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 $d$ defines a metric, as the grid graphs in QAPLIB instances. Adding valid inequalities linking $D$ and $x$, we have tested this model. The result shows a competitive average relative gap of 10.7% with a minimum of 3.4%.


Mon.2.H 2033

Evolution and phylogenetics

Organizers/Chair: Leo van Iersel, Centrum Wiskunde & Informatica - Invited Session

Manuque Fischer, Ernst-Moritz-Arndt-Universität Greifswald

When sets of species make an evolutionary tree unique

In a recent study, Sanderson and Steel defined and characterized so-called phylogenetically decisive sets of species sets. A set is called phylogenetically decisive if regardless of the evolutionary trees chosen for each of its species sets, as long as these trees are compatible with one another, their supertree is always unique. It remained unknown whether the decision if a set of species sets is phylogenetically decisive can always be made in polynomial time. This question was one of the "Penny Ante" questions of the Annual New Zealand Phylogenetics Meeting 2012. In my talk, I will explain phylogenetic decisiveness and demonstrate a new mathematical characterization, which then leads to a polynomial time algorithm – both for the [simpler] case of rooted trees as well as for the (more complicated) unrooted case.

Steven Kelk, Maastricht University (with Nela Lekic, Simone Liniz, Celine Scornavacca, Leen Stougie, Leo van Iersel)

Cycle killer ... qu’est-ce que c’est? On the comparative...
approximability 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 directed 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 (approximability of hybridization number in a much broader complexity context. On the positive side, we use results from the DFVS literature to give an $O((\log \log n)^{\Theta(1)})$ approximation for the hybridization number where $r$ is the correct value.

Céline Scornavacca, ISEM, 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 $O(k \cdot poly(n))$ 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 problem is a polynomial time result from Kelk et al. (On the elusive-ness of clusters, IEEE/ACM Transactions on Computational Biology and Bioinformatics, 2015). By first solving the concept of “level-$k$ gener-ator” to general networks, we then extend this fixed parameter tractability result to the problem where $k$ refers not to the level but to the reticula-tion number of the whole network.

Robert Voll, TÜ 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 avoid delays in their journey. 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. Our approach consists of a Branch-and-Price algorithm. Our branching rule destroys the simple subproblem structure of the aforementioned column gener-ation approach, but we overcome this problem by dynamical program-ming. We can take advantage from our branching rule by deriving effec-tive 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 Sozo, University of São Paulo (with André 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 with starting and ending at a single depot, and it is assigned to a single driver, whose total work hours are limited. A col-umn generation algorithm embedded in a branch-and-bound frame-work is proposed. The column generation pricing subproblem requires a specific elementary shortest path problem with resource constraints algorithm to deal with the possibility for each vehicle to perform multi-ple routes per day and to deal with the need to determine the weekday beginning instant of time within the planning horizon. To make the al-go-rithm efficient, a constructive heuristic and a metaheuristic based on tabu search were also developed.

Florian Dahm, RWTH Aachen University (with Markus Bohlin, Holger Flier, Sara Gestrelius, Matús Mihalák)

An extended formulation for allocating classification tracks in hump yards

A major task in railway operations is shunting trains in a hump yard. Freight cars need to be assigned to classification tracks where they can be formed into outgoing trains. Often the objective is to minimize the number of shunting operations like pulling out and rolling in cars to the hump yard.

Our model is based on the processes at the Hallsberg hump yard in Sweden. The problem formulation derived from these processes was already shown to be NP-hard by Bohlin et al.

Natural compact MILP formulations in general have only yielded very weak linear relaxations and could not be used to efficiently generate optimal solutions for problem instances of reasonable size.

We present an extended formulation that produces a very tight lin-ear relaxation and can be efficiently solved via column generation for large problem instances. For several real world instances we are now able to produce optimal solutions.

Furthermore we discuss issues like symmetry, branching decisions and problem specific heuristics necessary to improve the solving pro-cess.

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

Organizer/Chair: Vivek Farias, MIT - Invited Session

Advances in machine learning

Organizers/Chairs: Florian Dahm, RWTH Aachen University; Marco Lubbecke, RWTH Aachen University; Ignacio Grossmann, Carnegie Mellon University - Invited Session

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

Efficient shale-gas recovery requires a large number of wells in or-der to maintain a sustainable total gas supply. The wells and the pro-\n
Mon.2.RH011

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

Global mixed-integer nonlinear optimization II

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

Brage Krudop, 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 or-der to maintain a sustainable total gas supply. The wells and the pro-Nan-Jung Lai, Massachusetts Institute of Technology (with Robert Freund)
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 the objective function is to prevent liquid loading and avoid 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 Charnes 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 – B&B –, and extended cutting plane, alphaBB) as well as the branch-and-reduce global optimization algorithm implemented in BARON.


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

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

Multiparametric 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 might be 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.

Michael Stigmayer, University of Wuppertal

The multicriteria linear bottleneck assignment problem

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 the efficient updating scheme of Mostow’s algorithm. On our method, which computes the complete efficient set, we also suggest an approximation scheme for the efficient set with an adjustable quality. The uniformity and the dispersity of this representation can be bounded during the course of the algorithm. While we restrict ourselves to bicriteria cases, we show possible extensions to multiple criteria.

Luís Paquete, University of Coimbra (with Carlos Fonseca, Katiann Klammeth, Michael Stigmayer)

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 Stöpp, 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.

Nonlinear programming

Methods for nonlinear optimization II

Chair Csizmadia Zsolt, FICO

Art Gorka, Enkive College (with Michael Kostreva)

Parallel direction finding algorithm in method of feasible directions

A parallel version of the Method of Feasible Directions algorithm is presented. Parallelization allows for finding multiple directions simultaneously on parallel machines. The algorithm is tested on a number of problems with known solutions from Hock-Schittkowski and compared with sequential algorithms. A numberfold speedup ratios are reported.

James Hangelroft, 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 $P \subseteq \mathbb{R}^n$. We present new first and second order optimality conditions for this problem which are 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.

Csizmadia Zsolt, FICO

Pros and cons of first order methods for solving general nonlinear problems

Second order methods to solve non-linear problems are often the best off the shelf methods to solve general non-linear problems due to their robustness and favorable un-tuned convergence properties. However, there are several problem classes, where either due to the special structure of the problem, or their size make first order approaches several magnitudes faster compared to their second order counterparts. First order methods exhibit several well know numerically unfavorable properties; successful applications often rely on efficient, problem specific methods of addressing these challenges. The talk will focus on practical examples and applications where sequential linear program- ming approaches are either superior, or can be adjusted to achieve significantly better performance than second order methods if the right problem formulation or algorithmic features are used.
Nonlinear optimization II
Organizers/Chairs Frank E. Curtis, Lehigh University; Daniel Robinson, Johns Hopkins University - Invited Session

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

A primal-dual active set method for convex GP

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 to two-phase active-set methods, that are required, for example, for fast resolved 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 SQP

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.

Mon.2 H 0110

Nonlinear programming

Mon.2 H 0112

Nonlinear optimization

Structures, complexities, and eigenvalues of tensor forms and polynomial functions

Organizer/Chair Shuzhong Zhang, University of Minnesota - Invited Session

Shuzhong 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 tautology to test 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 Matryoshka 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.

Mon.2 H 0111

Nonsmooth optimization

Mon.2 H 1012

Nonsmooth optimization II

Constrained variational inequalities: Approximation and numerical resolution

Organizer/Chair Juan Peypouquet, Universidad Tecnica Federico Santa Maria - Invited Session

Juan Peypouquet, Universidad Tecnica Federico Santa Maria (with Pierre Frankel)

Lagrangian-penalization algorithm for constrained optimization and variational inequalities

Let X, Y be real Hilbert spaces. Consider a bounded linear operator A : X → Y and a nonempty closed convex set C ⊂ Y. In this paper we propose an inexact proximal-type algorithm to solve constrained optimization problems

\[ \inf_{x \in X} f(x) : Ax \in C, \]

where f is a proper lower-semicontinuous convex function on X, and variational inequalities

\[ 0 \in Mx + A^* N_C(Ax), \]

where M : X \rightrightarrows X is a maximal monotone operator and N_C denotes the normal cone to the set C. Our method combines a penalization procedure involving a bounded sequence of parameters, with the predictor corrector proximal multiplier method. Under suitable assumptions the sequences generated by our algorithm are proved to converge weakly to solutions of the aforementioned problems. As applications, we describe how the algorithm can be used to find sparse solutions of linear inequality systems and solve partial differential equations by domain decomposition.

Yboon Garcia Ramos, Universidad Del Pacifico (with Marc Lassonde)

Representable monotone operators and limits of sequences of maximal monotone operators

We show that the lower limit of a sequence of maximal monotone operators on a reflexive Banach space is a representable monotone operator. As a consequence, we obtain that the variational sum of maximal monotone operators and the variational composition of a maximal monotone operator with a linear continuous operator are both representable monotone operators.

Felipe Alvarez, Universidad de Chile (with Julio Lopez)

A strictly feasible Bundle method for solving convex nondifferentiable minimization problems under second-order constraints

We will describe a bundle proximal method with variable metric for solving nonsmooth convex optimization problems under positivity and second-order cone constraints. The proposed algorithm relies on a locally scaleable metric which is induced by the Hessian of the log barrier. An appropriate choice of a regularization parameter ensures the well-definedness of the algorithm and forces the iterates to belong to the relative interior of the feasible set. Also, under suitable but fairly general assumptions, we will show that the limit points of the sequence generated by the algorithm are optimal solutions. Finally, we will report some computational results on several test nonsmooth problems.
Commitment(MSUC) model to address this problem, where we approximate the nonlinear fuel cost functions by piecewise linear functions.

Permission 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 surrogate 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.

**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. Furthermore, we employ a branch-and-cut algorithm to solve MSUC by constructing strong inequalities for the substructures of the constraints.

**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 criterion. This survivability criterion is a generalization of the well-known N-k criterion, and it requires that at least (1 - k) fraction of the total demand is met even after failures of any k system components, for all k = 0, 1, ..., k_max. We present a mixed-integer formulation of this problem that takes into account both transmission and generation component failures. 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 intermediates solution and constraining the search space accordingly. Our empirical studies on modified instances from the IEEE test systems showed the effectiveness of our proposed techniques.

**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, contingency 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 multiple contingencies. The problem is modeled 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.

**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 wireless with a control central. Measurements are identified 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 installers and power demand. Graphic and mathematical tools PSLDMS, GEPath and Google Earth are employed to represent the grid under test. The methodology is applied in a real network of 4 km of extension. 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.

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Many researchers have used design optimization methods based on a user specified primal state iteration, corresponding adjoint iterations and appropriately preconditioned design steps. Our goal is to develop heuristics for the sequencing of these three subtasks in order to optimize the convergence rate of the resulting coupled iteration. We present numerical results that confirm the theoretical predictions.

**Robust optimization**

Chair: Daniel Fleschman, Cornell University

**Mon.2 H 2162**

**Sparse optimization & compressed sensing**

Organizer/Chair: Gitta Kühn, Technische Universität Berlin - Invited Session

Rayan Saab, Duke University (with Michael Friedlander, Hassan Mansour, Ozgur Yilmaz)

**PhaseLift: Exact phase retrieval via convex programming**

This talk introduces a novel framework for phase retrieval, a problem which arises in X-ray crystallography, diffraction imaging, astronomical imaging and many other applications. Our approach combines multiple structured illuminations together with ideas from convex programming to recover the phase from intensity measurements, typically from the modulus of the diffracted wave. We demonstrate empirically that any complex-valued object can be recovered from the knowledge of the magnitude of just a few diffracted patterns by solving a simple convex optimization problem inspired by the recent literature on matrix completion. More importantly, we also demonstrate that our noise- aware algorithms are stable in the sense that the reconstruction degrades gracefully as the signal-to-noise ratio decreases. Finally, we present some novel theory showing that our entire approach may be provably surprisingly effective.

Gitta Kühn, Technische Universität Berlin

**Clustering sparsity**

The novel research area of compressed sensing surprisingly predicts that high-dimensional signals, which allow a sparse representation by a suitable basis or, more generally, a frame, can be recovered from what was previously considered highly incomplete linear measurements, by using efficient algorithms. Lately, more attention has been paid to the fact that in most applications the nonzero entries of the sparse vector do not arise in arbitrary patterns, but are rather highly structured. It also became evident that often the interactions between columns of the sensing matrix in ill-posed problems are not arbitrary, but rather geometrically driven.

In this talk, we will introduce what we coin clustered sparsity to provide a meaningful mathematical framework for these considerations. We will discuss sparse recovery results and applications to data separation and inpainting. It is also intriguing to realize that this framework often naturally requires solving a different $\ell_1$ minimization problem, namely the minimization on the analysis rather than the synthesis side. This is related to the recently introduced co-sparsity model.

Sparsoptimization

Chair: Ralf Lenz, Zuse Institute Berlin (ZIB)

**Mon.2 MA 141**

**Applications in natural resources**

Chair: Raj K. Dave, Zuse Institute Berlin (ZIB)

Gankhayng Danza, Mongolian University of Science and Technology (with Bayangolyn Danza, Khadjiduman Navandambal)

**Regional economical mathematical models considering ecological factors**

Mongolia is experiencing rapid economic development attributable to growth in the mining sector. Exploration by major national and international mining companies has identified substantial reserves of coal, copper and other minerals. Exploitation of these reserves is under way with production expected to grow significantly in the next five years. However, while the nation is experiencing significant GDP growth, the exploitation of mineral reserves is having a negative impact on the environment. Natural resources are being depleted, chemicals are entering atmosphere, water is being polluted with toxic metals, pasture land is being destroyed and the incidence of sickness among the local populations is increasing.

There is now a growing demand for the development of mathematical models and related software to analyze the impact of and the interrelationship of different factors on the regional economies affected by the mining industry. Statistical and dynamical models have been de-
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 harvesting 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, and (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.

Adriana Piazza, Universidad Técnica Federico Santa María (with Bernardo Pagano)
A Lagrangian heuristic for delay constrained 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 node, a set of source nodes and a set of candidate relay nodes and delays provided on each possible link (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 Dijkstra and Lagrangian heuristic. The proposed polynomial time algorithm [complexity $O(n \cdot \log(d_{max}/m))$, where $n$ is the number of candidate relay nodes, $m$ is the number of edges and $d_{max}$ 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.

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 and economic equilibrium

Organizer/Chair: Alejandro Jofre, Universidad de Chile - invited Session

Sara Grundel, MPI Magdeburg (with Michael Overton)

Variational analysis of the spectral abscissa for defective and derogatory matrices

The spectral abscissa and radius are respectively the largest of the real parts and the largest of the moduli of the eigenvalues of a matrix. They are non-Lipschitz, nonconvex functions on the space of complex $n \times n$ matrices. To motivate our work, we briefly discuss a spectral radius optimization problem for parametrized matrices arising from subdivision surfaces, a method to construct smooth surfaces from polyhedral meshes used in computer graphics and geometric modeling. In this case, we find that the minimizing matrix is both defective and derogatory: the Jordan form of the optimal matrix has four blocks corresponding to eigenvalue zero, with sizes $4, 3, 2$ and $2$. Generally, spectral functions are not Clarke regular at such points in matrix space, and hence their subdifferential analysis is complicated. By refining results of Burke and Overton, we address the simplest such case, presenting a complete characterization of the Mordukhovich subgradients of the spectral abscissa for a matrix with an eigenvalue having two Jordan blocks of size 2 and 1.

Julia Eaton, University of Washington Tacoma (with James Burke)

On the subdifferential regularity of functions of roots of polynomials

Eigenvalue optimization problems arise in the control of continuous and discrete time dynamical systems. The spectral abscissa and spectral radius are examples of functions of eigenvalues, or spectral functions, connected to these problems. A related class of functions are polynomial root functions. In 2001, Burke and Overton showed that the abscissa mapping on polynomials is subdifferentially regular on the monic polynomials of degree $n$. We extend this result to the class of max polynomial root functions which includes both the polynomial abscissa and the polynomial radius mappings. The approach to the computation of the subgradient simplifies that given by Burke and Overton and provides new insight into the variational properties of these functions.
Approximation & online algorithms

Mon.3.I 3010

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 behavior is to greedily select the first option from a given set of alternatives at each stop. First, we give an O(n (log n + d²)) 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 δ 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, Tü Berlin [with Eyelp Grant, Jochen Künemann, 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.I 3004

Interactions between optimization and game theory in scheduling

Organizer/Chair Neil Olver, MIT - Invited Session

Marc Uetz, University of Twente [with Jelila Duives, Ruben Hoeksma]

Mechanism design for single machine scheduling by ILP

We consider the classical single machine scheduling problem to minimize total weighted completion times \( \sum w_j C_j \). The problem is easily solved in polynomial time, but here we assume that data is private information to the jobs. This gives rise to a situation where jobs may strategize by misreporting their private data. In order to do optimization in such a setting, also incentive constraints have to be taken into account. Since Myerson’s seminal work on optimal auction design, it is well known how such mechanism design problems can be solved when private data is single-dimensional, but not much is known for multi-dimensional mechanism design problems, neither in general nor for the scheduling problem at hand. In the spirit of what is called automated mechanism design, we use integer linear programming models to find optimal scheduling mechanisms for the 2-dimensional mechanism design problem. So far, this approach is prohibitive for all but toy problems, yet it allows to generate and test hypotheses. This way, we gain new insights into optimal mechanisms for the scheduling problem at hand.

Ruben Hoeksma, University of Twente [with Marc Uetz]

Price of anarchy for minsum related machine scheduling

We consider related machine scheduling to minimize the total completion time \( \sum C_j \). This problem is well known to be solved in polynomial time by a classical algorithm of Horowitz and Sahni. Instead of the centralized optimal solution, however, we are interested in the situation where each job individually chooses the machine on which it is processed. We analyze the quality of the resulting Nash equilibria in relation to the objective value in the optimal solution, also known as the price of anarchy. Complementing recent results by Cole et al. on the unrelated machine scheduling problem where the price of anarchy equals exactly 4, we show that the local SPT rule results in a price of anarchy between \( e/(e-1) \) and 2. To obtain the upper bound of 2, we use a smoothness argument in the flavor of recent work of Roughgarden, blended with a new characterization of the structure of optimal solutions.

Neil Olver, MIT [with Richard Cole, Jose Correa, Vasilis Gkatzelis, Vahab Mirrokni]

Approximation algorithms for scheduling via coordination mechanisms

We investigate the problem of scheduling on multiple unrelated machines, where the goal is to minimize the weighted sum of completion times. We primarily consider the game-theoretic version of the problem, where each job is an agent aiming to minimize its own completion time. However, as one outcome of our work we obtain the first combinatorial constant factor approximation algorithm for the NP-hard optimization problem.

We consider a number of different policies; rules specifying the scheduling on a machine for a given assignment. The most obvious choice is Smith’s rule; for a given assignment of jobs to machines, this yields the optimal schedule. However, we show that other policies that give a suboptimal scheduling actually have much better equilibrium schedules, due to better incentives. By finding an approximate Nash equilibrium for one such policy via local search, we obtain a factor \( 2 + \epsilon \) approximation algorithm.

These results are obtained by the application of a common technique: a mapping of the strategy vectors into a carefully chosen inner product space. Once this structure is in place, the proofs are relatively short and elegant.

Denis Cornaz, Université Paris-Dauphine [with Moudarres Philippa]

Strengthening Lovász bound for coloring with a new graph transformation

Let \( \alpha(G) \) and \( \varphi(G) \) denote the stability number and the clique-partition number of \( G \), respectively. Using a new graph transformation, one constructs a new operator \( \Phi \) which associates to any graph parameter \( B \) such that \( \alpha(G) \leq B(G) \leq \varphi(G) \) for all graphs \( G \), a graph parameter \( \Phi_B \) such that \( \alpha(G) \leq \Phi_B(G) \leq \varphi(G) \) for all graphs \( G \). We prove that \( \Phi(B) \leq \Phi_B(G) \) and that \( \Phi_B(G) \leq \Phi(G) \) for all graphs \( G \), where \( B \) is Lovász theta function and \( \Phi \) is the fractional clique-partition number. \( \Phi(B) \) is a significant better lower bound for \( \Phi \) than \( B \).

Frédéric Meunier, CERMICS, École des Ponts [with Daniel Chemla, Roberto Wolfe 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.

Mon.3.2 3005

Exact and approximation algorithms on graphs

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

Denis Cornaz, Université Paris-Dauphine [with Moudarres Philippa]

Strengthening Lovász bound for coloring with a new graph transformation

Let \( \alpha(G) \) and \( \varphi(G) \) denote the stability number and the clique-partition number of \( G \), respectively. Using a new graph transformation, one constructs a new operator \( \Phi \) which associates to any graph parameter \( B \) such that \( \alpha(G) \leq B(G) \leq \varphi(G) \) for all graphs \( G \), a graph parameter \( \Phi_B \) such that \( \alpha(G) \leq \Phi_B(G) \leq \varphi(G) \) for all graphs \( G \). We prove that \( \Phi(B) \leq \Phi_B(G) \) and that \( \Phi_B(G) \leq \Phi(G) \) for all graphs \( G \), where \( B \) is Lovász theta function and \( \Phi \) is the fractional clique-partition number. \( \Phi(B) \) is a significant better lower bound for \( \Phi \) than \( B \).

Frédéric Meunier, CERMICS, École des Ponts [with Daniel Chemla, Roberto Wolfe 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/Chairs Christian Wulff-Nilsen, University of Southern Denmark; Glencora Borradaile, Oregon State University - Invited Session

Ruchit Agarwal, 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 trade-off between space, stretch and query time — a phenomenon that does not occur in dense graphs. In particular, for any positive integer t and for any 1 ≤ n ≤ m, our distance oracle is of size O(m + n^t) and returns stretch (1 + 2/(t + 1)) distances in time O((αΔ)^t), where Δ = 2m/n is the average degree of the graph. The query time can be further reduced to O(2aΔ^t) 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^{5/3}).

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 ≥ 2, we show that a (2k − 1)-approximate distance oracle for G of size O((k^{1+1/k}) and with O(\log k) query time can be constructed in O(min\{km^{1/2}, \sqrt km + kn^{1+1/k}\}) time for some constant c. This simultaneously improves the O(km^{1/2}) preprocessing and the O(k) query time of Thorup and Zwick. For any 0 < ε ≤ 1, we also give an oracle of size O(kn^{1+1/ε}) that answers ((2 + ε)k)-approximate distance queries in O(1/ε) time. At the cost of a k-factor in size, this improves the I28k 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+1/k}) size bound of Mendel and Naor for any constant ε > 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 ≥ 1 it is possible to preprocess the graph in \Theta(m/n^{1/2}) time and generate a compact data structure of size O(n^{1+1/k}). 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^{5/3}) 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.

Combinatorial optimization

Mon.3 H 3012

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

Matthew Ocho, 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 new 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.

Combinatorial optimization

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, ..., x_n\} into clusters C_1, ..., C_k of prescribed sizes k_1, ..., k_k. We derive upper bounds on the diameter in the form of k_1 + k_2, n = k_1 + k_2. This is a direct generalization of the diameter 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 ≥ 4 and all k_1, k_2, there are cluster sizes k_1, k_2, n such that the diameter of the corresponding partition polytope is at least \lceil k_1k_2 \rceil.

Anastasia Shakhshnheyder, 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 not 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\sqrt{\epsilon}-approximate algorithm, where \(\epsilon\) is the size of an input vector. 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 clusterings 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.
mization problems and challenging open conjectures. We focus on two particular cases: TSP and bin packing.

Tamás Király, Eötvös University, Budapest (with Attila Beáthni, Máté-Nagy Gergely, Pap Gyula, Pap Júlia)

Multiplayer multicommodity flows

We investigate the Multiplayer 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 may have edge where one of them agrees to route the flow of the other player (up to a given capacity) between two specified nodes. In return, the second player pays an amount proportional to the flow value.

We show that the social optimum can be computed by linear programing. In contrast, an equilibrium solution, although it always exists, is not necessarily unique, and is PRAD-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 this digraph is a cycle.

Tom McCormick, UBC Sauder School of Business (with Brita Peis)

A primal-dual algorithm for weighted abstract cut packing

Hoffmann 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 abscences, 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 testing are very promising and show the practical viability of the approach.

Christian Kanzow, University of Würzburg (with Alfo Boccia)

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 of the affine price function; specifically, the framework includes constraints will be presented. In particular, the framework includes local superlinear convergence. These conditions enable the application to nonsmooth systems with nonisolated solutions. Different algorithms belonging to the framework will be described.

Mon.3 MA 314

Analysis and learning in variational inequalities

Organizers/Chair Shu Lu, University of North Carolina at Chapel Hill - Invited Session

Hao Jiang, University of Illinois at Urbana-Champaign (with Sean Meyn, Iyad Shanbag)

Learning parameters and equilbria in noise–corrupted Cournot games with misspecified price functions

We consider an oligopolistic setting in which myopic firms compete in a repeated Nash-Cournot game. In accordance with the Cournot assumption, prices are set based on aggregate output levels. We develop distributed learning schemes in a regime where firms are ignorant of a complete specification of an affine price function; specifically, firms learn the equilibrium strategy and correct the misspecification in the price function by simultaneously incorporating noise-corrupted observations and demand function. Differentiated by informational assumptions, two sets of schemes are developed and their performance is demonstrated on a networked Nash-Cournot game:

- Learning under common knowledge with unobservable aggregate output: Here, payoff functions and strategy sets are public knowledge but aggregate output is unobservable. When firms observe noise-corrupted prices, distributed best response schemes are developed which allow for simultaneously learning the equilibrium strategy and the misspecified parameter in an almost-sure sense. Furthermore, these statements may be extended to accommodate nonlinear generalizations of the demand function.

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Local analysis of variational conditions

We will present a mathematical framework for local analysis of variational conditions in finite-dimensional spaces, and will illustrate some of its applications. We will also illustrate some forms of the fundamental regularity conditions for this analysis, and discuss connections among these.

Stephen Robinson, University of Wisconsin-Madison

Mon.3 III 2034

Semidefinite programming applications

Chair Tomohiko Mizutani, Kanagawa University

Sunnyong Kim, Ewha W. University (with Masakazu Kojima, Makoto Yamashita)

A successive SDP relaxation method for distance geometry problems

We present a numerical method using cliques and successive application of sparse semidefinite programming relaxation to solving the semidefinite relaxation problem of distance geometry problems. We present a new theory for incorporating considerations of im.
lutions 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 fabrication of photonic crystals with large band-gaps. Such designs entail a wide interaction 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 q demanders. The key idea of the relaxation methods is in the change of variables to CTPs, and due to this, we can construct SDP relaxations whose matrix variables depend on \( \min(p,q) \) at each relaxation order. The sequence of optimal values of SDP relaxations converges to the global minimum of the CTP as the relaxation order goes to infinity. We show the performance of the relaxation methods through numerical experiments.

Houdou Qi, University of Southampton

Computing the nearest Euclidean distance matrix

The Nearest Euclidean distance matrix problem (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. 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.

Binh Wu, National University of Singapore (with Chao Ding, Defeng Sun, Kim-Chuan Toh)

The Moreau-Yosida regularization of the Ky Fan \( k \)-norm related functions

Matrix optimization problems (MOPs) involving the Ky Fan \( k \)-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 \( k \)-norm, we need to understand the first and second order properties of the Moreau-Yosida regularization of the Ky Fan \( k \)-norm function and the indicator function of its epigraph. As an initial step, we first study the counterparts of the vector \( k \)-norm related functions, including the metric projectors over the dual vector \( k \)-norm ball and the vector \( k \)-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 \( k \)-norm epigraph indicator function.

Renato Monteiro, Georgia Tech (with Benar Sunter)

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. Important 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 \( O(1/k^3/2) \) convergence rate, which improves upon the \( O(1/k^2) \) convergence rate bound for another accelerated Newton-type method presented by Nesterov.

Houduo Qi, University of Southampton

Yosida regularization of the Ky Fan \( k \)-norm

We discuss risk measures generated by general acceptance sets 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.

Bin Wu, National University of Singapore (with Chao Ding, Defeng Sun, Kim-Chuan Toh)

The Moreau-Yosida regularization of the Ky Fan \( k \)-norm related functions

Constraint programming standard and industrial applications

Roberto Casta˜neda Lozano, Swedish Institute of Computer Science (SICS) (with Mats Carlsson, Frej Dreghomm, 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.

Constraint programming with features such as flexible search and global constraints is a good candidate for robustly solving code generation problems.
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-Andrea 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 Fritelli 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.

Mon.3.M A 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 Guo, University of Liverpool (with Vincent Conitzer, Amy Greenwald, Nicholas Jennings, Victor Naroditskiy)
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.

Takahito Kuno, University of Tsukuba (with Tomohiro Ishihama)
A class of convergent subdivision strategies in the conical algorithm for concave minimization

We present a new proof of the convergence of the conical algorithm for concave minimization under a pure ω-subdivision strategy. In 1991, Tuy showed that the conical algorithm with ω-subdivision is convergent if a certain kind of nondegeneracy holds for sequences of nested cones generated in the process of the algorithm. Although the convergence has already been proven in other ways, it still remains an open question whether the sequences are nondegenerate or not. In this talk, we introduce a weaker condition of nondegeneracy, named pseudo-nondegeneracy, and show that the conical algorithm with ω-subdivision converges as long as the pseudo-nondegeneracy holds for sequences of nested cones generated by the algorithm. We also show that every sequence generated by the algorithm is pseudo-nondegenerate. The pseudo-nondegeneracy is not only a useful condition for proving the convergence, but suggests a possible class of convergent subdivision strategies.

Achim Wechsung, Massachusetts Institute of Technology (with Paul Barton)
Improving relaxations of implicit functions

A factorable function \( f : Y \to \mathbb{R}^n, Y \subseteq \mathbb{R}^n \) can be represented as a DAG. While it is natural to construct interval extensions of factorable functions, the DAG representation has been shown to also enable the backward propagation of interval bounds on the function’s range, i.e., to provide an enclosure of the intersection of \( Y \) with the function’s pre-image. One application is to eliminate points in the domain where no solution of \( f(y) = 0 \) exists. This idea can be extended to the case of constructing convex relaxations of implicit functions. When \( n > m \), it is possible to partition \( Y \) into \( X \subseteq \mathbb{R}^m \) and \( P \subseteq \mathbb{R}^{m-n} \). Assuming that \( X \) and \( P \) are intervals and that there exists a unique \( x : P \to X \) such that \( f(x(p)) = 0 \), it is then possible to construct relaxations of the implicit function \( x \) using the DAG representation of \( f \), backward propagation and generalized McCormick relaxation theory. These relaxations can be used to initialize other methods that improve relaxations of implicit functions iteratively.

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 family 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 Miesenbock, University of Zürich (with Yeon-Koo Cha, Jinwoo Kim)
Global optimization

Algorithms and relaxations for nonconvex optimization Problems
Organizer/Chair: Jeff Linderoth, University of Wisconsin-Madison - Invited Session

Bissan Ghaddar, Department of National Defence (with Juan Vera)
A global optimization approach for binary polynomial programs

In this talk, we present branch-and-dig, an algorithm to find global solutions for binary polynomial programming problems. Inequality generating techniques based on lift-and-project relaxations are developed for binary polynomial problems which can help speed up the branch-and-bound process by improving the bounds at each node, thus reducing the number of nodes of the tree. Computational results for small test problems of degree three are given. In the computational study, we investigate the performance of different branching rules and the impact of the dynamic inequality generation scheme.
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.

Philipp Christophel, SAS Institute Inc. (with Amir Narisety, 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.

Mon.3 H 1058

MILP software I

Organizer/Chair Thorsten Koch, ZIB - Invited Session

Dieter Weninger, FAU-Erlangen [with Gerald Gamrath, Thorsten Koch, Alexander Martin, Matthias Miltenberger]

SCIP preprocessing for MILPs arising in supply chain management

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Mon.3 H 2013

MILP formulations II

Chair Rui Oliveira, ISTAT

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. In the buildings scenario we present the room 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 Eran Sadeghi Asl, Hossein Shams Shemirani, Metin Turkyay]

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 academic 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, ISTAT [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 views on locations and 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.1 H 2012

Trends in mixed integer programming I

Organizers/Chairs Andrea Lodi, University of Bologna, Robert Weismantel, ETH Zürich - Invited Session

Giacomo Nannicini, Singapore University of Technology and Design [with Gérard Cornuéjols, François Margot]

On the safety of Gomory cut generators

Gomory mixed-integer cuts are one of the key components in branch-and-cut solvers for mixed-integer linear programs. The textbook formula for generating these cuts is not used directly in open-source and commercial software due to the limited numerical precision of the computations: Additional steps are performed to avoid the generation of invalid cuts. This paper studies the impact of some of these steps on the safety of Gomory mixed-integer cut generators. As the generation of invalid cuts is a relatively rare event, the experimental design for this study is particularly important. We propose an experimental setup that allows statistically significant comparisons of generators. We also propose a parameter optimization algorithm and use it to find a Gomory mixed-integer cut generator that is as safe as a benchmark cut generator from a commercial solver even though it rejects much fewer cuts.

Utz-Uwe Haus, IFOR, ETH Zürich [with Frank Pfueffer]

Split cuts for robust and generalized mixed-integer programming

Robust Mixed-Integer optimization problems are conventionally solved by reformulation as non-robust problems. We propose a direct method to separate split cuts for robust mixed-integer programs with polyhedral uncertainty sets, for both worst-case as well as best-case robustness. The method generalizes the well-known cutting plane procedure of Balas. Computational experiments show that applying cutting planes directly is favorable to the reformulation approach. It is thus viable to solve robust MILP problems in a branch-and-cut framework using a Generalized Linear Programming oracle.

Oktay Günlük, IBM Research [with Sanjeeb Dash, Neil Dobbs, Tomasz Nowicki, Grzegorz Swirszcz]

Lattice-free sets, branching disjunctions, and mixed-integer programming

We study the relationship between valid inequalities for mixed-integer sets, lattice-free sets associated with these inequalities and structured disjunctive cuts, especially the t-branch split cuts introduced by Li and Richard (2008). By analyzing n-dimensional lattice-free sets, we prove that every facet-defining inequality of the convex hull of a mixed-integer polyhedral set with n integer variables is a t-branch split cut for some positive integer t. Moreover, this number t does not depend on the data defining the polyhedral set and is bounded by a function of the dimension n only. We use this result to give a finitely convergent cutting-plane algorithm to solve mixed-integer programs. We also show that the minimum value t, for which all facets of polyhedral mixed-integer sets with n integer variables can be expressed as t-branch split cuts, grows exponentially with n. In particular, when n = 3, we observe that not all facet-defining inequalities are 6-branch split cuts.
Linear optimization

Chair: Angelo Sifaleras, University of Macedonia

Sergei Chubanov, 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 $O(n L_{min})$ time where $n$ is the number of variables and $L_{min}$ 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 $O(n^2)$ 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-starting 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 Sifaleras, 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. Many 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.

Mohammad Asaduzzaman, University of Waterloo

A new optimization model for brachytherapy dose plans

There are many types of radiotherapy, brachytherapy is one such. As a part of treatment planning, a dose plan needs to be constructed, this depends where and for how long to irradiate. Optimization of dose plans for brachytherapy is still an area that is relatively unexplored, and since the treatment is quite different, models used for external radiotherapy are not directly applicable. In this talk I will highlight the most important differences and then present the model we have formulated 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.

Laurence 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 $x(t) \in \mathbb{R}^d$ 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 $(r_1, \ldots, r_q)$ and $(f_1, \ldots, f_q)$ respectively. The problem for two delays has been investigated earlier in [1]. For $q \geq 1$ we now present 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 Ayo Babalola University, Ikija-Arakeji (with Samuel Awoiniyi, 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 opportunities. Through an 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 the 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 expresses. This study calculates the reduced total travel time between to compare three limited-service stop patterns: single express pattern, check-pattern system, and hierarchical system. The hierarchical system gives stops of upper type of express to include all stops of lower expresses. The check-pattern system does not allow sharing stops between different types of expresses. Though the check-pattern system does not become common, it will give more expresses than the hierarchical system during high train density. Some simple assumptions in this railway model facilitate analytical representation to locate limited-service stops for maximizing reduced travel times. We will de-
scribe the optimal limited-service stop patterns and the optimal number of stops of three systems.

Paola Pellegrini, IFSTTAR - Univ. Lille Nord de France (with Gregory Marlière, 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 delayed: 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 optimal routing and scheduling of trains on a network. Solution cost is assessed in terms of either punctuality or fluidification. In the literature, this problem, known as “real time railway traffic management problem”, is typically tackled with heuristic algorithms. Optimal approaches appear only when few network details are considered. We propose a two-phase gradient projection model which considers real railway junctions details. They differ in the computation of solution 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, computation time is very short. Interestingly, different junctions are different complex for the two models. We will devote further research to the explanation of these differences, and to the identification of effective valid inequalities.

Mon.3.H 1011 Network problems
Chair Kwong Meng Teo, National University of Singapore

Th omas Kalinowski, Universität Rostock (with Natasha Boland, Harshit Witterer, Larob Zengi) 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 the 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 Freber, Petrobas – Petroleo 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 facilities. Without resorting to integer variables, we extend the model to estimate on each time slot dynamic flow capacities which depend on in-transit inventory. Hence, they may underestimate the utilization of pipelines and risk proposing impracticable solutions. We take into account 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 facilities. With respect to integer 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 Hue 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 applications such as multi-commodity flows, traffic assignment and telecommunications 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 practice. We propose a two-phase gradient projection algorithm to bridge this gap. The proposed algorithm is designed to address the weaknesses of traditional gradient projection approaches reported in the literature, 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 adoption and to handle industrial size problems. We evaluate and compare the performance of the proposed algorithm with other approaches under common network flow scenarios such as (i) integral or continuous flows and (ii) explicit or non-explicit objective.
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 Goetzmann, TU Berlin (with Christina Büsing, Jannik Mütschke, 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.

Yuan Shen, Nanjing University (with Bingteng 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 problems. 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 subproblems 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 the lack of 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.

Mohiddin Al-Baali, Sultan Qaboos University (with Mohamed Al-Lawati)

Hybrid damped-BFGS/Gauss-Newton methods for unconstrained 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 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 safely the positive definiteness property of Hessian approximations.

Masoud Ahookhosh, University of Vienna (with Norsadikou 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 strategy 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 derivative information and advantages 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.

Nonlinear programming

Methods for nonlinear optimization III

Chair: Masoud Ahookhosh, University of Vienna

Unconstrained optimization I

Chair: Roummel Marca, University of California, Merced

Nonlinear programming

Convergence properties of augmented Lagrangian methods under the second-order sufficient 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 the weaker $R$-rate of convergence and required the stronger assumptions cited above. Finally, we show that under our assumptions one of the popular rules of controlling the penalty parameters ensures they stay bounded.

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

Infasestability 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 in the optimization of complex systems, one often finds that nonlinear optimization methods can fail and 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 Oztork, 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 under 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.

Mon.3 H 0107

Nonlinear programming

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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.

Tome 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.

Roummel 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 product calculations. This approach has broad applications in trust region and barrier methods.

Thomas Pock, Graz University of Technology [with Karl Kunisch]

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.


Optimization in energy systems

Mon.3.A 547

Optimization models for renewables integration

Organizers/Chairs Rodrigo Moreno, Imperial College London, Luc Borroni, PSR - Invited Session

Ezequiel 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 Amari, Bruno Fáñøres, Lucas Freire, Deliber 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-influenced 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/redundency 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.

Enzo Sauma, Pontificia Universidad Catolica de Chile [with Javier Contreras, David Pozo]

Stochastic optimization for electricity production and trading

Organizers/Chair Ramirud Kovačević, 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 however 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 Arashi, 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 are 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 of 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.

\textbf{PDE-constrained opt. & multi-level/multi-grid meth.}

\textbf{Mon.3 MA 415}

Numerical methods in shape and topology optimization

Organizer/Chair Antoine Laurain, TU Berlin - Invited Session

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 workpiece made of a mixture of steel different phases. For instance, 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.

Volkert Schütz, University og Trier

On the usage of the shape Hessian in aerodynamic shape optimization

The talk demonstrates 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 in terms 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.

\textbf{Robust optimization}

\textbf{Mon.3 MA 3053}

Extensions of robust optimization approaches

Chair Mohammad Mehdi Nasrabadi, Payam Noor University

Phantipa Thipwiatipotpana, 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 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).

\textbf{Robust network optimization}

\textbf{Mon.3 MA 054}

Robust network optimization

Organizer/Chair Ebrahim Nasrabadi, Massachusetts Institute of Technology - Invited Session

Sebastian Stiller, TU Berlin (with Dimitris Bertsimas, Telsa Claudio, Ebrahim Nasrabadi, Kai-Simon Gansbeke)

Robust network flows

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 Adjiashvili, 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 results in exactly one realization 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. This 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 Orlin)

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.

Sparsity optimization & compressed sensing

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 L1 and nuclear norm minimization with a globally linearly convergent algorithm

L1 minimization tends to give sparse solutions while the least squares (LS) give dense solutions. We show that minimizing the weighted sum of L1 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 L1+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 L1 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 thorough theoretical analysis of their global iteration complexity. 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 Biergisser, Arkadi Nemirovskii)

First-order methods for eigenvalue optimization

Many semidefinite programming problems encountered in practice can be recast 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.

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 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 true 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 order of preference 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 Badol, Sabanci University (with Nilay Nguyen)

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 preferences 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 Cioacă, 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 Roterd 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.

Miguel Lejeune, George Washington University (with Alexander Kopan)
Threshold boolean form for the reformulation of joint probabilistic constraints with random technology matrix
We construct a partially defined boolean function (pdBf) representing the satisfiability of a joint probabilistic constraint with random technology matrix. We extend the dBf as a threshold Boolean light minorant to derive a series of integer reformulations equivalent to the stochastic problem. Computational experiments will be presented.

Ahmed Shabbir, Georgia Institute of Technology (with Dimitri Papageorgiou)
Probabilistic set covering with correlations
We formulate deterministic mixed-integer programming models for distributionally robust probabilistic set covering problems with correlated uncertainties. By exploiting the supermodularity of certain substructures we develop strong valid inequalities to strengthen the formulations. Computational results illustrate that our modeling approach can outperform formulations in which correlations are ignored and that our algorithms can significantly reduce overall computation time.

Pavlo Krishnam, University of Iowa (with Alexander Vezel)
On polyhedral approximations in \( p \)-order conic programming
We consider (generally mixed integer) \( p \)-order conic programming problems that are related to a class of stochastic optimization models with risk-based objectives or constraints. A recently proposed approach to solving problems with \( p \)-cone constraints relies on construction of polyhedral approximations of \( p \)-cones. In this talk we discuss computational techniques for efficient solving of the corresponding approximating problems. The conducted case studies on problems of portfolio optimization and data mining demonstrate that the developed approach compare favorably against a number of benchmark methods.

Mon.3 MA 376
Advances in probabilistically constrained optimization
Organizer/Chair Miguel Lejeune, George Washington University - Limited Session

Mon.3 H 3022
Optimization of optical networks
Organizer/Chair Brigitte Jaumard, Concordia University - Invited Session

Brigitte Jaumard, Concordia University (with Minh Bui, Anh Hoang)
Path vs. cutset column generation models for the design of IP-over-WDM optical networks
Multi-layer network models have recently evolved towards IP-over-WDM networks. Therein, in order to avoid protection/restoration redundancies against either single or multiple failures, synergies need to be developed between IP and optical layers in order to reduce the costs and the energy consumption of the future IP-over-WDM networks.

We propose two new column generation models. The first one is an enhanced cutset model. The second one is a path model, based on a multi-flow formulation. Both models can solve exactly most benchmark instances, which were only solved heuristically so far.

Jørgen Rhaa, University of Copenhagen (with Thomas Sildesø, Martin Zachariasen)
Heuristic planning of shared backup path protection
Protecting communication networks against failures is becoming increasingly important as they have become an integrated part of our society. Cable failures are fairly common, but it is unacceptable for a single cable failure to disconnect communication even for a very short period and hence protection schemes are employed. The most utilized protection schemes today are ring protection and 1+1 protection. Both schemes do however require a significant extra network capacity. A more advanced protection method such as shared backup path protection (SBPP) can be used instead. SBPP is a simple but efficient protection scheme that can be implemented in backbone networks with technology available today. We prove that SBPP planning is a NP-hard optimization problem. Previous work confirms that it is time-consuming to solve the problem in practice using exact methods. We present heuristic algorithms and lower bound methods for the SBPP planning problem. Experimental results show that the heuristic algorithms are able to find good quality solutions in few minutes. A solution gap of less than 12% was achieved for seven test networks.

Philippe Malick, ISIMA - Université de Clermont-Ferrand (with Christophe Dumarque, Alexandre Martins, Rodney Saldaña, Mauricio Scozzi)
Algorithms for lower and upper bounds for routing and wavelength assignment
In all-optical networks a traffic demand is carried from source to destination through a lightpath, which is a sequence of fiber links carrying the traffic from end-to-end. The wavelength continuity constraint implies that to a given lightpath a single wavelength must be assigned. Moreover, a particular wavelength cannot be assigned to two different lightpaths sharing a common physical link. The routing and wavelength assignment (RWA) problem arises in this context as to establish lightpaths that carry traffic demands. The problem is found in two versions: (i) to minimize the number of wavelengths to meet fixed traffic requests; and (ii) to maximize the traffic requests satisfied given a fixed number of wavelengths. In this work, we develop algorithms to tackle the RWA via lower and upper bounds. We present, by combining column generation models from the literature, a fast procedure to obtain lower bounds. We also present heuristic approaches based on variable neighborhood descent (VND) with iterated local search (ILS) for the min-RWA. We report numerical results showing optimality gaps obtained on benchmark instances from the literature.

Mon.3 H 3225
Lower order exact penalty functions
Organizer/Chair Xiaojiao Yang, The Hong Kong Polytechnic University - Invited Session

Xiaojiao Yang, The Hong Kong Polytechnic University (with Kuiwen Meng)
Optimality conditions via exact penalty functions
In this presentation, we study KKT optimality conditions for constrained nonlinear programming problems and strong and Moreau-Kirchhoff stationarities for mathematical programs with complementarity constraints using \( p \) penalty functions with \( 0 \leq p \leq 1 \). We introduce some optimality indicator sets by using contingent derivatives of penalty function terms. Some characterizations of optimality indicator sets by virtue of the original problem data are obtained. We show that KKT optimality condition holds at a feasible point if this point is a local minimizer of some \( p \) penalty function with \( p \) belonging to the opti-
An interior-point $\epsilon_1/2$-penalty method for nonlinear programming

In this presentation, we solve general nonlinear programming problems by using a quadratic relaxation scheme for their $\epsilon_1/2$-lower order penalty problems. Combining an interior point method, we propose an interior point $\epsilon_1/2$-penalty function method, and design some robust algorithms. Using some relaxed constraint qualifications, we obtain first-order optimality conditions of relaxed $\epsilon_1/2$-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.

Zhangyou Chen, The Hong Kong Polytechnic University (with Xiaoqi 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, $I\alpha$-type and integral-type 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.

Andrew Eberhard, RMIT University (with Boris Mordukhovich, Charles Pearce, Robert Wenczel)

Combinatorial optimization

Generalizing shortest paths, cycles, and Steiner trees

Chair Stefano Gualandi, University of Pavia

Stefano Gualandi, University of Pavia (with Federico Malucelli)

Resource constrained shortest paths with a super additive objective function

We present an exact solution approach to the constrained shortest path problem with a super additive objective function. This problem generalizes the constrained shortest path problem by considering a cost function $c(\cdot)$ such that, given two consecutive paths $P_1$ and $P_2$, the following relation holds $c(P_1) + c(P_2)$. Since super additivity violates the Bellman optimality conditions, known resource constrained shortest path algorithms must be revisited. Our exact solution algorithm is based on a two stage approach: first, the size of the input graph is reduced as much as possible using a Lagrangian reduced-cost fixing algorithm. Then, since the Lagrangian relaxation provides a tight lower bound, the optimal solution is computed using a new shortest path enumerative algorithm that exploits such lower bound. We present two alternative algorithms to solve the Lagrangian relaxation, and compare their behaviors in terms of reduction of the input graph, quality of the lower bounds, and computation time. Computational results show
that the constrained shortest path with a super additive objective function is indeed a challenging problem.

Hirschge Dan, Kansai University (with Tatsuya Shigehata)

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 given, and one needs 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 Karbstein, 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.

Maxim Sviridenko, University of Warwick (with Rishi Saket)

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 $(k-1)(1-\frac{\ln D}{\ln(k-1)})+1$, 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.

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 Santià demonstrated in 2010 an $\ln(4)+\varepsilon=1.39$ approximation algorithm based on a so-called hypergraphic LP relaxation. Interestingly, even though their approach is LP based, they do not obtain 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 (Slater 2003). 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 1976. 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 Mohamad 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 \( O(n^{1/2+\varepsilon}) \) by Nagarajan and Ravi. Our approach requires bounds on integrality gaps of LP relaxations for the asymmetric traveling salesman problem and a variant using two paths.
finally, we derive a new recursive greedy heuristic which achieves an average number of $2n/5$ color changes.

Marcin Krzywowsk, Gdańsk University of Technology

**An algorithm listing all minimal dominating sets of a tree**

We provide an algorithm listing all minimal dominating sets of a tree of order $n$ in time $O(1.4656^n)$. This leads to that every tree has at most $1.4656^n$ minimal dominating sets. We also give an infinite family of trees of odd and even order for which the number of minimal dominating sets exceeds $1.4167^n$, thus exceeding $2^{n^2}$. This establishes a lower bound on the running time of an algorithm listing all minimal dominating sets of a given tree.

Yasuksu Matsui, Tokai University (with Kenta Kizaka, Hiroki Yoshida)

**An enumeration algorithm for the optimal cost vertex-colorings for trees**

The cost vertex-coloring problem is to find a vertex-coloring of a graph such that the total costs of vertices is as small as possible. In 1997, Kroon et al. gave the problem can be solved in linear time for trees. In this talk, we first propose an enumeration algorithm for the optimal cost vertex-colorings for trees, if there exists. Our algorithm has a polynomial-time delay property and requires polynomial space.

Jens Poppenborg, 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 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 Adjachsheli, 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 inserts 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.

Jens Vygen)

**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 signal delays, 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 Geister, 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 Geister, 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 colors, for example. The recent industrial designs require new color heuristics to resolve conflicts between different layers. Additionally, other objectives, such as robustness against manufacturing yield, are of importance.

Winfried Hochstädtler, FernUniversität in Hagen (with Stephan Andres)

**Some heuristics for the binary paint shop problem and their expected number of colour changes**

In the binary paint shop problem we are given a word on $n$ characters of length $2n$ where every character occurs exactly twice. The objective is to color the letters of the word in two colors, such that each character receives both colors and the number of color changes of consecutive letters is minimized. Amini et. al. proved that the expected number of color changes of the heuristic greedy coloring is at most $2n/3$. They also conjectured that the true value is $n/2$. We verify their conjecture and, furthermore, compute an expected number of $2n/3$ color changes for a heuristic, named red first, which behaves well on some worst case examples for the greedy algorithm. From our proof method,
Complementarity & variational inequalities

Complementarity properties of linear transformations on Euclidean Jordan algebras
Organizer/Chair Jiyuan Tao, Loyola University Maryland - Invited Session

Jiyaraman Indupappasamy, 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 \(x \in K\), \(y := L(x) + q \in K\), and \(\langle x, q \rangle = 0\). This problem includes the standard, semidefinite and second order linear complementarily problems. To study the existence and uniqueness of solution of the linear complementarity problem, several matrix classes have been introduced which includes P and semimonotonicity properties. Motivated by these concepts, the matrix classes were extended to linear transformations on \(S^n\), 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).

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 Snajder, Bowie State University (with M. Sathyarama 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 subtransformation of a linear transformation defined on two finite dimensional real Hilbert spaces. We study various complementarity properties of linear transformations in relations to subtransformations, principal pivot transformations, and Schur complements. We also investigate some relationships with dynamical systems.

Complementarity & variational inequalities

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 Ilan Adler)
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 equivalent problems and investigate a different (possibly novel) algorithm for exposing “elusive” equilibrium points.

Gabriele Uchida, University of Vienna (with Immanuel Bomze, Werner Schachinger)
Think completely positive! Algebraic properties of matrices belonging to the copositive or related cones
In the context of conic programming (optimizing a linear functional over a convex cone subject to linear constraints) properties of, and relations between, corresponding matrix classes play an important role. A well known subclass of this problem family is semi-definite programming and, to a quickly expanding extent, copositive programming. 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.

Combinatorial & variational inequalities

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semidefinite and a nonnegative matrix whereas this is possible for every copositive \( n \times n \)-matrix with \( n \leq 4 \).

Cristian Odre, 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 Odre)

Exploiting symmetry in copositive programming

We study the solution of copositive programs using a sequence of improving relaxations, as the ones used by Gaddar-Vera-Anjos 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 exploiting the symmetry of Polya-like representations for copositive polynomials in a novel manner.

Constraint programming

Jean-Guillaume Fages, École des Mines de Nantes (with Xavier Lecra)

Solving the Traveling salesman problem with constraint programming

The Traveling Salesman Problem (TSP) is one of the most studied problem 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, I3S CNRS – Université Nice Sophia Antipolis (with Christelle Guéret, Louis-Martin 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-Martin Rousseau, CIRREL – Polytechnique Montréal (with Nicolas Chabadas, Marc Joliveau, Pierre L’Ecuyer)

Portfolio optimization

Organizer/Chair John Birge, University of Chicago. Invited Session

Giovanni Fasano, University Ca Foscari of Venice (with Giampaolo Liuzzi, Stefano Lucidi, Francesco Rinaldi)

An exact penalty method for constrained Lipschitz optimization

In this work we consider the minimization of a real function subject to inequality constraints along with bound constraints on the variables. In the latter problem we assume that both the objective function and the constraints are Lipschitz continuous. We first study the solution of a bound constrained minimization problem and propose a line search type derivative free method for its solution. Then, to take into account the presence of nonlinear constraints, we consider the minimization of a new Lipschitz continuous exact penalty function subject to bound constraints. We prove the equivalence of the original inequality constrained problem with the penalized problem subject to bound constraints.

In particular, we show that using our derivative free line search approach, global convergence to Clarke-stationary points is guaranteed for the penalized problem. Then, convergence to Clarke-stationary points is also guaranteed for the original constrained problem. We complete our work with a numerical experience on significant test problems, showing the reliability of our proposal.

Kevin Kofler, University of Vienna (with Arnold Neumaier, Hermann Schichl)

Derivative-free optimization with equality constraints using data analysis

This talk will present an algorithm (BBQOMA – Box Black-Box Optimization Method of Analysis) we developed to solve constrained black box optimization problems globally. Our techniques do not require gradients nor direct derivative approximations. Instead, we approximate the functions by a quadrature version of covariance models from data analysis. A particular focus is on constraints: in addition to bound constraints, we also handle black box inequality and equality constraints.

In particular, we support equality constraints given in implicit form \( f(x) = 0 \) where \( f \) is a black box function and \( x \) a vector of one or more variables. That is achieved by bounding those implicit equality constraints by quadratic approximations using linear programming. We thus obtain surrogate models which we can solve by derivative-based optimization software.

Finally, we attempt a heuristic global search by another method from data analysis: We use Gaussian mixture models to locate holes in the search space to fill with sample points. Our approach is particularly tuned for problems where function evaluations are expensive. It requires significantly fewer function evaluations than evolutionary algorithms.

Mid Powell, University of Cambridge

On derivative-free optimization with linear constraints

The current research of the speaker is on optimization without derivatives when there are linear constraints on the variables. Many features of his NEWUOA software for unconstrained optimization are retained, but it is necessary to include the linear constraints in the subproblem that minimizes the current quadratic model approximately within a trust region. Truncated conjugate gradients is still chosen for solving this subproblem, a restart being made if the usual steplength of an iteration has to be reduced in order to prevent a constraint violation. Each restart gives a smaller subproblem that is regarded as unconstrained after using active constraints to eliminate some of the variables. The active set of the first of these subproblems is chosen carefully, so that the steplength of the first conjugate gradient iteration cannot be made arbitrarily small by the need for feasibility. The progress of this work will be reported, with some preliminary numerical results.
the complexity of large scale portfolio selection problems using some concordance measures. We first analyze the large scale static problem and then we discuss a first extension to the dynamic portfolio problem. Finally we propose an empirical application to the large scale portfolio problem.

Jun-Ya Gotoh, Chuo University (with Keita Shinozaki, Akiko Takeda)

Robust portfolio techniques for coherent risk minimization

Coherent measures of risk have gained growing popularity in financial risk management during the first decade of this century. However, optimal solutions to their minimization are highly susceptible to estimation error of the risk measure because the estimate depends only on a portion of sampled scenarios. In this talk, by employing robust optimization modeling for minimizing coherent risk measures, we present a couple of ways for making the solution robust over a certain range of estimation errors. Specifically, we show that a worst-case coherent risk minimization leads to a penalized minimization of the empirical risk estimate. Besides, inspired by Konno, Waki and Yuuki (2002) we examine the use of factor model in coherent risk minimization. In general, the factor model-based coherent risk minimization along the lines of Goldfarb and Iyengar (2003) is shown to be intractable, and we present a global optimization algorithm for solving the intractable case. Numerical experiment shows that robust approaches achieve better out-of-sample performance than the empirical minimization and market benchmarks.

Amy Stodola, Akioma (with Ameen Saama, Robert Shubik)

Factor alignment problem in quantitative portfolio management

The understimation of risk of optimized portfolios is a consistent criticism about risk models and optimization. Quantitative portfolio managers have historically used a variety of ad hoc techniques to overcome this issue in their investment processes. In this talk, we construct a theory explaining why risk models underestimate the risk of optimized portfolios. We show that the problem is not necessarily with a risk model, but is rather the interaction between alphas, constraints, and risk factors in the risk model. We develop an optimization technique that incorporates a dynamic Alpha Alignment Factor (AAF) into the factor model during the optimization process. Using actual portfolio manager backtests, we illustrate both how pervasive the underestimation problem can be and the effectiveness of the proposed AAF in correcting the bias of the risk estimates of optimized portfolios.

Tue.1.MA 043

Game-theoretic models in operations

Organizer/Chair Ilan Lobel, New York University - Invited Session

Ilan Lobel, New York University (with Omar Besbes)

Intertemporal price discrimination: Structure and computation of optimal policies

We consider the problem of a firm selling goods over time to customers with heterogeneous patience levels. We let customer valuations be correlated with their willingness-to-wait and look for a dynamic pricing policy that maximizes the long-term revenue of the firm. We prove that the optimal pricing policy is composed of cycles with a period that is at most twice the maximum willingness-to-wait. We also prove that the prices typically follow a nonmonotonic cyclic behavior. Finally, we show that optimizing over dynamic pricing policies can be accomplished in time that is polynomial on the maximum willingness-to-wait among all customers.

Hamid Nazerzadeh, Marshall School of Business

Buy-it-now or take-a-chance: A mechanism for real-time price discrimination

I present a simple sequential mechanism to allocated online advertisement space. The mechanism is motivated by increasingly sophisticated consumer tracking technology that allow advertisers to reach narrowly targeted consumer demographics. Such targeting enhances advertising efficiency by improving the matching quality between advertisers and users, but can also result in thin markets for particular demographic groups.

Georgia Perakis, MIT (with Pavithra Harsha, Zachary Leung)

Markdown optimization for a fashion e-tailer: The impact of returning customers

We study a model for markdown optimization, i.e., how to set prices to maximize the revenue from selling a fashion good in the context of an e-tailer. Due to the convenience of Internet shopping, a significant proportion of customers may wait for the price of a fashion item to decrease, strategically returning multiple times to check on the price. This is an important issue that e-tailers need to account for when pricing their products. In this talk, we propose a model that incorporates returning customer behavior. We focus on the case of a monopolist e-tailer selling a single product over a finite horizon. For classes of demand functions, we develop convex reformulations that are tractable. We derive general insights on pricing strategies in the presence of returning customers. We compare the prices and revenue of a myopic pricing policy, which treats returning customers the same as first-time customers, to the optimal pricing policy. This allows us to estimate the value of smart pricing.

Tue.1.I 1058

MILP software II

Organizer/Chair Thorsten Koch, ZIB - Invited Session

Martin Tieves, RWH Aachen (with Arie 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
strategies of searching in the branch and bound tree. These solvers are run as blackbox-solvers on parallel threads, exchanging potential information as primal solutions or dual bounds via callbacks at runtime. We apply the above on the MIPLIB data-sets and show a promising speed-up in computation for many instances.

Michael Jorjor, TU Darmstadt (with Evgenii Gavrilow)

polymake for integer linear programming
polymake is a software tool for experiments in polytope theory and related areas. Most recently, new functionality useful for integer linear programming was added. This includes Hilbert bases (via interface to Normaliz), Gomory-Chvátal closures, point lattice enumeration, standard contractions, and more.

The system has been developed since 1997 and continuously expanded. Many contributions over the years, see http://www.polyMAKE.org/doku.php/team for the complete list.

See also a new tutorial related to optimization by Marc E. Pfetsch and Sebastian Pokutta: http://www.polymake.org/doku.php/tutorial/optimization

Frédéric Gardi, LocalSolver (with Thierry Benoist, Julien Darby, Bertrand Estellier, Romain Megel, Karim Nouioua)

LocalSolver: A mathematical programming solver based on local search
We present LocalSolver 2.0 (http://www.localsolver.com), a mathematical programming solver founded on local-search techniques. LocalSolver offers simple APIs as well as an efficient modeling language for fast prototyping. Actually, it is designed to tackle combinatorial problems, that is, models with 0-1 decision variables only. LocalSolver can handle very large nonlinear problems with millions of binary decisions in minutes of running times only. Its practical performance relies on innovative autonomous moves coupled with a highly-optimized incremental evaluation machinery. In this way, LocalSolver is able to explore millions of feasible solutions in minutes of running times, ensuring a fast convergence toward high-quality solutions. It has been tested on classical benchmarks and succeeded the first phase of the Google ROAD/DEF/EURO Challenge (ranked 25th among 80 participating teams).

Moreover, LocalSolver is used in several real-life applications: TV media planning, maintenance planning, energy optimization, mobile network partitioning, car sequencing, project management. For the next version, we plan to extend its capabilities to deal with mixed-variable models.

Keisuke Hotta, Bunkyo University

Enumeration and characterization of the electoral districting for the decision support
In Japan, 300 members of the House of Representatives, the Lower House, are elected by the single-seat constituency system. Each electoral district is made by the apportionment to the 47 prefectures and the redistricting in each prefecture. The apportionment gives the lower bound of the gap in the value of individual votes. Because of the density of population in an urban area, the lower bound of the ratio is close to 2 times. As a result, the gap is more than 2 by the redistricting.

In Japan the state of the same condition has been continuing for over ten years. By optimizing both the apportionment problem and the redistricting problems respectively, the limit of the disparity is 1.939 for the population in 2010 and the provinces in 2011. The 0–1 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.

Magnus Önnheim, Chalmers University of Technology (with Tango Almegren, Nícalas Andréasson, Michael Patriksson, Ann-Britt Strömberg, Adam Wojciechowski)
The opportunistic replacement problem: Model, theory and numerics
We present a 0–1 integer linear programming (ILP) model for determining optimal opportunistic maintenance schedules for a system of components with maximum replacement intervals; it is a natural starting point for modelling replacement schedules of more complex systems. We show that this problem is NP-hard and that all the necessary inequalities induce facets. We further present a new class of facets defined by \( \{0, \frac{1}{2}\}\)-Chvátal–Gomory cuts. For costs monotone with time a class of elimination constraints, allowing for maintenance only when replacement 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&bound nodes and simplex iterations for most integer classes with time dependent costs. For instance classes with time independent costs and few components the elimination constraints are used favourably.

Top.1/H 2032
Trends in mixed integer programming II
Organizers/Chairs Andrea Lodi, University of Bologna, Robert Weismantel, ETH Zurich – Invited Session

Gustavo Angulo, Georgia Institute of Technology (with Shabbir Ahmed, Santanu Dey)

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 particular cases of this set are considered, for which we present complete descriptions of the convex hull in terms of linear inequalities and extended formulations. We study the efficacy of the polyhedral results on a class of semi-continuous transportation problems.

Domenico Salvagnin, University of Padova (with Matteo Fischetti, Michele Monaci)

Randomness and tree search
Many mixed integer linear programs exhibit a high performance variability 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 imperfect tie-breaking (degeneracy of the instance at hand further complicates the picture).

We investigate whether randomness can be a useful tool to overcome the issue of performance variability and to actually take advantage of it to speed up the solution process. Preliminary computational results show that the proposed approach is promising.

Stefano Smriglio, University of L’Aquila (with Andrea Lodi, Ted Ralphs, Fabrizio Rossi)

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 solution cover, we can obtain a branching disjunction for which each child is guaranteed to contain at least one improving solution. Computing a minimal improving solution cover amounts to solving a discrete 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 Poljak, 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 prior 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, projection on which is a very simple operation. We consider two methods: projected pseudo-gradient (PPG) and extra pseudo-gradient (EPG), for which the progress on the objective function is quadratic. Both PPG and EPG are the main optimization. Based on previous work by Fujishige et al. we will present algorithms using a sequence of minimum norm point calculations iterating to order to achieve some advancement in this direction which stimulated our research.

As shown by, i.e., Papadimitreou and Stieglitz, linear programming problems may w.l.o.g. be considered to be bounded. It is possible to reduce bounded LP to a sequence of LPs on onoptotolues which can easily be solved by a greedy algorithm. The approach presented is based on the zeroth 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 approaches for calculating the minimum norm point will be compared with respect to certain drawbacks in a previously applied algorithm of Wolfe.

Tue.1.I 0186
Routing with time windows
Chair Paul Sturberg, TU München
Juan Otero, Havana University (with Erick Landford)
A hybrid evolutionary approach for solving the vehicle routing problem with time windows (VRPTW)

In this paper an evolutionary strategy for solving the VRPTW is proposed. The main idea of this approach is to use routing constructive heuristics for generating the initial population and for designing the genetic operators. Modifications of the push forward insertion heuristic [2] and of an efficient insertion heuristic proposed by Campbell and Savelsbergh [1] are introduced. Both algorithms are used in an adequate proportion, depending on the number of customers, in order to combine the simplicity of the first and the high performance of the second one. In order to analyze the behavior of the proposed approach, it was programmed in C#. Computational tests were performed, using ten problems of the Gehring/Homberger library. The results were very similar to the best solutions reported in the literature and, for some problems, the obtained solutions are the best known so far.


Tiago Montanher, Mathematics and Statistics Institute of University of São Paulo
An integer programming model for the oil transference in refineries under time window constraints

Programmers of oil refineries often face the problem of moving their commodities between tanks. The transference is made through a shared pipeline network. Each pipeline can take only one transference at time which has costs due to degradation and safety issues. The programmer also needs to consider delivery times at each destination which is usually expressed in terms of a time window. We model this scenario as the problem to find k-vertex disjoint paths in a graph under time window constraints. Here k is the number of transferences. Each edge (pipeline) has a cost and a transfer time depending on the commodity transferred. We ask for independent paths to satisfy time constraints while minimizing total transference costs. Our formulation leads to a branch and price algorithm which combines an integer programming model with a Dantzig Wolfe decomposition reformulation in order to treat time constraints. We show numerical results in a real but simplified plant with 117 equipments, 230 pipelines and a variable number of simultaneous transferences.

Paul Sturberg, TU München (with Rone Brandenburg, Michael Ritter)
Vehicle routing with flexible load carriers

In many Vehicle Routing applications, using containers allows to shorten loading times and compose [potentially more efficient] tours more flexibly. We examine the optimization problem that occurs in settings, where a small number of containers is used to fulfill transportation tasks on a graph. To derive an ILP model, we consider a graph, where each task is represented by a vertex and arcs correspond to tasks directly succeeding each other. Now, the problem is related to the Vehicle Routing Problem with Time Windows, but constraints added to account for container usage render common decomposition approaches more or less useless. Instead, we can embed the problem into a broader framework which encompasses applications from routing on a multi-graph to Line Crew Scheduling. The framework uses of a number of independent transportation layers which passengers can travel on and change between to fulfill certain objectives. This approach motivates a new model which treats containers as passengers in the described framework, thus circumventing major deficiencies of the original model, significantly decreasing its size and allowing a number of new instances to be solved to optimality.

Zachary Voller, Iowa State University (with Zhijun Wu)
An optimal solution to the generalized distance geometry problem

NMR experiments on a protein yield a set of inter-atomic distance ranges. A number of structures satisfying the distance constraints, derived from distance range and bond information, are then generated. This ensemble of structures is often under represented and inaccurately represents the protein’s structural fluctuations. In this presentation we present an alternative problem where its solution, derived from interior point optimization, provides a single representation for a protein’s conformation and its ensemble of possible structures.

Antonio Machinera, IRIS (with Luis Carvalho, Virginia Costa, Carlile Lavor, Nelson Maculan)
Re-ordering protein side chains for the discretization of MDGPS

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 (DMDP). 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 Gebrer, University of Potsdam (with Carito Guziolowski, Mihail Ivanchev, Torsten Schaub, Anne Siegel, Sue Thiele, Philippe Thiebaut)
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.
Speed optimization in a ship pickup and delivery problem: balancing economic and environmental performance

Harilaos Psaraftis, National Technical University of Athens (with Christos Kontovos)

We consider a single ship pickup and delivery problem with multiple origins and multiple destinations, in which ship speed is one of the decision variables. Each port can be visited as many times as necessary so as to pick up and deliver cargoes originating from it and destined to it. These operations can be combined in a single port stop if this is warranted. Cargoes to or from distinct ports can co-exist on the ship, so long as ship capacity is not exceeded. Cargoes cannot be split. Costs include fuel, vessel charter and in-transit cargo inventory costs. In general, different speeds can be chosen for different legs of the route, so long as they are between known lower and upper bounds. Both bounds are dictated by the maximum power and technology of the engine, and by ship payload. Fuel consumption is a known function of speed and ship payload. It can be shown that on each leg of the route the speed decision can be decomposed from the pickup and delivery decision. We develop algorithms that optimize the ship’s route and we compare minimum cost solutions with minimum emissions solutions. Several scenarios are examined and computational experience is reported.

On box constrained quadratic programming with binary indicators

Thomas Stidsen, Technical University of Denmark (with Christopher Ryther)

We present a branch & cut algorithm for bi-objective TSP

Organizers/Chairs Leo Liberti, École Polytechnique; Pietro Belotti, Clemson University - Invited Session

Solving MINLPs with SCIP

Thomas Stidsen, Technical University of Denmark (with Christopher Ryther)

Gulsah Karakaya, Middle East Technical University (with Murat Kucukkalkan)

Non-radial models to define the preference measure for convex cone-based strict partial orders

Hariga Dong, University of Wisconsin-Madison

On box constrained quadratic programming with binary indicators

We consider (nonconvex) quadratic programming with box constraints and binary variables that are the “on/off” switches for continuous variables. We prove some geometric results on the corresponding convex hull, and show how to lift a class of valid inequalities for Box QP to include binary indicators. We prove that the separation problem for these lifted cuts is polynomially solvable, as long as the number of binary variables included is not too many. Finally computational results will be reported to verify the effectiveness of these cuts.
block, we consider the case where the saddle-point system is very badly conditioned due to the combined effect of very small eigenvalues of the $(1,1)$ block and of very small singular values of the off-diagonal block. Under the assumption that spectral information related to these very small eigenvalues/singular values can be extracted separately, we propose an approximate approach based on the ‘ideal’ block diagonal preconditioner of Murphy, Golub and Wathen (2000) with exact Schur complement, based on an approximation of the Schur complement that combines the available spectral information. We also derive a practical algorithm to implement the proposed preconditioners within a standard minimum residual method and illustrate the performance through numerical experiments on a set of saddle-point systems.

Hans-Bernd Qiu, University of Stuttgart [with Christian Ebenbauer]

Continuous-time saddle point algorithms with applications in control

We present some recent results on a novel class of smooth optimization algorithms that compute saddle points which arise in convex optimization problems. In contrast to many related results, we are dealing with optimization algorithms which are formulated as ordinary differential equations, i.e. as smooth continuous-time vector fields, which we analyze from a dynamical systems theory perspective. The idea of using a differential equations to find a saddle point of a Lagrangian function goes back to K. J. Arrow, L. Hurwicz and to H. Uzawa. They proposed a gradient-like vector field (AHU-flow) with a non-smooth component, an alternative vector field for saddle point problem is presented in this work. Like the AHU-flow, its trajectories are converging to the saddle point of the Lagrangian. However, this vector field has two distinct features. First, we prove that the flow also converges for linear programs, which is not the case for the AHU-flow, and second, the vector field is smooth which can be exploited in control theory to design distributed feedback laws for multi-agent systems. Furthermore, the convergence of a continuous-time Nesterov-like fast gradient variant is proved.

Roger Fletcher, Dundee University

On trust regions and projections for an SLCP algorithm for NLP

The speaker has recently developed a first derivative trust region filter algorithm for NLP (SIOPT Darmstadt 2011) based on successive linear constraint programming (SLCP) (Robinson’s method). Open source code is available through COIN-OR. Numerical evidence suggests that it is comparable in run time to the second derivative code filterSQP. An important feature of the code is the occasional use of projection steps to control feasibility violations, which can significantly improve the speed of (global) convergence on some highly nonlinear problems.

Discussions with other researchers have identified a possible area for improvement in that these projection steps take no account of the objective function value, in contrast say to second order correction (SOC) steps. The speaker has been investigating the possibility of replacing projection steps by additional LCP calculations. New insights is provided as to how a trust region might be designed to operate in an NLP context. Early indications are that significant gains in both speed and reliability may be possible, both in feasibility restoration and in finding local optimality. There are also indications for proving global convergence.

Jennifer Enway, Wake Forest University

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.

Hans Joachim Ferreau, KU Leuven [with Moritz Diehl, Rien Quirynen, Milan Vukonić]

The ACADO code generation tool for high-speed model predictive control and moving horizon estimation

Model predictive control (MPC) is an advanced feedback control strategy that predicts and optimises the future behaviour of a dynamic system in real-time. This requires full knowledge of the current system state, which typically needs to be estimated from noisy measurements, e.g., by means of moving horizon estimation (MHE). Both MPC and MHE require to solve a constrained, nonlinear optimisation problem in real-time, possibly on slow embedded hardware. The recently proposed ACADO Code Generation tool allows the user to automatically export linear real-time iteration algorithms that are customised based on a symbolic MPC/MHE problem formulation. This talk presents major algorithmic extensions of this tool: First, it now also handles dynamic systems described by differential algebraic equations. Second, not only explicit but also implicit Runge-Kutta integrators can be exported now. Third, auto-generated sparse quadratic programming solvers have been added for speeding-up solution in case of long prediction horizons. We illustrate the efficiency of the exported MPC/MHE algorithms by controlling small-scale but challenging nonlinear systems at sampling times of a few milliseconds.

Janick Frasch, Interdisciplinary Center for Scientific Computing (IWR), University of Heidelberg [with Hans-Georg Bock, Sebastian Sager, Leonard Wirsching]

Fast mixed-level iteration schemes for nonlinear model predictive control on multicore architectures

Nonlinear model predictive control (MPC) algorithms generally require the approximated solution of a nonlinear program (NLP) at each sampling time for feedback generation. Providing sufficiently high feedback rates therefore poses a major computational challenge for systems with fast dynamics. Recent approaches to overcome this challenge extend the multiple shooting-based real-time iteration scheme to multi-level iteration schemes. These algorithms generate feedback by repeatedly solving a quadratically program (QP), updating its data parts – constraint residuals, gradients, and Hessians and constraint Jacobians of the NLP – on three levels of increasing computational complexity. In this contribution we consider mixed-level updates of the QP data, which intervalwise apply different update levels. In particular we apply higher-level updates more frequently on the first intervals of the control horizon, given their importance in the MPC context. Targeting at modern computers with multi-core processing units, we describe an efficient parallel implementation of the mixed-level iteration approach and apply it to a benchmark problem from automotive engineering.

Moritz Diehl, KU Leuven [with Hans Joachim Ferreau, Attila Kozma]

Real-time optimization of large distributed systems

When large interconnected systems shall be optimally operated using model-based optimization, it is desirable to have parallelism in the used algorithms as well as decentralized decision making. As decentralized decision making with only vector exchanges leads to extremely slow linear or even sublinear convergence rates to the centrally optimal solution, we focus on parallelism with decentralized data storage, but coordinated decision making.

In particular, we discuss the distributed multiple shooting (DMS) method that allows one to decompose large-scale optimal control problems in both space and time and to completely parallelize the expensive function and derivative generation in shooting methods. Due to their superior warm starting capabilities in the real-time context, we focus on SQP type methods. Here, the SQP solution is the only part of the algorithm that is not trivial to distribute, and we discuss several strategies for distributed SQP solution and compare their convergence properties and warm starting capabilities.

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and Talbot. This study gives a new insight on this approach and yields original a posteriori estimates.

Elias 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 minimization bringing together $\epsilon$-subgradient algorithms and methods for the convex feasibility problem. This development is a natural step for $\epsilon$-subgradient methods in the direction of constrained optimization since the Euclidean projection frequently required in such methods is replaced by an approximate projection, which is often easier to compute. The developments are applied to incremental subgradient methods, resulting 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 presentation of several operators, both for the optimality step and for the feasibility step of the prototypical algorithm.

Jerome Fehrenbach, ITAV

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 efficient method to restore these images. A model of stationary noise is presented, 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 problem. The minimization is performed using a preconditioned primal-dual algorithm proposed by Chambolle and Pock in 2011. Our framework allows to take into account several components of noise, and the proposed approach can be extended to multivariate noise, above stripes and Gaussian white noise. 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 programs with general coherent risk measures

In this work we discuss the solution of multi-stage stochastic linear programs with general coherent risk measures, using sampling-based algorithms and a new dual dynamic programming (DDP) scheme. We describe a computational approach that changes the probability measure of the outcomes of next stage problems to compute the outer approximation of the future cost function (cuts in DDP). This provides a lower bound on the certainty-equivalent value of the optimal policy and requires little modification of conventional algorithms. 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 results 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 Girardeau, 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 Germany 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 an $\epsilon$-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 generation and transmission investments for the New Zealand electricity system.

Kangy Bastry, EDF R&D – OSRIS dept (with Ares Guillag, Aimad Lemor)

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 demand, 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 flexibility in building subproblems. We are going to present the algorithm and we are going to show how it behaves.
PDE-constrained opt. & multi-level/multi-grid meth.

Adaptive methods in PDE constrained optimization
Organizer/Chair: Stefan Ulbrich, TU Darmstadt - Invited Session

Winfried 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
\[
\min_{q \in \mathbb{R}^{2d}} J(u)
\]
subject to the constraints
\[
(q \sigma(\nabla u), \nabla \phi) = (l) \quad \forall \phi \in H^1_0(\Omega; \mathbb{R}^2),
\]
\[
0 < q_{\min} \leq q \leq q_{\max},
\]
where $H^1_0(\Omega; \mathbb{R}^2)$ denotes the usual $H^1$-Sobolev space with certain Dirichlet boundary conditions, and $\sigma(\nabla u)$ 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. Hinze, Y. Hishah)

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.

Teo.1.MA 015

Dynamic optimization and its applications
Organizer/Chair: Vinay Goyal, Columbia University - Invited Session

Dan Iancu, Stanford University (with Mayank Sharma, Maxim Srivindensko)

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 Nohadani, 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.

Teo.1.MA 004

Robust optimization

Dynamic optimization and its applications
Organizer/Chair: Vinay Goyal, Columbia University - Invited Session

Machine learning algorithms and implementations
Organizer/Chair: Mark Schmidt, École normale supérieure - Invited Session

Mark Schmidt, École normale supérieure (with Francis Bach, Michael Friedlander, Nicolas Le Roux)

Linearly-convergent stochastic gradient methods
This talk considers optimizing 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 insensitive 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 still achieves a linear convergence rate. Numerical experiments indicate that the new algorithms can dramatically outperform standard methods.

Sewoong Oh, MIT (with Shah Devavrat, Negabhan Sahand)

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 comparison 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.

Teo.1.MA 1028

Sparse optimization & compressed sensing

Methods of risk-averse optimization
Organizer/Chair: Andrzej Ruszczynski, Rutgers University - Invited Session

Csaba Fabian, Kecskemét College

Computational aspects of risk-averse optimization
We deal with solution methods for two-stage stochastic linear programming problems, with an emphasis on variants that include convex risk measures. We consider cutting-plane and bundle-type methods.

Teo.1.MA 141

Stochastic optimization

Organizer/Chair: Dan Iancu, Stanford University - Invited Session
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 Cao)
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, El Wotheagen)
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.

Organizer/Chair Laureano Escudero, Universidad Rey Juan Carlos - Invited Session
Stochastic optimization
Recent advances in risk representation
Organizer/Chair Erick Delage, HEC Montréal - Invited Session
Erick Delage, HEC Montréal (with Benjamin Armbruster)
Decision making under uncertainty when preference information is incomplete
We consider the problem of optimal decision making under un-
certainty but assume that the decision maker’s utility function is not
completely known. Instead, we consider all the utilities that meet some
criteria, such as preferring certain lotteries over certain other lotter-
ies and being risk averse, s-shaped, or prudent. This extends the no-
tion of stochastic dominance. We then give tractable formulations for
such decision making problems. We formulate them as robust util-
ity maximization problems, as optimization problems with stochastic
dominance constraints, and as robust certainty equivalent maximiza-
tion problems. We use a portfolio allocation problem to illustrate our
results.

Desislava Pachamanova, Babson College (with Cheknik Latow, Melony Sim)
Skewness-aware asset allocation: A new theoretical framework and
empirical evidence
This paper presents a new measure of skewness, skewness-aware
deviation, that can be linked to prospective satisfying risk measures
and tail risk measures such as Value-at-Risk. We show that this mea-
sure of skewness arises naturally also when one thinks of maximizing
the certainty equivalent for an investor with a negative exponential
utility function, thus bringing together the mean-risk, expected utility,
and prospective satisfying measures frameworks for an important class
of investor preferences. We generalize the idea of variance and covariance
in the new skewness-aware asset pricing and allocation framework. We
show via computational experiments that the proposed approach re-
sults in improved and intuitively appealing asset allocation when returns
follow real-world or simulated skewed distributions. We also suggest
a skewness-aware equivalent of the classical capital asset pricing model
beta, and study its consistency with the observed behavior of the stocks
traded at the NYSE between 1963 and 2006.

Chen Chen, Columbia University (with Guad Jangpar, Ciamac Moullemi)
An axiomatic approach to systemic risk
Systemic risk is an issue of great concern in modern financial mar-
kets as well as, more broadly, in the management of complex systems.
We propose an axiomatic framework for systemic risk. Our framework
allows for an independent specification of (1) a functional of the cross-
sectional profile of outcomes across agents in the system in a single
scenario of nature, and (2) a functional of the profile of aggregated out-
comes across scenarios of nature. This general class of systemic risk
measures captures many specific measures of systemic risk that have
recently been proposed as special cases, and highlights their implicit
assumptions. Moreover, the systemic risk measures that satisfy our
conditions yield decentralized decompositions, i.e., the systemic risk
can be decomposed into risk due to individual agents. Furthermore, one
can associate a shadow price for systemic risk to each agent that cor-
rectly accounts for the externalities of the agent’s individual decision-
making on the entire economy.

Organizer/Chair Laureano Escudero, Universidad Rey Juan Carlos - Invited Session
Stochastic optimization
Multistage stochastic mixed 0-1 optimization: Algorithms and
applications
Organizer/Chair Laureano Escudero, Universidad Rey Juan Carlos - Invited Session
Laizibon Orzuela, University of the Basque Country (with Laizibon Orzuela, Gloria Perez, Laureano
Escudero, Euge Maria Arozabe)
Scenario cluster Lagrangian decomposition
We introduce four scenario cluster based Lagrangian decomposi-
tion (CLD) procedures for obtaining strong lower bounds to the (optimal)
solution value of two-stage stochastic mixed 0-1 problems. At each it-
eration of the Lagrangian based procedures, the traditional aim consists
of obtaining the solution value of the corresponding Lagrangian dual via
solving scenario submodels once the nonanticipativity constraints have
been dualized. Instead of considering a splitting variable representation
over the set of scenarios, we propose to decompose the model into a set of scenario clusters. We compare the computational performance of
the subgradient method, the volume algorithm, the progressive hedging
algorithm and the dynamic constrained cutting plane scheme for differ-
ent numbers of scenario clusters. Our computational experience shows
that the CLD procedures outperform the traditional LD scheme for sin-
gle scenarios both in the quality of the bounds and computational effort.
Additionally, our CLD approach obtains very frequently the optimal so-
lution of the problem outperforming the plain use of a state-of-the art
MIP solver. An extensive computational experience is reported.

Laureano Escudero, Universidad Rey Juan Carlos (with Juan Monge, Dolores Romero-Morales)
Stochastic tactical supply chain management under uncertainty
The uncertainty in the supply tactical chain management (STSM) is
due to the stochasticity inherent in some parameters for dynamic (mul-
tiperiod) planning problems, mainly: product demand and demand loss,
production cost and resources availability, and it is treated via scenario
analysis. We present a modeling framework for solving the multiperiod
stochastic mixed 0-1 STSM problem. A scenario tree based scheme is
used to represent the parameters’ uncertainty and for designing the de-
terministic equivalent model (DEM) for risk management by implement-
ing the risk averse strategies based on scenario immunization, average
conditional value-at-risk and stochastic dominance constraints. Solving
the huge DEM instances is not affordable by using plain MIP solvers.
Instead of that, we present an extension of a stochastic dynamic pro-
gramming metaheuristic, by including the handling of constraints link-
ning variables from different scenarios and constraints that do have vari-
ables that do not belong to any specific scenario. Some computational
experience is reported.

María Garin, University of the Basque Country, UPV/EHU (with Laureano Escudero, María Menés, Gloria
Pérez)
A BFC-MS algorithm for solving multistage mixed 0-1 stochastic
problems with risk averse stochastic dominance constraints
In the context of stochastic optimization, the multistage mixed 0-1
deterministic equivalent models (DEM) use to be very large and difficult
to solve. So, the plain use of even MIP state-of-the art solvers for op-
timizing the related DEM requires an unaffordable computing effort or
simply cannot be solved. The alternative is to use decomposition meth-
ods of the full model in smaller MIP submodels. Moreover, the general
approach (so named risk neutral) has the inconvenience of providing a
solution that ignores the variance of the objective value of the scenarios,
and so, the occurrence of scenarios with an objective value below the
expected one. In this work we present the optimization of the objective
function expected value subject to stochastic dominance constraints for
a set of profiles. The price to pay is that the DEM becomes much bigger,
augmented by new variables and constraints. So, we present the intro-
duction of our BFC that consider nonsymmetric scenario trees, where a
special treatment is given to the constraint that link variables from
different scenarios.

Organizer/Chair Clemens Thielen, University of Kaiserslautern
Telecommunications & networks
Flow and path problems
Chair Clemens Thielen, University of Kaiserslautern
Clemens Thielen, University of Kaiserslautern (with Stephan Westphal)
Maximum flows with minimum quantities
We consider a variant of the maximum flow problem where the flow
on each arc in the network is restricted to be either zero or above a
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 general case. Main results show that the problem is weakly 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 \((2 - \frac{1}{e})\)-approximation algorithm for this case, where \(e\) denotes the common minimum quantity of all arcs.

Marco Senatore, University of Rome “Tor Vergata” [with David Adjushvili]

**The online replacement path problem**

We study a natural online 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 \(P^*\) for every edge \(e \in P\). 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. Considerably, the online replacement path problem, which asks to find a nominal \(s, t\)-path \(Q\) and detours \(Q_e\) for every edge \(e\) 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 \(O(m\log n)\) 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.

Joaquin Paulino Araujo, Pontificia Universidad Catoólica (PPUC-RIO) [with Pascal Berthomieu, Magdalena Dially, Fernanda Raupe]

**An algorithm for the multi-terminal maximum flow**

In this talk, two results for Riemannian manifolds with positive curvature. Finally, some results for Riemannian 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.

Laurentus Leustean, Simon Steinitz 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 Gládston Bento, 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 quasiconvex. 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 consider descent methods and the 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.
The last make possible to deduce lower bounds for the graphic TSP. – minmax theorems of these subjects transformed to linear program-spanning subgraph problem. The key ingredients are: and a fractional riccoststhatobeytriangleinequality. Boyd and Carrobservethatwedo
withlittleprogressmade in thirty years in the general case of symmet-
ration betweentheoptimalvaluesoftheTSPanditslinearprogramming
algorithmfor cubic graphs with approximation ratio \(\frac{3}{2}\). We prove that a fractional 2-matching has no cut edge, we can further prove that an optimal 2-matching is at most \(\frac{10}{9}\) times the cost of the fractional 2-matching.

András Sebő, CNRS, Grenoble-INP, U.P. (with Jens Vygen)
Shorter tours by nicer ears
I will sketch some ideas leading us to a 7/5-approximation algo-
rithm for the graphic TSP, a 3/2-approximation algorithm for the mini-
num connected T-join problem containing the graphic s – t-path TSP and a 4/3-approximation algorithm for the smallest 2-edge-connected spanning subgraph problem. The key ingredients are:
– a special kind of ear-decomposition using matching theory (theorems of Lovász and Frank),
– optimization of the used ear-decomposition using matroid intersec-
tion,
– minmax theorems of these subjects transformed to linear program-
ming weak duality.
The last make possible to deduce lower bounds for the graphic TSP. These are necessary for proving the approximation ratio and the inte-
grality gap of some associated linear programs.

Rodrigo Carrasco, Columbia University (with Garud Iyengar, Cliff Stein)
Experimental results of approximation algorithms for energy aware scheduling
The increasing awareness of the environmental impact of massive data centres has led to an increased interest in energy management algorithms. We have developed several new constant factor approxi-
imation algorithms for energy aware scheduling problems. The objec-
tive is to minimize the sum of the total energy consumed and the total weighted completion time or the total weighted tardiness in the one ma-
iche non-preemptive setting, allowing for arbitrary precedence con-
straints and also release dates for the weighted completion time. Unlike previous known algorithms our new algorithms can handle general job-
dependent energy cost functions extending their application to settings that have maintenance costs, wear and tear, replacement costs, etc., which in general also depend on the particular job being processed. In this work we seek to understand the practical performance of these algorithms. We show that the practical performance is significantly su-
prior to the theoretical bounds and in fact are very close to optimal. Addi-
tionally, we present heuristic improvements and we also investigate their performance in other settings: online, total weighted flow time, multiple machines, etc.

Eeyeifur Agerfason, Reykjavik University (with Pradip Mita)
Performance of distributed game theoretic algorithms for single slot scheduling in wireless networks
We consider the capacity problem in wireless networks where the
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 maxi-

mization introduced by Andrews and Dinitz, where the key to the approx-
imation is 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 \(O(\log \Delta)\) 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 dis-
tributed 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 person-
nel 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 algo-
rithm is a \(O(1)\)-speed algorithm for computing a bicriteria solution. We prove our computational results demonstrating how our model can be used to both assess scheduling decisions as well as help guide planning.

Organizers/Chairs Sylvia Boyd, University of Ottawa; David Shmoys, Cornell University. Invited Session
Travelling salesman problem I
Anke van Zuylen, Max Planck Institute for Informatics (with Frans Schalekamp, David Williamson)
A proof of the Boyd–Carr conjecture
Determining the precise integrality gap for the subtour LP relaxation of the traveling salesman problem is a significant open question, with little progress made in thirty years in the general case of symmetric costs that obey triangle inequality. Boyd and Carr observe that we do not even know the worst-case upper bound on the ratio of the optimal 2-matching to the subtour LP, they conjecture the ratio is at most \(\frac{3}{2}\).
In this paper, we prove the Boyd–Carr conjecture. In the case that a fractional 2-matching has no cut edge, we can further prove that an optimal 2-matching is at most \(\frac{10}{9}\) times the cost of the fractional 2-matching.

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 man-
ner, 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 decompression, 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, sur-
viving what is known in the area.

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 tech-
nique relies on a clever linear extended formulation for the two-
dimensional regular \(2^{\Delta}\)-gon. Since these polytopes approximate the two-
dimensional disc, polyhedral approximations for any second-order cone optimization problem can be derived. These approximations are com-
 pact in the sense that they feature a number of vertices that is expo-
nential 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 con-
struction features links with cyclic polytopes and the trigonometric mo-
moment curve. We also report on numerical experiments demonstrating usefulness of this technique.
Combinatorial optimization

**Tue.2.H 3005**

**Lift-and-project methods for combinatorial optimization problems**
Organizer/Chair Konstantinos Georgiou, University of Waterloo - Limited Session

Eden Chlamtac, Tel Aviv University

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 it approximates — 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 Ewine 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.

Madhu Sudan, Toyota Technological Institute at Chicago

**Tue.2.H 3008**

**Combinatorics and geometry of linear optimization I**
Organizers/Chairs Antoine Deza, McMaster University; Jesus 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 43 (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 5 can not lead to non-Hirsch polytopes, and S.-Matthieke-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 Hållgren, suggested by the work of Eisenbrand et al. in the abstract setting of "connected layer sequences" would imply that $nf$ is an upper bound.

Niccolò Romito, 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 greatest 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 its 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 $d(a-1)$ 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.

Yury Zinchenko, University of Calgary (with Antoine Deza, Tamas 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 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.

**Tue.2.H 3012**

Algorithms for transistor-level layout
Organizer/Chair Stefan Hougardy, University of Bonn - Limited Session

Tim Nieberg, University of Bonn (with Stefan Hougardy, Jan Schneider)

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.

**Tue.2.H 3013**

Matching and related problems
Organizer/Chair Gyula Pap, Eötvös University - Limited Session

Kristóf Bérczi, Eötvös Research Group, Eötvös Loránd University, Budapest

Restricted $\Delta$-matchings

A $C_4$-free 2-factor is a 2-factor not containing cycles of length at most 4. Cornuéjols and Pulleyblank showed that deciding the existence of such a subgraph is NP-complete for $\Delta \geq 5$. On the other hand, Hartvigsen proposed an algorithm for the triangle-free case ($\Delta = 3$). The existence of a $C_4$-free or $C_3$-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.
Considering the maximum weight version of the problems, there is a firm difference between triangle- and square-free 2-factors. Király showed that finding a maximum weight square-free 2-factor is NP-complete even in bipartite graphs with 0 – 1 weights. On the other hand, for subcubic graphs, polynomial-time algorithms were given by Hartvigsen and Li, and recently by Kobayashi for the weighted $C_3$-free 2-factor problem with an arbitrary weight function. The former result implies that we should not expect a nice polynomial description of the square-free 2-factor polytope. However, the latter suggests that the triangle-free case may be solvable.

Kenjiro Takazawa, RIMS and G-SCOP (with Sylwia Boyd, Satoru Iwata)

Covering cuts in bridgeless cubic graphs

In this talk we are interested in algorithms for finding 2-factors that are certain edge-cuts in bridgeless cubic graphs. We present an algorithm for finding a minimum-weight 2-factor covering all the 3-edge cuts in weighted bridgeless cubic graphs, together with a polyhedral description of such 2-factors and that of perfect matchings intersecting all the 3-edge cuts in exactly one edge. We further give an algorithm for finding a 2-factor covering all the 3- and 4-edge cuts in bridgeless cubic graphs. Both of these algorithms run in $O(n^3)$ time, where $n$ is the number of vertices.

As an application of the latter algorithm, we design a 6/5-approximation algorithm for finding a minimum 2-edge-connected subgraph in 3-edge-connected cubic graphs, which improves upon the previous best ratio of 5/4. The algorithm begins with finding a 2-factor covering all 3- and 4-edge cuts, which is the bottleneck in terms of complexity, and thus it has running time $O(n^3)$. We then improve this time complexity to $O(n^2 \log^4 n)$ by relaxing the condition of the initial 2-factor and elaborating the subsequent processes.

David Hartvigsen, University of Notre Dame (with Yuan Li)

A generalized sorting problem

A simple $k$-matching in a graph is a subgraph all of whose nodes have degree at most $k$. The problem of finding a simple $k$-matching with a maximum number of edges is well studied and results include a maximum theorem and polynomial-time algorithm. A simple $k$-matching is called $j$-restricted if each connected component has more than $j$ edges. In this talk we consider the problem of finding $j$-restricted simple $k$-matchings that have a maximum number of edges. We present a maximum theorem and polynomial-time algorithm when $j < k$. Previous work on this problem considers the special case $j = k = 2$.

Combinatorial optimization

Sampling, sorting and graph traversal: Algorithms for finding permutations

Organizer/Chair: Alantha Newman, DIMACS - Invited Session

Zhiyi Huang, University of Pennsylvania (with Sampath Kannan, Sanjeev Khanna)

Algorithms for the generalized sorting problem

We study the generalized sorting problem where we are given a set of $n$ elements to be sorted but only a subset of all possible pairwise element comparisons is allowed. The goal is to determine the sorted order using the smallest possible number of allowed comparisons. The generalized sorting problem may be equivalently viewed as follows. Given an undirected graph $G = (V, E)$ where $V$ is the set of elements to be sorted and $E$ defines the set of allowed comparisons, adaptively find the smallest subset $E' \subseteq E$ of edges to probe so that the graph induced by $E'$ contains a Hamiltonian path. When $G$ is a complete graph, it is the standard sorting problem. Another well-studied case is the nuts and bolts problem where the allowed comparison graph is a complete bipartite graph between two equal-size sets. For these cases, it is known there are deterministic sorting algorithms using $O(n \log n)$ comparisons. However, when the allowed comparison graph is arbitrary, no bound better than the trivial $O(n^2)$ one was known. Our main result is a randomized algorithm that sorts any allowed comparison graph using $O(n^{3/2})$ comparisons with high probability.

Sarah Matzke, Georgia Institute of Technology (with Prateek Bhakta, Dana Randall, Amanda Streib)

Mixing times of self-organizing lists and biased permutations

Sampling permutations from $S_n$ is a fundamental problem from probability theory. The nearest neighbor transposition chain is known to mix in time $O(n \log n)$ in the unbiased case and time $O(n^2)$ in the constant bias case. It was conjectured that the chain is always rapidly mixing when the weights assigned to the edges are positively biased, i.e., we put nearest neighbor pair $x < y$ in order with bias $1/2 \leq p_{xy} \leq 1$ and out of order with bias $1 - p_{xy}$. We prove the chain is rapidly mixing for two classes: "Choose Your Weapon," where we are given $r_1, \ldots, r_n$ with $r_i \geq 1/2$ and $p_{xy} = r_i$ for all $x < y$ (the dominant player chooses the game, thus fixing their probability of winning), and "League hierarchies," where there are two leagues and players from the A-league have a fixed probability of beating players from the B-league, players within each league are divided into sub-leagues, and so forth recursively. Moreover, we also prove that the conjecture is false by exhibiting values for the $p_{xy}$ with $1/2 \leq p_{xy} \leq 1$ for all $x < y$, but for which the chain will require exponential time to converge.

Katarzyna Paluch, Institute of Computer Science, University of Wroclaw (with Khaled Elbassioni, Anke van Zuylen)

Simpler approximation of the maximum asymmetric traveling salesman problem

We give a very simple approximation algorithm for the maximum asymmetric traveling salesman problem. The approximation guarantee of our algorithm is $2/3$, which matches the best known approximation guarantee by Kaplan, Lewenstein, Shafir and Srividenko. Our algorithm is simple to analyze, and contrary to previous approaches, which need an optimal solution to a linear program, our algorithm is combinatorial and only uses maximum weight perfect matching algorithm.

Complementarity & variational inequalities

MPECs in function space I

Organizers/Chairs: Michael Hintermüller, Humboldt-Universität zu Berlin; Christian Meyer, TU Dortmund - Invited Session

Daniele Wachsmuth, Universität Würzburg (with Karl Kunisch, Anton Schiela)

Convergence analysis of smoothing methods for optimal control of stationary variational inequalities

In the talk an optimal control problem subject to a stationary variational inequality is investigated. The optimal control problem is complemented with pointwise control constraints. The convergence of a smoothing scheme is analyzed. There, the variational inequality is replaced by a semilinear elliptic equation. It is shown that solutions of the regularized optimal control problem converge to solutions of the original one. Passing to the limit in the optimality system of the regularized problem allows to prove $C$-stationarity of local solutions of the original problem. Moreover, convergence rates with respect to the regularization parameter for the error in the control are obtained. These rates coincide with rates obtained by numerical experiments.

Thomas Summaec, Humboldt University of Berlin (with Michael Hintermüller)

A PDE-constrained generalized Nash equilibrium problem with pointwise control and state constraints

We formulate a class of generalized Nash equilibrium problems (GNEP) in which the feasible sets of each player’s game are partially governed by the solutions of a linear elliptic partial differential equation (PDE). In addition, the controls (strategies) of each player are assumed to be bounded pointwise almost everywhere and the state of the entire system (the solution of the PDE) must satisfy a unilateral lower bound pointwise almost everywhere. Under certain regularity assumptions on the constraint qualifications, we prove the existence of a pure strategy Nash equilibrium. After deriving multiplier-based necessary and sufficient optimality conditions for an equilibrium, we develop a numerical method based on a non-linear Gauss-Seidel iteration, in which each respective player’s game is solved via a nonsmooth Newton step. Convergence of stationary points is demonstrated and the theoretical results are illustrated by numerical experiments.

Carlos Rautenberg, Karl-Franzens-University of Graz (with Michael Hintermüller)

Hyperbolic quasi-variational inequalities with gradient-type constraints

The paper addresses a class of hyperbolic quasi-variational inequality (QVI) problems of first order and with constraints of the gradient-type. We study existence and approximation of solutions based on recent results of appropriate parabolic regularization, monotone operator theory and $C_0$-semigroup methods. Numerical tests, where the subproblems are solved using semismooth Newton methods, with several nonlinear constraints are provided.

Conic programming

Advances in convex optimization

Organizer/Chair: Juan Peña, Carnegie Mellon University - Invited Session

Luís Zuluaga, Lehigh University (with Juan Peña, Juan Vera)

Positive polynomials on unbounded domains

Certificates of non-negativity are fundamental tools in optimization. A “certificate” is generally understood as an expression that makes the
non-negativity of the function in question evident. Recently, sum-of-squares certificates of non-negativity for polynomials have been used to obtain powerful numerical techniques for solving polynomial optimization problems; in particular, for mixed integer programs, and non-convex binary programs. We present a new certificate of non-negativity for polynomials over the intersection of a closed set S and the zero set of a given polynomial h(x). The certificate is written in terms of the set of non-negative polynomials over S and the ideal generated by h(x). Our certificate of non-negativity yields a cooptimistic programming reformulation for a very general class of polynomial optimization problems.

Martin Lozt, 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 can be found or approximated efficiently can often be cast in terms of a convex feasibility problem. In particular, condition numbers introduced for the complexity analysis of convex optimization problems play an important role in the analysis of such problems. We present results and geometric methods from the probabilistic analysis of condition numbers for optimization problems, and indicate how this analysis can be used to obtain sparse and simple recovery thresholds for problems with noise.

Javier Pena, Carnegie Mellon University (with Negr Sobeil)

A smooth primal-dual perceptron-von Neumann algorithm

We propose an elementary algorithm for solving a system of linear inequalities $A^\top y > 0$ or its alternative $Ax \geq 0, x \neq 0$. Our algorithm is a smooth version of the perceptron and von Neumann’s algorithms. Our algorithm retains the simplicity of these algorithms but has a significantly improved convergence rate.

Tue 2.20 1308

Applications of semidefinite programming

Organizer/Chair Etienne de Klerk, Tilburg University - Invited Session

Amir Ali Ahmadi, MIT (with Raphael Jungers, Pablo Parrilo, Mardarv Razdohbani)

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 path-complete graph Lyapunov functions which produces several hierarchies of asymptotically exact semidefinite programming relaxations with provable approximation guarantees. Our algorithms are based on new connections between ideas from control theory and the theory of finite automata.

Uwe Tutuutsch, Tilburg University (with Etienne de Klerk, Renata Sotirov)

A “smart” choice of relaxation for the quadratic assignment problem within a branch-and-bound framework

The practical approach to calculate an exact solution for a quadratic assignment problem (QAP) via a branch-and-bound framework depends strongly on a “smart” choice of different strategies within the framework, for example the branching strategy, heuristics for the upper bound or relaxations for the lower bound. In this work, we compare different relaxations from the literature, in particular two promising semidefinite programming relaxations introduced by Zhao, Karisch, Rendl, and Wolkowicz, and by Peng, Zhu, Luo and Toh respectively. The aim of our work is to generate and present a size-dependent choice of an appropriate relaxation that can be successfully used at a given node within a branch-and-bound framework.

Xuan Viet Doan, University of Warwick (with Stephen Vavasis)

Feature extraction and data clustering with SDP-representable norms

We propose a convex optimization formulation with some SDP-representable norms to find approximately rank-one submatrices of a given nonnegative matrix. It has several applications in data mining, which includes feature extraction and data clustering. We develop a first-order method to solve the proposed optimization problem and report some promising numerical results.

Tue 2.20 3083

CP hybrids for scheduling

Organizer/Chair Chris Beck, University of Toronto - Invited Session

Michele Lombardi, University of Bologna (with Andrea Bartolini, Luca Benini, Michela Milano)

Hybrid off-line/online workload scheduling via machine learning and constraint programming

Advances in combinatorial optimization in the last decades have enabled their successful application to an extensive number of industrial problems. Nevertheless, many real-world domains are still impervious to approaches such as constraint programming (CP), mathematical programming or metaheuristics. In many cases, the difficulties stem from problems in formulating an accurate declarative model of the system to be optimized. This is typically the case for systems under the control of an on-line policy: even when the basic rules governing the controller are well known, capturing its behavior in a declarative model is often impossible by conventional means. Such a difficulty is at the root of the classical, sharp separation between off-line and on-line approaches.

In this work, we investigate a general method to combine off-line and on-line optimization, based on the integration of machine learning and combinatorial optimization technology. Specifically, we use an artificial neural network (ANN) to learn the behavior of a controlled system and plug it into a CP model by means of so-called neuron constraints.

Chris Beck, University of Toronto (with Tung Tran, Ken-Yoo Koo, Jean-Paul Watson)

Loosely coupled hybrids: Tabu search, constraint programming and mixed integer programming for job shop scheduling

Since their introduction, metaheuristic algorithms have consistently represented the state of the art in solution techniques for the classical job-shop scheduling problem. This dominance is despite the availability of powerful search and inference techniques for scheduling problems developed by the constraint programming (CP) community and substantial increase in the power of commercial mixed integer programming (MIP) solvers. Building on observations of the performance characteristics of metaheuristic, CP, and MIP solvers, we investigate simple, loosely coupled hybrid algorithms for job-shop scheduling. Our hypothesis is that the fast, broad search capabilities of modern tabu search algorithms are able to very quickly converge on a set of very good, but likely sub-optimal, solutions. CP or MIP can then be seeded with these solutions to improve them and search for optimality proofs.

Thibaut Feydy, NICTA (with Andreas Schutt, Peter Stuckey)

Lazy clause generation for RCSPSP

Lazy clause generation (LCG) is a recent generic method for solving constraint problems. LCG solvers integrate tightly finite domain propagation (FD) with the conflict analysis features of Boolean satisfaction (SAT) solvers. This technology is often of order of magnitudes faster than traditional finite domain propagation on some hard combinatorial problems. In particular, we have used methods based on lazy clause generation to solve the resource constrained project scheduling problem (RCSPSP) as well as the more general resource constrained project scheduling problem with generalized precedence relations (RCSPSP-Max). These scheduling models have applications areas such as project management and production planning. Our experiments show the benefit of lazy clause generation for finding an optimal solution and proving its optimality in comparison to other state-of-the-art exact and non-exact methods. Our methods is able to find better solution faster on hard RCSPSP and RCSPSP-Max benchmarks. We were able to close many open problem instances and generates better solutions in most of the remaining instances.

Thu 2.20 3523

New techniques for optimization without derivatives

Organizers/Chairs Stefan Wild, Argonne National Laboratory; Luis Nunes Vicente, University of Coimbra - Invited Session

Margaret Wright, Courant Institute of Mathematical Sciences

Defining non-monomone derivative-free methods

Non-monomone strategies in optimization avoid imposing a monotonicity requirement at every iteration with the goal of achieving rapid convergence from an alternate descent strategy over a longer sequence of approximations. We consider how to define non-monomone derivative-free methods with, broadly, this same spirit, especially in light of recent worst-case complexity results that are closely tied to monotonicity requirements.

Genetha Gray, Sanadi National Labs (with Ethan Chan, John Gunther, Herbee Lee, John Sirola)

Calculating and using sensitivity information during derivative-free optimization routines

The incorporation of uncertainty quantification (UQ) into optimiza-
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 accuracy is then a crucial component in robust optimization. An uncertainty set is formed to define the region 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.

Satyajit 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 test the performance of algorithms for 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.

Qihan 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.

Somayeh Moazeni, 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. In this paper, issues of uncertainty in the price impact parameters in the optimal portfolio 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 the approach, the uncertainty set is regularized through a regularization constraint. The regularized robust solution is then more stable with respect to variations 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.

Laurent Sourav, CMRS (with Bruno Escoffier, Jerome Monnot)
On the price of anarchy of the set cover game

Given a collection \( C \) of weighted subsets of a ground set \( E \), the set cover problem is to find a minimum weight subset of \( C \) which covers all elements of \( E \). We study a strategic game defined upon this classical optimization problem. Every element of \( E \) is a player which chooses one set of \( C \) where it appears. Following a public tax function, every player is charged a fraction of the weight of the set that it has selected. Our motivation is to design a tax function having the following features: it can be implemented in a distributed manner, existence of an equilibrium is guaranteed and the social cost for these equilibria is minimized.

Rudolf Müller, Maastricht University (with Birgit Heydenreich, Marc Uetz)
Mechanism design for decentralized online machine scheduling

Traditional optimization models assume a central decision maker who optimizes a global system performance measure. However, problem data is often distributed among several agents, and agents take autonomous decisions. This gives incentives for strategic behavior of agents, possibly leading to sub-optimal system performance. Furthermore, in dynamic environments, machines are locally dispersed and administratively independent. We investigate such issues for a parallel machine scheduling model where jobs arrive online over time. Instead of centrally assigning jobs to machines, each machine implements a local sequencing rule and jobs decide for machines themselves. In this context, we introduce the concept of a myopic best response equilibrium, a concept weaker than the classical dominant strategy equilibrium, but appropriate for online problems. Our main result is a polynomial time, online mechanism that – assuming rational behavior of jobs – results in an equilibrium schedule that is \( 3.281 \)-competitive with respect to the maximal social welfare. This is only slightly worse than state-of-the-art algorithms with central coordination.

Martin Gairing, University of Liverpool (with Giorgos Christodoulopoulos)
Coordination mechanisms for congestion games

In a congestion game, we are given a set of resources and each player selects a subset of them (e.g., a path in a network). Each resource has a univariate cost (or utility) function that only depends on the load induced by the players that use it. Each player aspires to minimise (maximise) the sum of the resource costs (utilities) in its strategy given the strategies chosen by the other players. Congestion games have played a starring role in recent research on quantifying the inefficiency of game theoretic equilibria. Most of this research focused on the price of anarchy. In this talk, we will discuss coordination mechanisms for congestion games. That is, we study how much we can improve the price of anarchy by certain local modifications to the resource cost/utility functions. We will also discuss when such modifications yield polynomial-time convergence of best-reply dynamics.

Somayeh Moazeni, Princeton University (with Thomas Coleman, Yuying Li)
A comparison of software and algorithms in unconstrained simulation optimization problems
laxation, hereby reducing the computational effort for the solution of the relaxations during the branch and bound process.

Ferenc Domes, CNRS/LINA UMR 6141 (with Alexandre Goldsztejn)
Finding global robust solutions of robust quadratic 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 Marrokt, 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 if 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 GlopLab.

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, Thibault Feydy, Julien Fischer, Maria Garcia de la Randa, 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 Z, 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.

Tue.2.N 2013

Advances in mixed integer programming
Organizer/Chaired Andra Lodi, University of Bologna - Invited Session
Alejandro Toriello, University of Southern California
Optimal toll design: A lower bound framework for the traveling salesman problem

We propose a framework of lower bounds for the asymmetric traveling salesman problem based on approximating the dynamic programming formulation, and give an economic interpretation wherein the salesman must pay tolls as he travels between cities. We then introduce an exact reformulation that generates a family of successively tighter lower bounds, all solvable in polynomial time, and compare these new bounds to the well-known Held-Karp bound.

Minjiao Zhang, The Ohio State University (with Simge Kucukyavuz)
Cardinality-constrained continuous mixing set

We study the polyhedron of continuous mixing set with a cardinality constraint (CMC), which arises as a substructure of a dynamic decision-making problem under a joint chance constraint. We give valid inequalities and alternative extended formulations for CMC. We develop a branch-and-cut algorithm and test it on a dynamic lot-sizing problem with stochastic demand in which a specific service level must be met over the finite planning horizon. Our computational experience shows that the branch-and-cut algorithm is effective in solving the probabilistic dynamic lot-sizing problems with a moderate number of scenarios.

Ricardo Fukasawa, University of Waterloo (with Ahmad Ali)
New inequalities for mixing sets arising in chance constrained programming

Luuk de et al (2010) and Kucukyavuz (2010) study a mixing set arising when reformulating chance-constrained programs with joint probabilistic constraints in which the right-hand-side vector is random with a finite discrete distribution. These two papers introduce facet-defining inequalities for the convex hull of such sets, like the strengthened star inequalities and the (T, II) inequalities. We present a new class of inequalities that generalizes all these previously derived inequalities (both for the equal and unequal probabilities case).

Die He, Georgia Tech & Yale (with Shabbir Ahmed, George Nemhauser)
Minimum concave cost network flow over a grid network

The minimum concave cost network flow problem (MCCNFP) is NP-hard, but efficient polynomial-time algorithms exist for some special cases, such as the uncapacitated multi-echelon lot-sizing problem. We consider the computational complexity of MCCNFP as a function of the underlying network topology and the representation of the concave
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 inflow of any node for all extreme points, which generalizes Zangwill’s result for the multi-echelon lot-sizing problem.

Tamtam Kus, MTA SZTAKI

**Strengthenting 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 consider 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 (MRKP) 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 $\mathcal{NP}$. In addition, even computing the regret of a solution with respect to a scenario requires the solution of an $\mathcal{NP}$-hard problem. We examine the behavior of classical combinatorial optimization approaches when adapted to the solution of the MRKP. We introduce an iterated local search approach and a Lagrangian-based branch-and-cut algorithm, and evaluate their performance through extensive computational experiments.

Johannes Köster, University 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 encoding 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 hypernetworks, rather than in networks, allows to better infer also the functional necessity and synthetic lethality of proteins in yeast.

Gunnar Klau, CWI (with Stefan Canzar, Mohammed El-Kebir, Khalid Elbassioni, Daan Geerke, Alpesh Malde, Alan Mark, Rend Pooi, Leen Stougie)

**Charge group partitioning in biomolecular simulation**

Molecular simulation techniques are increasingly being used to study biomolecular systems at an atomic level. Such simulations rely on empirical force fields to represent the intermolecular 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 encoding 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 hypernetworks, rather than in networks, allows to better infer also the functional necessity and synthetic lethality of proteins in yeast.

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 $\mathcal{NP}$-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 Uwe 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 strategic 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.

Vinicius 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.

Hiroaki Mohri, Waseda University

**Some extended network hub problems**

Network hub (location) problems (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 conditionals independently.

(i) Network flow capacity on each arc.
(ii) The number of hubs should not be fixed a constant $p$. (No constraints. Otherwise, inequality constraints.)
(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.
An integrated approach to tactical logistics network optimization

In global logistics operations, tactic planning aims at laying the groundwork for cost-efficient day-to-day operation by deciding on transport routes, and delivery frequencies between facilities in the network. We consider a fixed charge multi-commodity network flow model to optimize supply chains on the tactical level, that is, the infrastructure is already in place and we seek cost optimal transport and storage modes. Model characteristics include a frequency pattern expansion to capture the tradeoff between inventory costs and economies of scale for transport costs, as well as multi-commodity flow properties and complex tariff structures. We devise local search type and combinatorial heuristics that can be combined with mixed integer programming techniques. To evaluate the quality of these approaches we present a computational study on a set of large-scale real-world instances provided by our industrial cooperation partner. The model and the obtained results are part of the MultiTrans project, a cooperation between the COGA group at TU Berlin and 4fIow AG, a market leader in logistics and supply chain management consulting.

Cyclic routing of unmanned aerial vehicles

Developing autonomous monitoring systems for Unmanned Aerial Vehicles (UAVs) to facilitate scanning and monitoring a set of targets on the ground is of growing interest in security applications. These monitoring systems have to support complex tasks that include multiple UAVs that should scan and monitor multiple distant predefined targets, with a known distance matrix, in cyclic routes. Each target is associated with a temporal constraint, namely, a relative deadline, that is, the maximum permitted time interval between two successive scanning of the target. Our aim is to determine the minimum number of UAVs required for suitable cyclic route that visits, under the temporal constraints all targets. We formulate the problem as MILP and as Satisfiability Modulo Theories (SMT) problem. We use several solution methods, such as Mosek, Z3 and DFS and demonstrate their numerical results.

Optimal control of battery switching stations

We introduce a new on-line scheduling problem motivated by the business model of Better Place Ltd. The company sells electric vehicles (EV) with replaceable lithium ion batteries and provides battery replacement services in Battery Switching Station (BSS). The BSS Scheduling Problem is defined as follows: a stream of requests for battery switches to be fulfilled is governed by a known, non-homogenous, stochastic process. The disassembled batteries are recharged and used to fulfill future requests. Partly charged batteries can be supplied at a penalty cost that depends on their charging level. The charging duration and power consumption during the process varies depending on the battery and charging technologies. The cost of electricity and the maximum allowed power consumption varies during the planning horizon. The operational goal is to establish a charging policy so as to minimize the expected total electricity and penalty costs. We develop an on-line heuristic for the BSS problem, based on an efficient algorithm for a deterministic version of this problem, and demonstrate its efficiency by an extensive numeric experiment in a realistic setting.

Interactive multiobjective optimization

The talk considers a multi-objective generalization of the inventory routing problem, a problem arising in transportation/the physical distribution 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 the use of metaheuristics, and numerical results are compared and reported. Particular emphasis has been placed 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.

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 directly search for Pareto optimal solutions. 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 search for interesting regions in the objective space. More specifically, the new interactive method can conveniently exploit the convexity of the Pareto optimal set and thus find better solutions in the neighborhood of a given reference point.
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 Dirickx, Fraunhofer IFW

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 remeasuring of a ship's defect, selecting, assimilating 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 decision graphs, applicable by non-experts, too. Both tools are combined in a web portal.

Nonlinear programming

Methods for nonlinear optimization V

Chair Marco Ruzic, Helmut-Schmidt-University Hamburg

Manuel Jaraczewski, Helmut-Schmidt-Universität - Universität der Bundeswehr Hamburg (with Marco Ruzic, 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, for 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 Ruzic, 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 was used 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 analyze 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 (control) and that the key ideas of the presented results can be extended to the linearization of the full coupled problem.

Anders Forsgren, KTH Royal Institute of Technology

Inexact Newton methods with applications to interior methods

Newton’s method is a classical method for solving a nonlinear equation. We discuss how Jacobian information may be reused without sacrificing the asymptotic rate of convergence of Newton’s method. In particular, we discuss how inexact Newton methods might be used in the context of interior methods for linear and convex quadratic programming.

Wenwen Zhou, SAS Institute Inc. (with Joshua Griffin)

Numerical experience of a primal-dual active set method and its improvement

SAS has recently developed and implemented a multi-threaded Krylov-based active set method based on the exact primal dual augmented Lagrangian merit function of P. E. Gill and D. Robinson [1] for large-scale nonconvex optimization. The merit function has several attractive properties, including a dual regularization term that effectively relaxes restrictions for what preconditioner types can be used with the corresponding Newton equations. Numerical experience and strategies for improving convergence for this approach will be reported in this talk.


Nonlinear programming

Real-time optimization II

Organizers/Chairs Victor Zavala, Argonne National Laboratory; Sebastian Sager, Universität Magdeburg

Mihai Anitescu, Argonne National Laboratory (with Victor Zavala)

Scalable dynamic optimization

In this talk, we discuss scalability issues arising in dynamic optimization problems such as model predictive control and data assimilation. We present potential strategies to avoid them, where we focus on scalable algorithms for methods that track the optimal manifold with even one quadratic program per step. This builds on recent work of the authors where we proved using a generalized equations framework that such methods stabilize model predictive control formulation even when they have explicit inequality constraints. In particular, we present alternatives to fast active-set detection and matrix-free implementations.

Christian Kirchen, University of Chicago / University of Heidelberg (with Hans-Georg Bock, Sebastian Sager)

A real-time iteration scheme for mixed-integer nonlinear model predictive control

A class of nonlinear model predictive control problems with both continuous and binary controls is considered. Partial outer convexification and relaxation is used to obtain a continuous model predictive control problem with possibly increased control dimension. The problem can then be solved by combining a direct method for optimal control with a rounding scheme. Feasibility and optimality certificates hold, while numerical computations typically do not involve an exponential runtime effort. It is argued that the idea of real-time iterations proposed by Diehl et al. can be used to devise a new mixed-integer real-time iteration scheme for this problem class. To this end, it is shown that adding a rounding step to one iteration of the scheme can be interpreted as carrying out a step of an perturbed Newton-type method. Sufficient conditions for local contractivity of such a perturbed method are derived. Based on this local contractivity argument, a proof of locally
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 Mats Jadrant, Yu Dong 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 joint chance constraints. A tailored interior point method is proposed to explore the special structure of the resulting SMPC problem computing the input sequence and the risk allocation. In 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 every 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.

Primal convergence from dual subgradient methods for convex optimization

Emil Gustavsson, Chalmers University of Technology (with Michael Patriksson, Ann-Brith Strömberg) Nonsmooth optimization methods

Some methods for solving perturbed variational inclusions

This paper deals with variational inclusions of the form \( 0 \in (f(x) + g(x) + F(x)) \) where \( f \) is a Fréchet differentiable function, \( g \) is a Lipschitz function and \( F \) is a set-valued function in \( \mathbb{R}^n \).

In a first time in this talk, we recall some existing results in relation with metric regularity. In a second time, we focus on the case where the set valued map \( F \) is a cone and in this case we introduce different algorithms to approximate a solution \( x^* \) of the variational inclusion. Different situations are considered: the case where \( g \) is smooth, the case where \( g \) is semi-smooth (existence of differences divided, ...), and the case where \( g \) is only Lipschitz. We show the convergence of these algorithms without the metric regularity assumption.

Christopher Hendrich, Chemnitz University of Technology (with Ratu Bar) A double smoothing technique for solving nondifferentiable convex optimization problems

The aim of this talk is to develop an efficient algorithm for solving a class of unconstrained nondifferentiable convex optimization problems. To this end we formulate first its Fenchel dual problem and regularize it in two steps into a differentiable strongly convex one with Lipschitz continuous gradient. The doubly regularized dual problem is then solved via a fast gradient method with the aim of accelerating the resulting convergence scheme.

Emil Gustavsson, Chalmers University of Technology (with Michael Patriksson, Ann-Brith Strömberg) Primal convergence from dual subgradient methods for convex optimization

When solving a convex optimization problem through a Lagrangian dual reformulation, subgradient optimization methods are favourably utilized, since they often find near-optimal dual solutions quickly. However, an optimal primal solution is generally not obtained directly through such a subgradient approach. We construct a sequence of convex combinations of primal subproblem solutions, a so-called ergodic sequence, which is shown to converge to an optimal primal solution when the convexity weights are appropriately chosen. We generalize previous convergence results from linear to convex optimization and present a new set of rules for constructing the convexity weights defining the ergodic sequence of primal solutions. In contrast to previous approaches, we exploit more information from later subproblem solutions than from earlier ones. We evaluate the proposed rules on a set of nonlinear multicommodity flow problems and demonstrate that they clearly outperform the previously proposed ones.

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.

Boris Defourcy, Princeton University (with Ethan Fang, Warren Powell, Hugo Simao) 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 approximating 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 newsboy-type problems where the overage and underage costs of wind energy forecasts have to be estimated, given a day-ahead schedule.

Oscar Carrera, XM S.A.E.S.P (with Jaime Castillo, Carlos Correa) Developing optimization software for Colombian power system planning

Motivated by the liberalization process of electricity markets led by Chile in 1982 and followed by England and Wales in 1990 and Norway in 1991, Colombia restructured its electricity industry in 1995 evolving to a novel electricity market in the region based on price offers. From then until now, several market rules have changed and evolved, causing modifications in the optimization planning models used for system operation. As a result, the system operator has improved and developed new models and strategies in order to be timely at the forefront of the changing market. XM, Colombian Independent System Operator (ISO), has led this assignment, acquiring state-of-the-art commercial optimization software. Therefore, the optimization models used by XM to plan short- and very short-term have been developed by its own I+D team. This paper presents both, the IT and mathematical formulation, for the most important models developed and daily used by XM, and also show-
of the control system and mention the well-posedness. Then we discuss the ordinary differential equation is derived from the induction law. The possible liquids (>5 S/cm) with or without solids. The volume flow measurement is performed differentially with a pulsed magnetic field to suppress noise voltages as efficiently as possible. The key question in the talk is: How should the coil voltage be optimized using the progressive hedging algorithm? Hydro-Qubec, 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 mid-term 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 (PHMA) (Rockafellar and Wets 1991). In our model, hydroelectric 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-Qubecs power system (21 large reservoirs and 22 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. 

Partial differential equations. Turbulent fluid flows, magnetic fields and radiation boundary conditions occur. We report on recent progress that has been made in the treatment of such problems. The medium-term operation planning 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 (PHMA) (Rockafellar and Wets 1991). In our model, hydroelectric 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-Quebecs power system (21 large reservoirs and 22 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.

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 wells themselves. Inspired by the concept of a dual control problem classed with an ordinary differential equation for the electrical current. The ordinary differential equation is derived from the induction law. In the talk we present the necessary first order optimality conditions of the control system and mention the well-posedness. Then we discuss numerical methods used to calculate the optimal coil voltage. Finally we present computations based on industrial flow meter geometries.

Applications of optimal control in electromagnetic flow measurement

In this paper we present a comprehensive analysis of an optimal control boundary 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.
tional tests show that the proposed model significantly improves target attainment and performs favourably in different problem instances.}

Robust optimization

Advances in robust optimization
Organizer/Chair Daniel Kuhn, Imperial College London - Invited Session

Huan Xu, National University of Singapore (with Constantine Caramanis, Shie Mannor)

A distributional interpretation of robust optimization, with applications in machine learning

Motivated by data-driven decision making and sampling problems, we investigate a distributional interpretation 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. Specifically, 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 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 Hauska, 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 (GSIOP), 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. GSIOPs 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 GSIOPs 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 GSIOP 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 model 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 the worst-case performance with a confidence of at least $1 - \beta$. Our method 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 that are well suited for the parallelization we have in mind. 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 conclude with some encouraging computational results applied to huge-scale LASSO and sparse SVM instances.

Martin Takac, University of Edinburgh (with Jakub Marecek, Peter Richtarik)

Distributed block coordinate descent method: Iteration complexity and efficient hybrid implementation

In this work we propose solving huge-scale instances of regularized convex minimization problems using a distributed block coordinate descent method. We analyze the iteration complexity of the (asynchronous) algorithm and show how it depends on the way the problem data is partitioned to the nodes. Several variations of the basic method are obtained based on the way updates are handled (P2P, broadcasting, asynchronous). Finally, we report encouraging numerical results for an efficient hybrid MPI + Open MP implementation applied to LASSO and sparse support vector machine instances.

Rachael Tappenden, University of Edinburgh (with Jakob Gondzio, 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 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.

Stochastic optimization

Stochastic optimization – Confidence sets, stability, robustness
Organizer/Chair Petr Lachout, Charles University in Praha - Invited Session

Silvia Vogel, TU Ilmenau

Confidence regions for level sets: Sufficient conditions

Real-life decision problems usually contain uncertainties. If a probability distribution of the uncertain quantities is available, the successful models of stochastic programming can be utilized. The probability distribution is usually obtained via estimation, and hence there is the need to judge the goodness of the solution of the ‘estimated’ problem. Confidence regions for constraint sets, optimal values and solution sets of optimization problems provide useful information. Recently a method has been developed which offers the possibility to derive confidence sets employing a quantified version of convergence in probability of random sets instead of the whole distribution of a suitable statistic. Uniform concentration-of-measure inequalities for approximations of the constraint and/or objective functions are crucial conditions for the approach. We will discuss several methods for the derivation of such inequalities, especially for functions which are expectations of a random function.

Petr Lachout, Charles University in Praha

Local information in stochastic optimization program

Historical observations contain information about local structure of the considered system. We can use them to build an local estimator of the probability distribution leading the system. This approach is also available as expert suggestions and forecasts, knowledge about density smoothness, etc. We intend to describe structure of such optimization programs together with a stability discussion.

Milos Kopa, Charles University in Prague (with Jitka Dupačová)

Robustness in stochastic programs with risk and probabilistic constraints

The paper presents robustness results for stochastic programs with risk, stochastic dominance and probabilistic constraints. Due to their frequently observed lack of convexity and/or smoothness, these programs are rather demanding both from the computational and robustness point of view. Under suitable conditions on the structure of the problem, we exploit the contamination technique to analyze the resistance of optimal value with respect to the alternative probability distribution. We apply this approach to mean-risk models and portfolio efficiency testing with respect to stochastic dominance criteria.

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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 cellphone service provider.

Raghu 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 formulations for optimization under uncertainty. The most general formulation 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.

Jonas Schweiger, Zuse Institute Berlin
Multi-scenario topology optimization in gas networks
With the deregulations in the gas markets, the requirements on the network change rapidly and demand more flexibility from the network operators. Gas network operators therefore have to invest into their network infrastructure. As these investments are very cost-intensive and long-living, network extensions should not only focus on one bottleneck scenario, but should increase the flexibility to fulfill different demand scenarios.

In this presentation, we formulate a model for the network extension problem for multiple demand scenarios. That is, we search cost-optimal network extensions such that a variety of demand scenarios can be realized in the extended network. We propose a decomposition along the scenarios and solve the problem by a branch&bound-algorithm which uses the single-scenario problem as subproblem. Since the single-scenario problem itself is a challenging mixed-integer non-convex optimization problem, we solve them to global optimality only in the leaf nodes of our branch&bound-tree, but still use valid bounds and solutions in every node of the tree.

Miriam Kießling, Technische Universität München (with Sascha Kurz, Jörg Rambau)
ISPO – integrated size and price optimization for a fashion discounter with many branches
We present an integrated size and price optimization problem (ISPO) for a fashion discounter with many branches. Branches are supplied by pre-packaged bundles consisting of items of different size and number – so-called lot-types. Our goal is to find a revenue-maximizing supply strategy. Based on a two-stage stochastic programming model including the effect of markdowns as recourse, we developed an exact branch-and-bound algorithm where dual bounds are obtained by combinatorial bounds combined with LP-relaxations. For practical purposes we developed a production-compliant heuristic, the so-called ping-pong-heuristic, that uses the special structure of the problem to efficiently solving pricing and size optimization. In all test cases we obtain very small optimality gaps (< 0.03 %). In a field study we show that a distribution of supply over branches and sizes based on ISPO solutions leads to better results in terms of realized return than a one-stage optimization of the distribution ignoring the possibility of optimal pricing.

Konrad Schade, Volkswagen AG
The stochastic guaranteed service model
Order policies are crucial in supply chain management. This talk is about the two-stage stochastic–guaranteed-service-model (SGSM) and its usefulness in finding cost-minimizing orderpoints within a multi-echelon inventory system applying the (s, S)-strategy. The guaranteed-service-model (SGSM) provides such orderpoints under the assumption of reliable internal lead times and bounded total demand. We introduce the SGSM – a two-stage stochastic MILP – that extends the GSSM and enables recourse actions. To solve the SGSM we generate scenarios with the sample average approximation. We reduce the number of scenarios considered in the solution algorithm through a scenario reduction technique, the fast forward selection. We get the best results using an asymmetric distance based on the objective function of the SGSSM we want to solve between the scenarios. Simulation based on real world data of a large German car manufacturer show the improvement of applying the SGSSM. The results are compared to the GSSM, a decent solution without optimization within the network and another stochastic optimization method.

Pedro Moure, CID - University of Lisbon (with Luis Gouveia, Ana Soares)
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 to the received signal on another channel. Due to propagation effects, the signal strength on the receiver side decreases as the distance from the transmitter side increases. Therefore, the maximum distance between antennas that allow the link to work properly, depends on the amount of interference introduced by all the frequency channels used on its end nodes. We consider different types of links that may be installed between two nodes depending on the distance between them and their degrees. We propose three models and compare the linear programming relaxations. We also test these models against a set of instances with up to 100 nodes.
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 minimizes the first stage installation cost 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 H 2035

Control and optimization of impulsive systems I

Organizers/Chairs: Aram Arutyunov, Peoples’ Friendship University of Russia; Fernando Pereira, Porto University-FEUP-Institute for Systems and Robotics Porto - Invited Session

Dmitry Karamzin, Computing Centre RAS (with Aram Arutyunov, 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 proves 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 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 Invertibility Type Condition on Impulsive Optimal Control Systems

We discuss an extension of the optimal control theory that the maximum principle fulfills 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 invertibility 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 invertibility notion, called KT-invertibility is introduced for mathematical programming problems. Martin took into account the KT conditions when he designed the KT-invertibility. In this work we do the same, but with the Maximum Principle for optimal control problems in the impulsive setting.

Variational analysis

Tue.2 H 2051

Regularity and sensitivity in multicriteria optimization

Organizer/Chair: Constantin Zalinescu, University Alexandru Ioan Cuza Iasi - Invited Session

Marinus Durea, Al. I. Cuza University 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.

Radu Strugariu, Gh. 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 optimal control 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 Lysternik Graves Theorem. Also, we classify the at-point regularities (or subregularities) of set-valued mappings into two categories and then we analyze their relationship so 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 Alexandru 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 Shayan Oveis Gharan, Amin Saberi)

A randomized rounding approach to the traveling salesman problem

For some positive constant $\varepsilon$, we give a $(2 + \varepsilon)$-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 in which the underlying metric is defined by shortest path distances in $G$. The result improves on the $\frac{3}{2}$-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 integrality, we select the spanning tree random sampling from minimum 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 Mömke, KTH Royal Institute of Technology (with Ola Svensson)

Approximation of metric 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 (Graph-TSP), our 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 $4/3$.

Marcin Mucha, University of Warsaw

13. Approximation of metric 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 Christofides’s algorithm with approximation factor of $\frac{3}{2}$, even though 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-
cuit 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 Mômke and Svensson. In this paper, we provide an improved analysis of the approach used by the latter yielding a bound of $\frac{1}{2} + \epsilon$ on the approximation factor. We also provide improved bounds for the related graphic TSP path problem.

**Tue.3.4 3084**

**Combinatorial optimization**

**Extended formulations in discrete optimization I**

Organizers/Chairs: Samuel Fiorini, Université libre de Bruxelles (ULB); Gauthier Stauffer, University Bordeaux 1 – INRIA – Limited Session

Sebastian Pokutta, University of Erlangen-Nürnberg (with Rémi Louveaux, 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 $2^n(1-\epsilon)$. 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 AOC (with Yuri Faenza, Samuel Fiorini, Tiwary Hans Raj)

**Tue.3.4 3085**

**Combinatorial optimization**

**Matroid parity**

Organizer/Chair: Tamás Király, Eötvös University, Budapest – Limited Session

Ho Yee Chan, 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 $O(mn^{\omega-1})$, which improves the $O(mn^2)$-time algorithm by Gabow and Stallmann. We also present a very simple alternative algorithm with running time $O(mn^2)$. We further improve the algebraic algorithms for some specific graph problems of interest. We present faster randomized algorithms for the Mader’s disjoint $\mathcal{S}$-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 $\mathcal{S}$-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).

Independently 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.

**Tue.3.4 3088**

**Combinatorial optimization**

**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 the 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 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 NP ∩ 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)

The width of 4-prismatoids

Santos’ construction of a counterexample to the Hirsch conjecture highlights a particular 5-dimensional “prismatoid” polytope. We use the Euler characteristic to prove that there is no analogous 4-dimensional prismatoid.

David Bremer, University of New Brunswick (with Yan Cui)

Minimum norm points on the boundary of convex polytopes

Given two sets of vectors in $P, Q \subseteq \mathbb{R}^d$ the maximum margin hyperplane is defined by the solution to the following

$$\text{margin}(P, Q) = \sup_{w \in \text{conv}(P) \setminus Q} \inf_{q \in Q} \langle w, p - q \rangle$$

where $B$ is the relevant unit ball.

In the case where $\text{margin}(P, Q) > 0$, the (separable case), this problem is dual to finding the minimum norm point in the Minkowski sum $P + Q \subseteq \text{conv}(P) \cup Q$ and can thus be solved efficiently.

When $0 \in \text{int}(P \cap Q)$, margin is dual to finding the smallest translation that makes the two sets separable. It turns out this is defined by the minimum norm point on the boundary of $P + Q$. In this case the feasible is only piecewise convex, and the problem is NP-hard.

In this talk I will discuss experimental results from two approaches to the non-separable case. The first approach solves one convex min-
imization per facet of $P \otimes Q$. The second approach (applicable only to polytopal norms) solves one LP per vertex of the unit ball $B$.

Combinatorial optimization

LP relaxations

Chair Dorit Hochbaum, UC Berkeley

Maria Teresa Godinho, IPEAes & CIO (with Luís Gouveia, Pierre Pesneau)

On a time-dependent formulation for the travelling salesman problem

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 Voudouris [1995], Larrosa et al [1990], Gouveia and Pires [1999], Ormazabal 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 $c$-circuit sub-problem 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, normalized cut and conductance better than the spectral method

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 rate-limited 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 strongly 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 visual quality of the segmentation, compared to the spectral method in image segmentation and image denoising instances.

Yong-Hong Kuo, The Chinese University of Hong Kong (with Jenny 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.

Combinatorial optimization
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 Shirang Ahbyankar, Mihai Anitescu, Junhge 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 used 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 Hassan 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-stationary conditions.

Complementarity & variational inequalities

MPECs in function space II

Organizer/Chairs: Christian Meyer, TU Dortmund; Michael Hintermüller, Humboldt-Universität zu Berlin - Invited Session

Stanislav 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 multi-valued and nonmonotone laws. 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 stationary 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.

Todd Munson, Barry Smith

Conic programming

Intermediate gradient methods for smooth convex optimization problems with inexact oracle

Between the slow but robust gradient method and the last 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 Herskowitz, COPPE / Federal University of Rio de Janeiro (with Miguel Anjos, 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 presented. The results are obtained in similar schemes already used in practice. We also establish conditions under which the complexity of the algorithm is polynomial in the problem dimension.

Olivier Devolder, Université Catholique de Louvain (UCL) (with Francis Facchine, Yurii Nesterov)

Intermediate gradient methods for smooth convex optimization problems with inexact oracle

An inexact first-order algorithm for non-linear 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 of 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 presented. The results are obtained in similar schemes already used in practice. We also establish conditions under which the complexity of the algorithm is polynomial in the problem dimension.

Jose Herskowitz, COPPE / Federal University of Rio de Janeiro (with Miguel Anjos, Jean Roche)
from larger datasets can be exploited to reduce the runtime of inference. The computational complexity of an inference procedure when one has all necessary data.

Venkat Chandrasekaran, Caltech (with Michael Jordan)

Multifrontal barrier computations for sparse matrix cones

Multifrontal and supernodal sparse Cholesky factorization methods. The results will be illustrated with applications in covariance selection and semidefinite programming.

Luen Van den Bergh, UCLA (with Martin Andersen)

Conic and convex programming in statistics and signal processing I

Organizer/Chair: Parikshit Shah, University of Wisconsin - Invited Session

Bamdev Mishra, University of Liège (with Rodolphe Sepulchre)

Fixed-rank matrix factorizations and the design of invariant optimization algorithms

Optimizing over fixed-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 transformations 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.

Multifrontal barrier computations for sparse matrix cones

We discuss conic optimization problems involving two types of conic 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.

Toby Walsh, NICTA and UNSW

Constraint programming methodology

Chair: Burak Gokgur, bmir University of Economics

Tobias Bandyopadhyay, Princeton University (with Katya Scheinberg, Luis Nunes Vicente)

Variable and value symmetry in constraint satisfaction and optimization problems

Factoring out the symmetry in a model is important for solving many constraint satisfaction and optimization problems. Symmetries can act on the variables, or on the values, or on both the variables and the values in a model.

A simple but nevertheless effective method to deal with symmetry is to post static constraints which eliminate symmetric assignments. If a model has value symmetry in addition to variable symmetry, we might simply post the relevant value symmetry breaking constraints in addition to the variable symmetry breaking constraints. We consider three issues with this approach.

- Soundness: Is it safe to post together the variable and value symmetry breaking constraints?
- Completeness: Does this combination of symmetry breaking constraints eliminate all symmetry from the problem? If not, how can we eliminate all symmetry?
- Completeness: What is the complexity of breaking all variable and value symmetry? And of propagating the combination of the variable and value symmetry breaking constraints together?
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 algorithm. Regret is defined as the difference between the expected cumulative benefit and the optimal cumulative benefit. In this work, we present a regret-minimization algorithm that is based on the zeroth order algorithm of Nemirovski and Judin from the 70’s. 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

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The project using fuzzy sets. The net present value or NPV used as the main objective. The main objective of his algorithm. We provide this and it yields a particularly simple proof of the fact that the set of equilibria is convex. 

Building on the works of Eaves and Garg, Mehta, Sohoni and Vazirani, we obtain an LCP that captures exactly the set of equilibria for Arrow-Debreu markets under separable, piecewise-linear concave (SPLC) utilities, despite the PPAD-completeness of this case. As a corollary, we obtain the first elementary proof of existence of equilibrium for this case. In 1975, Eaves had given such an algorithm for the case of linear utilities and had asked for an extension to the piecewise-linear, concave utilities. Our result settles the relevant subcase of his problem as well as the problem of Vazirani and Yannakakis of obtaining a path following algorithm for SPLC markets, thereby giving a direct proof of membership in PPAD.

We also prove that SPLC markets have an odd number of equilibria up to scaling, hence matching the classical result of Shapley about 2-Nash equilibria, which was based on Lemke-Howson algorithm.

For the linear case, Eaves had asked for a combinatorial interpretation of his algorithm. We provide this and it yields a particularly simple proof of the fact that the set of equilibria is convex.

The free energy rate free premix bi-linear model appears to give better results that maximizes the seller's revenue. (The seller can keep some units of the item.) This problem is known to be NP-hard. We thus propose 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. [11] 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 valuation truthfully.

From quadratic through factorable to black-box global optimization

A new global optimization method based on a sparse grid metamodel

A new global optimization method is presented here aimed at solving a general black-box optimization problem where function evaluations are expensive. Our work is motivated by many problems in the oil industry, coming from several domains like reservoir engineering, molecular modeling, engine calibration and inverse problems in geosciences. Even if evolutionary algorithms are often a good tool to solve these problems, they sometimes need too many function evaluations, especially in high-dimension cases. To overcome this difficulty, we propose here a new approach, called SGOM, using the Sparse Grid interpolation method with a refinement process as metamodel.

We give a practical algorithm for computing an equilibrium for Arrow-Debreu markets under separable, piecewise-linear concave (SPLC) utilities, despite the PPAD-completeness of this case. As a corollary, we obtain the first elementary proof of existence of equilibrium for this case. In 1975, Eaves had given such an algorithm for the case of linear utilities and had asked for an extension to the piecewise-linear, concave utilities. Our result settles the relevant subcase of his problem as well as the problem of Vazirani and Yannakakis of obtaining a path following algorithm for SPLC markets, thereby giving a direct proof of membership in PPAD.

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For the linear case, Eaves had asked for a combinatorial interpretation of his algorithm. We provide this and it yields a particularly simple proof of the fact that the set of equilibria is convex.
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 Tsiourkouas, Massachusetts Institute of Technology (with Alexander Mitsos)

Extension of McCormick’s composition to multi-variate outer functions

Gérard J.M. corps (Math Prog 1976) provides the framework for the convex/concave relaxations of factorable functions involving functions of the form $F = f$, where $F$ is a univariate function. We give a natural reformulation of McCormick’s Composition theorem which allows for a straightforward extension to multi-variate outer 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.

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 (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.I 2013

Integer & mixed-integer programming

Advances in mixed integer programming

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.

Monfred 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 integer primal 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.II 2013

Integer & mixed-integer programming

Trends in mixed integer programming V

Tiziano Parriani, DEIS - 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 Maner 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 instability 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 particular MCFP
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 linear integer programs previously considered intractable. However, a significant number of real-world linear and linear 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.

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.

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 [Baldacci, 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.

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.

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.

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 which on 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

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 overextension 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 nonlinear 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 nonlinear 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.

Applications of multiobjective optimization

Chair: Gennady Zabrodsky, Omnik Branch of Sobolev Institute of Mathematics Siberian Branch of Russian Academy of Sciences

Ceren Tuncer Sakar, Middle East Technical University (with Murat Kikicaalan)

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, Aurea Martinez, Miguel Vazquez-Mendonza)

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, Omnik Branch of Sobolev Institute of Mathematics Siberian Branch of Russian Academy of Sciences (with Igor Amir)

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.

Jean-Lou Goffin, Université Catholique de Louvain (with Jim Luedtke, Ashutosh Mahajan, Mahdi Namazifar)

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 nonlinear semidefinite programming which is based on the inherent duality. We present the algorithm and its numerical results for a large-scale semidefinite programming problem.

Mouna Hassan, Rey Juan Carlos University (with Javier Maguerza, Andrés Redchuk)

The i^t - Penalty Interior Point Method

The problem of global 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 I^t-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 subproblem, we use a Cauchy step which would be computed inside the Newton step and the proposed algorithm would make a duality gap decrease in the span 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 multipliers are finite, then the corresponding penalty parameter is finite. Global convergence properties do not require the regularity conditions on the original problem. The solution to the penalty-barrier problem converges to the optimality that may satisfy the Karush-Kuhn-Tucker point or Fritz- JOHN point, and may satisfy a first-order critical point for the measure of the

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Jens Voss, Braunschweig University of Technology (with Igor Amir)

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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.

Philipp 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 convex constrained quadratic subproblem (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 far 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 coupling.

Examples are presented.

Nicholas Gould, STFC Rutherford Appleton Laboratory (with Sven Leyffer, Yueling Loh, Daniel Robinson)

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 Riccati method, tailored to the delta transform, for efficiently solving the resulting KKT systems that arise within an interior point solver.

Eric Kerrigan, Imperial College London (with George Constantinides, Shirtao Longe, Juan Jerez)

Tue.3.1012

Large-scale structured optimization
Organizer/Chair Anatoli Juditsky, LJK, Université J. Fourier - Invited Session
Arkadi Nemirovski, Georgia Institute of Technology (with Anatoli 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 large-scale 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 propose a special version 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 Yurii Nesterov)

Primal-dual subgradient method for huge-scale conic optimization problems and its applications in structural design
For huge-scale optimization problems, we suggest a new primal-
Optimization in energy systems

A high accuracy optimization model for gas networks

Björn Geißler, FAU Erlangen-Nürnberg, Discrete Optimization (with Alexander Martin, Antonio Morsi, Thomas Lehmann)

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 allow 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 Gugolz, 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 parameterized 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 Yousept, 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 current. Applications of such equations can be found in many modern technologies such as in induction heating, magnetic levitation, optimal design of mechanical structures. Such a problem can be posed in a conic form, with high sparsity of corresponding linear operator.

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design of electromagnetic meta-materials, and many others. In this talk, we discuss several PDE-constrained optimization problems involving time-harmonic eddy current equations as equality constraints. Recent theoretical and numerical results are presented.
approximate projections using conjugate gradients, and provides empirical evidence for the effectiveness of the proposed HOC.

Spartak Zikmin, Linköping University (with Mats Andersson, Oleg Bubnovik, Hans Knutsson)

Sparse optimization techniques for solving multilinear least-squares problems with application to design of filter networks

The multilinear least-squares (MLLS) problem is an extension of the linear least-squares problem. The difference is that a multilinear operator used in place of a matrix-vector product. The MLLS 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 MLLS problem originates, for instance, from the design of filter networks.

For the design of filter networks, we consider the problem of finding a decision rule approximation scheme, we can model and solve a probability distribution over the sub-filters that compose the network. This results in a MLLS problem augmented by an additional constraint that poses an upper limit on the number of nonzero components in the solution. This sparse multilinear least-squares problem is NP-hard. We present an approach for approximately solving the problem. In our numerical experiments, a greedy-type sparse optimization algorithm is used for designing 2D and 3D filter networks.

The efficiency of our approach is illustrated by results of numerical experiments performed for some problems related to the design of filter networks.

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 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 $x$ is constrained to a hypercube, then $y$ is constrained to a hyperoctahedron, a zonotope. 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 zonotope as a system of linear inequalities.

Angélos Georgiou, Imperial College London (with Daniel Kuhn, Wolfram Wiesemann)

A stochastic capacity expansion model for the UK energy system

Energy markets are currently undergoing one of their most radical changes in history. Both market liberalisation and the increasing penetration of renewable energy sources highlight the need to accommodate uncertainty in the design and management of future energy systems. This work aims to identify the most cost-efficient expansion of the UK energy grid, given a growing future demand for energy and the target to move towards a more sustainable energy system. To this end, we develop a multi-stage stochastic program where the investment decisions (generation capacity that should be built) are taken here-and-now, whereas the operating decisions are taken in hourly time stages over a planning horizon. Both market liberalisation and the increasing penetration of renewable energy sources highlight the need to accommodate uncertainty in the design and management of future energy systems.
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 optimization

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 instantiation, a recourse route is computed – but costs here become more expensive by a factor \( \lambda \). We present an \( O(\log^2 n \log(1/\varepsilon)) \)-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

Inge Goertz, Technical University of Denmark (with Vinayanan Nagarajan, Rishi Saket)

Stochastic vehicle routing with recourse

In this paper, we study a problem 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.

Gwen Spencer, Cornell University (with David Shmoys)

Communication network design

Marc Ruiz, Universitat Politècnica de Catalunya (with Jaume Comellas, Luis Valencas)

Multi-constructive meta-heuristic for the metro areas design problem in hierarchical optical transport networks

Optical connections in flexgrid-based optical networks will be able to convey up to 1 Tbps in the near future. Before designing those core networks however, it is required to introduce some hierarchy defining metropolitan areas so to reduce the number of locations participating in the core network. Those areas are then interconnected through the core network, and so expenditure costs of the latter can be dramatically reduced by minimizing the amount of traffic to be handled. As a result of the problem complexity we propose an iterative meta-heuristic that, at each iteration, builds a feasible solution by applying either a greedy-randomized or a pure random constructive procedure. To reach local optima, a local search procedure is afterwards applied. Finally, diversification is exploited by applying path-relinking between new and elite solutions. The performance of single and multi-constructive meta-heuristics was compared against exact solutions obtained from an ILP model. Finally, a real instance from a nation-wide network operator was solved. This work was supported by the Spanish science ministry through the TEC2011-27310 ELASTIC project.

Aram Arutyunov, Peoples' Friendship University of Russia (with Dmitry Karamzin, Fernando Pereira)

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Youngho Lee, Korea University (with Chanwoo Park, Gijyoung Park, Junsang Yuh)

A nonlinear mixed integer programming problem in designing local access networks with GoS constraints.

We study necessary conditions of optimality for optimal control problems. In this talk, we present nonlinear mixed integer programming models for solving the local access network design problem with GoS 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 pre-scribed 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 GoS constraints by imple-menting mixed-integer linear constraints with auxiliary variables. By ex-ploiting the special structure of the problem, we devise an outer approx-imation algorithm that implements cut generation strategies for cutting off the violated solution at each iteration. Computational results are pre-sented for demonstrating the effectiveness of cut generation strategies.

Varun Krishnamurthy, University of Waterloo (with Anupam Gupta, Ravishankar Krishnaswamy, Marco Molinaro)

Optimal control problem: Revisited

We study necessary conditions of optimality for optimal control problem with state constraints in the form of the Pontryagin’s max-imum principle (for short MP). For problems with state constraints these conditions were first obtained by R.V. Gamkrelidze in 1959. The latter can be dramatically simplified by the classic monograph by the four authors. This MP was obtained under a certain regularity assumption on the optimal trajectory. Somewhat later, in 1963, A.Ya. Dubovitski and A.A. Milyutin proved another MP for problems with state constraints. In contrast with
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

\[ Q_1(x(t^-)) = 0, \quad Q_2(x(t)) = 0, \quad \Psi(x(t^-)) \leq 0, \quad \Psi(x(t)) \leq 0 \text{ v.a.e. on } [0, T]. \]

Here, \( x(t^-), x(t) \) are the left and right limits of a state trajectory \( x \) at time \( t \), a non-negative scalable 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.

Laurent Pfeiffer, Inria-Saclay and CMAP, École Polytechnique (with Joseph Benosman, Oana Serea)

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 \([2]\), 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 of the problem. Using the decomposition principle \([1]\), we prove that the upper estimate is an exact \( 1 \)-approximation.

\[ \text{[2]} \ A.A. Milyutin, N.P. Osmolovskii. Calculus of variations and optimal control. 1998. \]

Variational analysis

Recent advances on linear complementarity problems

Organizer/Chair Héctor Ramírez, Universidad de Chile - Invited Session

Julio López, Universidad Técnica Federico Santa María (with Rubén López, Héctor Ramírez)

Characterizing Q-linear transformations for linear complementarity problems over symmetric cones

In this work, we introduce a new class, called \( F \), of linear transformations defined on a Euclidean Jordan algebra. This concept is illustrated in some known examples of Euclidean Jordan algebras: \( n \)-dimensional vectors, quadratic forms and \( n \)-dimensional symmetric matrices. Also, within this new class, we show the equivalence between \( Q_- \) and \( Q_+ \)-transformations. We also provide conditions under which a linear transformation belongs to \( F \). Finally, we present some examples of transformation: Lyapunov, Quadratic, Stein and relaxation transformation.

Jean-Baptiste Hiriart-Urruty, Paul Sabatier University (Toulouse III) (with Hai Yen Le)

A variational approach of the rank function

We consider here the rank (of a matrix) from the variational viewpoint. Actually, besides being integer-valued, the rank function is lower-semicontinuous. We are interested in the rank function, because it appears as an objective (or constraint) function in various modern optimization problems, the so-called rank minimization problems (P). A problem like (P) has some bizarre and/or interesting properties, from the optimization or variational viewpoint. The first one, well documented and used, concerns the “relaxed” forms of it. We recall here some of these results and propose further developments:

- [Global optimization] Every admissible point in (P) is a local minimizer.
- [Moreau-Yosida approximation] The Moreau-Yosida approximate (or regularized version) of the objective function in (P), as well as the associated constrained proximal mapping, can be explicitly calculated.
- [Generalized subdifferentials] The generalized subdifferentials of the rank function can be determined. Actually, all the main ones coincide and their common value is a vector subspace!

Héctor Ramírez, Universidad de Chile (with Rubén López, Julio López)

Existence and stability results based on asymptotic analysis for semidefinite linear complementarity problems

This talk is devoted to the study of existence and stability results of semidefinite linear complementarity problems (for short SDLCP). Our approach consists of approximating the variational inequality formulation of the SDLCP by a sequence of suitable chosen variational inequalities. This provides particular estimates for the asymptotic cone of the solution set of the SDLCP. We thus obtain new coercive and monotone existence results, as well as new properties related to the continuity of the solution sets of the SDLCP (such as outer/upper semicontinuity, Lipschitz-type continuity, among others). Moreover, this asymptotic approach leads to a natural extension of the class of Garcia linear transformations, formerly defined in the context of linear complementarity problems, to this SDLCP setting.

Rosemary Ripon, Max Planck Institute for Informatics (with Xujin Chen, Benjamin Doerr, Xiaodong Hu, Weidong Ma, Carola Witzig)

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 received relatively little attention. We 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.

Wed.1.H, 10:30
Scheduling and packing: Approximation with algorithmic game theory in mind

Organizer/Chair: Acaž Levin, The Technion - Invited Session

Leah Epstein, University of Haifa (with Gyorgy Dosa)

Generalized selfish bin packing

In bin packing games, an item has a positive weight and each item has a cost for every valid packet of the items. We study a class of such games where the cost of an item is the ratio between its weight and the total weight of items packed with it, i.e., cost sharing is based linearly on the weights of items. We study several types of pure Nash equilibria (NE): standard NE, strong NE, and strictly/pareto optimal NE. We show that any game of this class admits all these types of equilibria. We study the (asymptotic) prices of anarchy and stability (PoA and PoS) of the problem for these types of equilibria and general/unit weights. While the case of general weights is strongly related to First Fit, and all the PoA values are 1.7, for unit weights they are all below 1.7. The strong PoA is equal to approximately 1.691 (another well-known number in bin packing) while the strictly Pareto optimal PoA is lower. The PoS values are 1, except for those of strong equilibria, which is 1.7 for general weights, and approximately 1.611824 for unit weights.

Acaž Levin, The Technion (with Leah Epstein, Rob van Stee)

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 machines 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 to show that it is possible to compute in polynomial time a structured nearly optimal schedule. This is achieved in contrast to all known PTAS’s, we avoid bounding 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.

Rob van Stee, Max Planck Institute for Informatics (with Xujin Chen, Benjamin Doerr, Xiaodong Hu, Weidong Ma, Carola Witzig)
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
Matthieu Van Vyve, Université catholique de Louvain (with Laurence Wotzlaw)

Projecting an extended formulation

We describe when it is possible to use 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 \( Q = \{(x, w) \in \mathbb{R}^n \times \mathbb{R}^d | Bx + Dw \geq d \} \) 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 \( Bx + Dw \geq d \) 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.

Kanstantsin 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 tools to construct such 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 polynomials 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 \( G \)-permutahedron of all finite reflection groups \( G \) (generalizing both Goemans’s extended formulation of the permutohedron of size \( Q(\log n) \)) 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 semifinite extended formulations

Among other, similar, statements, we prove the following: Theorem. Every positive semifinite extended formulation for the Cut polytope of \( K_n \) dominating the 3-clique inequalities must have size at least \( \Omega(n^3) \). (The size of a positive semifinite formulation is the dimension of the positive semifinite matroid.) This contrasts the fact that the famous Goemans-Williamson relaxation has linear size: it dominates only a weakened form of the 3-clique inequalities.

Invited Session

Combinatorics and geometry of linear optimization III
Organizers/Chairs: Jesus De Loera, University of California, Davis; Antoine Deza, McMaster University - Invited Session
Shogo 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 LP’s to zero-sum games, a Karp-type reduction which is applicable to LP’s with rational (as well as algebraic) data, and a Cook type reduction which is applicable to LP’s 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.

Ur Zwick, 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 \( 2^{\Omega(n)} \), for some \( a > 0 \)) 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 Matoušek, Sharir and Welzl. Our lower bound for the random-facet pivoting rule essentially matches the subexponential upper bounds given by Kalai and by Matoušek et al. Lower bounds for random-edge and random-facet were known before only in abstract settings, and not for concrete linear programs.
A divide-and-bridge heuristic for Steiner minimal trees on the Euclidean plane

This paper describes the construction of Steiner minimal trees on the Euclidean plane using a divide-and-bridge heuristic. A lexicographically sorted set of terminal sites is divided into subsets. These subsets with three, four or five vertices in each set are created using an exponential time exact algorithm. Any two neighboring trees calculated above, can be bridged by the edge of shortest length. Because of the repeated division of the given set into halves, an outlying terminal of a subset may better suit the total connectivity if it is included in the neighboring subset. We start with a feasible division that may not be optimal, and then look for the optimal division by moving the boundary between two subsets, if it is promising. Split operations may be required at the terminals of the bridge edge, to obtain the minimal tree for the merged set. After every bridge operation or split operation, the optimal coordinates are calculated by an algorithm, that works in \( O(N) \) time since the topology is known.

A heuristic algorithm for the set multicover problem with upper bound constraints

We consider an extension of the set covering problem (SCP) introducing \( \ell \) multicover and \( l \) generalized upper bound (GUB) 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 Athanassiadou, Fordham University of Mashhad (with Hossein Tajeddine Khakii)

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 \( N = \{ G, u, r, t \} \) be the associated dynamic network with arc capacities \( u \), flow traversal times \( r \), and arc interdiction costs \( c \). 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.

Planar min-cost flow in nearly \( O(n^{3/2}) \)

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 \( O(n^{3/2}) \) time for bounded costs and capacities. We demonstrate techniques to obtain \( O(n^{3/2}) \) 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 conditions come from applications 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.

Routing for public transportation

Organizer/Chair 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 reality 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

Thomas Pajor, Karlsruhe Institute of Technology (with Daniel Delling, Renato Werneck)

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 single 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 each route (such as a bus line) 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,
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, cancelled 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.

Amitabha Bagchi, Indian Statistical Institute

Some new results on semidefinite linear complementarity problems

Given a linear transformation \( L : S^p \rightarrow S^p \) and \( Q \in S^p \), the semidefinite linear complementarity problem (SDLCP) \((L,Q)\) is to find an \( X \in S^p_+ \) such that \((L+Q)X=0\) and \((L(X)+Q)\geq 0\). This paper investigates 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.

Chandrahekaran Arunagasi, Central University of Tamil Nadu

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.

Amitabh Bagchi, Indian Statistical Institute

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 value 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 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 in which the set of states are partitioned into sets \( S_1, S_2 \) and \( S_3 \) 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 \( S_3 \) 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 appropriately 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.

Nathan Krislock, INRIA Grenoble Rhône-Alpes (with Jérôme Malick, Frédéric Roupin)

Improved semidefinite bounding procedure for solving max-cut problems to optimality

We present an improved algorithm for finding exact solutions to Max-Cut and the related binary quadratic programming problem, both classic problems of combinatorial optimization. The algorithm uses a branch-and-cut-and-bound paradigm, using standard valid inequalities and nonstandard semidefinite bounds. More specifically, we add a quadratic regularization term to the strengthened semidefinite relaxation in order to use a quasi-Newton method to compute the bounds. The ratio of the tightness of the bounds to the time required to compute them can be controlled by two real parameters; we show how adjusting these parameters and the set of strengthening inequalities gives us a very efficient bounding procedure. Embedding our bounding procedure in a generic branch-and-bound platform, we get a competitive algorithm: extensive experiments show that our algorithm dominates the best existing method.

Andreas Schmutzer, University of Cologne (with Miguel Anjos, Fabio Liers, Gregor Pande)
equity 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.

Angelia Nitepege, Alpen-Adria-Universität Klagenfurt (with Elgoeth Adams, Miguel Angos, 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 succesful in these problems. Besides 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. First the 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.

Pankajv Shah, University of Wisconsin (with Venkata Chandrasekaran)

Group symmetry and covariance regularization

Statistical models that possess symmetry arise in diverse settings such as random fields associated to geometrical phenomena, exchangeable processes in Bayesian statistics, and cyclostationary processes in engineering. We formalize the notion of a symmetric model via a group invariant model and we propose a group invariant fixed point subspace as a fundamental way of regularizing covariance matrices in the high-dimensional regime. In terms of parameters associated to the group we derive precise rates of convergence of the regularized covariance matrix and demonstrate that significant statistical gains may be expected in terms of the sample complexity. We further explore the consequences of symmetry on related model-selection problems such as the learning of sparse covariance and inverse covariance matrices.

Carl Kelley, NC State University (with David Mokrauer)

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 Hare, 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 \( F = \max_i (f_i) \). We work under the assumption that each \( f_i \) is provided via an oracle function that is analytically unavailable. Commonly such problems are dealt with using subgradient techniques. In this talk we propose 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.

Peter Endriss, 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 re-inforced 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 inventory, 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 price take into account the seasonal structures of spot prices and are consistent under the arbitrager-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, HB/EF 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 suggests an equivalent formulation 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.

Glenda Wolf Kohn, University of Washington (with Zelda Zabinsky)
Solving non-linear discrete optimization problems via continualization: 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 an easier task than for discrete problems. In this talk, we present a continualization 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 problem 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.

Zelda Zabinsky, University of Washington (with Wolf Kohn)
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 estimation. 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 continualization 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 to 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 decomposition 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 respect 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.
sure sufficient weekend off days are given and work stretch limits are not exceeded.

Andy Fleet, UW-Sauk Point (with Eli Todd)

MIP model for athletic conference scheduling

We examine a MIP model used for determining the specific dates and locations for athletic conference match ups given predetermined available dates and teams. The model takes into account home/away game equivalency, the number of consecutive home/away games, as well as any other stipulations requested by the conference. It accommodates multiple sports spanning multiple seasons. Such models have been utilized by the UWSP Center for Athletic Scheduling to generate optimal schedules for NCAA Division-III athletic conferences adhering to the given constraints.

Andrea Raiti, The University of Auckland (with Amelia White)

Minimising tardiness in parallel machine scheduling with setup times and mould type restrictions

We study a parallel machine scheduling problem with sequence-dependent setup time. The jobs in this machine-scheduling problem have due dates and each job is of a particular job family. Each job family requires a specific mould to be installed on the machine for production. The setup time of the moulds is significant and there is only a small number of each type of mould available. We present preliminary results of our research into this problem. We propose a time-indexed integer programming formulation that minimises overall job tardiness. The formulation has constraints that model both setup times of the moulds and constraints that restrict the number of machines that can work on items of the same family at the same time due to limited availability of moulds. We show that some of the constraints can be relaxed and that the obtained optimal solutions of the relaxed problem can be post-processed to derive optimal mould-feasible solutions thus speeding up computation times. We give an indication of expected running times for some test problem instances.

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 evaluated 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.

Enrico Malaguti, DEIS – University of Bologna (with Fabio Furini)

Algorithms for 2-dimensional 2-staged guillotine cutting stock problems

Given a set of rectangular items classes with an associated positive demand and infinitely many identical rectangular bins, the 2-dimensional cutting stock problem requires cutting all the items by using the minimum number of bins or, equivalently, by minimizing the global area of the used bins. We consider the 2-dimensional 2-staged guillotine cutting stock problem, where items must be obtained through at most two stages of guillotine cuts (we allow trimming, i.e., a third stage cut can be used to separate a rectangle from a waste area). This is a generalization of the corresponding 2-dimensional bin packing problem, where the demand is equal to 1 for all the item classes. In this talk, we describe a branch-and-price algorithm for the problem, and discuss the adaptation of generic branching rules to the specific case. In addition, we extend a compact integer linear programming model from the literature, proposed for the bin packing case, to the more general cutting stock problem. The performance of the proposed models and solution algorithms is evaluated through computational experiments on a set of benchmark instances from the literature.

Friedrich Eisenbrand, TU Berlin (with Dömötör Pálvölgyi, Thomas Rothvoss)

On bin packing, the MIRUP conjecture and discrepancy theory

Bin packing a classical combinatorial optimization problem for which the development of approximation algorithms and integer programming methods is an impressive success story. Yet, a prominent problem related to bin-packing is still open: Is there an OPT+1 approximation algorithm and does the column-generation ILP of Gilmore and Gomory have a constant additive integrality gap?

In this talk, I survey some recent results around this open problem that deal with a relationship of approximation algorithms for bin packing and discrepancy theory. In particular, I describe the limits of LP-rounding for bin packing problems implied by a recent lower bound on the discrepancy of three permutations by Newman and Nikolov.
We consider the stochastic on-time arrival (SOTA) problem which consists in finding a policy that maximizes the probability of reaching a destination within a given budget. We propose novel algorithmic methods for the fast computation of its solution in general graphs with stochastic and strictly positive minimal network-wide edge weights, with application to road networks in particular. Results show the effectiveness of the proposed method.

Samaranayake)
Sebastien Blandin, IBM Research Collaboratory - Singapore (with Alexandre Bayen, Samitha Samarasekera)

Moritz Kobitzsch, Karlsruhe Institute of Technology

A geometric branch and bound approach for nonlinear mixed-integer optimization

Geometric branch-and-bound techniques are popular solution algorithms for continuous, non-convex global optimization problems. The most important task throughout these algorithms is the calculation of good lower bounds on the objective function. Several techniques do to exist. They can be compared theoretically by their rate of convergence.

The aim of this talk is to extend these geometric branch-and-bound methods to mixed integer nonlinear optimization problems, i.e. to objective functions with some continuous and some combinatorial variables. The idea is to do a geometric branching for the continuous variables and to approximate the remaining discrete problem in order to obtain the required bounds. This is in contrast to the classical integer branch-and-bound in which branching is done on the discrete variables.

We derive several bounding operations and theoretical results about their rate of convergence. Moreover, we discuss an extension of the method which leads to exact optimal solutions under certain conditions. The suggested techniques are applied to some mixed-integer facility location problems in which we succeed in finding exact optimal solutions.

Laura Galli, University of Warwick. (with Adam Letchford)

Reformulating mixed-integer quadratically constrained quadratic programs

It is well known that semidefinite programming (SDP) can be used to derive useful relaxations for a variety of optimisation problems. Moreover, in the particular case of mixed-integer quadratic programs, SDP has been used to reformulate problems, rather than merely relax them. In recent papers, B likenet et al. (2009), (2012) present their reformulation method, which they call Quadratic Convex Reformulation (QCR), and apply it respectively to equality-constrained 0 – 1 QP and general mixed-integer QP (MIQP). In their second paper (2012), they use binary expansion to convert bounded integer quadratic instances into 0-1 QP. We show that binary expansion never causes the SDP bound to get any worse and sometimes can lead to an improvement. Then we show that, under certain conditions, the QCR method can be extended to the even more general case of mixed-integer quadratically constrained quadratic programming (MIQCP). Handling quadratic constraints turns out to be a non-trivial exercise. In our computational results we implement different reformulation schemes and compare the corresponding bounds.

Ti-Shau Niu, CRNS - French National Center for Scientific Research (with T. Pham-Dinh)

On combination of DCA branch-and-bound and DC-Cut for solving mixed-01 linear programs

We propose a new hybrid approach based on DC (Difference of convex functions) programming and DCA (DC algorithm) with combination of Branch-and-Bound (BB) framework and new local cutting plan technique (DC-Cut) for globally solving mixed-01 linear program. We firstly reformulate a mixed-integer linear program as a DC program with a DC penalty technique in order to get an efficient local optimization algorithm. DCA is proposed for searching upper bound solutions. The new DC-Cut technique can construct cutting plans from some integer and non-integer local minimizers of DC program which helps to reduce the feasible set and accelerate the convergence of BB. This algorithm can be naturally extended for mixed-01 nonlinear program. Preliminary numerical results comparing with some existing methods will be reported.

Anita Schöbel, Georg-August Universität Göttingen (with Daniel Schöbel)

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We derive several bounding operations and theoretical results about their rate of convergence. Moreover, we discuss an extension of the method which leads to exact optimal solutions under certain conditions. The suggested techniques are applied to some mixed-integer facility location problems in which we succeed in finding exact optimal solutions.
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 Bonnel, 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 belongs to so-called 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 Collonge, University of New Caledonia (with Henri Bonnel)

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-NL 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-NL optimization solutions \( N = 1, 2, \ldots \) 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 sets. 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-NL optimal values \( N = 1, 2, \ldots \) converges almost surely to the true optimal value. A numerical example is presented.

Regularization techniques in optimization I

Organizer/Chair: Jacky Gondzio, University of Edinburgh - Invited Session

Recent advances in the matrix-free interior point method

The matrix-free interior point method allows for solving very large optimization problems without the need to store them explicitly formulated. The method uses the problem matrix only as operators to deliver the results of matrix-vector multiplications. Recent advances including the new theoretical insights and the new computational results will be presented.

Paul Armand, XLIM Research Institute – University of Limoges (with Jöel Benoist)

A boundedness property of the Jacobian matrix arising in regularized interior-point methods

We present a uniform boundedness property of a sequence of inverses of Jacobian matrices that arises in regularized primal-dual interior-point methods in linear and nonlinear programming. We then show how this new result can be applied to the analysis of the global convergence properties of these methods. In particular, we will detail the convergence analysis of an interior point method to solve nonlinear optimization problems, with dynamic updates of the barrier parameter.

Michael Saunders, Stanford University (with Christopher Muro)

QPBLUR: A regularized active-set method for sparse convex quadratic programming

QPBLUR is designed for large convex quadratic programs with many degrees of freedom. [Such QPs have many variables but relatively few active constraints at a solution, and cannot be solved efficiently by null-space methods.] QPBLUR complements SNOPT as a solver for the subproblems arising in the quasi-Newton SQP optimizer SNOPT. QPBLUR uses a BCL algorithm (bound-constrained augmented Lagrangian) to solve a given QP. For each BCL subproblem, an active-set method solves a large KKT system at each iteration, using sparse LDL factors of an initial KKT matrix and block-LU updates for a series of active-set changes. Primal and dual regularization ensures that the KKT systems are always nonsingular, thus simplifying implementation and permitting warm starts from any starting point and any active set. There is no need to control the inertia of the KKT systems, and a simple step-length procedure may be used without risk of cycling in the presence of degeneracy.

We present the main features of QPBLUR and some numerical results from the Fortran 95 implementation on a test set of large convex QPs and on the QPs arising within SNOPT.

Nonlinear programming

Solution methods for matrix, polynomial, and tensor optimization

Organizer/Chair: Shuzhong Zhang, University of Minnesota - Invited Session

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

Alternative direction method of multiplier (ADMM) applies alternating technique on the KKT system of augmented Lagrangian function, which is a powerful algorithm for optimization problems with linear equality constraints and certain separable structures. 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.

Zhenxing Li, Shanghai University (with Bilian Chen, Simai He, Shuzhong 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

An iterative algorithm for tensor $n$-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 $n$-rank minimization problem and adopt twice tractable convex relaxations to transform it into a convex, unconstrained minimization 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.

Jérôme Bolte, Toulouse School of Economics

Recent advances in optimization methods

Organizer/Chair Marc Teboulle, Tel Aviv University. Invited Session

Recent advances in optimization methods

Well known smoothing approaches tackling nonsmooth optimization problems are applied to the nonsmooth case; thus only provide an $\varepsilon$-optimal solution to the approximated smoothed problem. In this talk, we prove that independently of the structure of the function being minimized, and of a given fast first order iterative scheme, by solving an adequately smoothed approximation, the original nonsmooth problem can be solved with an $O(\varepsilon^{-1})$ efficiency estimate. Our approach allows for clarification and unification to several issues on the design, analysis, and the potential applications of smoothing methods when combined with fast first order algorithms, and eventually answer to the question posed in the title!

Marc Teboulle, Tel Aviv University (with Amir Beck)

Nonsmooth optimization

Optimization in energy systems

Optimization in energy systems

Optimization in energy systems

Vincent Leclerc, École des Ponts ParisTech (with Mathieu Graselli, Mike Ludkovski)

The priority option: The value of being a leader in complete and incomplete markets

In a recent paper, Bensoussan, Diltz and Hoe (2010) provide a comprehensive analysis of optimal investment strategies under uncertainty and competition. They consider two firms competing for a project whose payoff can be either a lump-sum or a series of cash-flows, in both complete and incomplete markets. Despite its generality, the analysis is restricted to a Stackelberg scheme, where the roles of leader and follower are predetermined. In this talk, I’ll extend the analysis to the case where these roles emerge as the result of a symmetric, Markov, sub-game perfect equilibrium, extending the seminal work of Grenadier (1996) and (2000) to incomplete markets. As a result, one can calculate the amount of money that a firm would be willing to spend in advance (either by paying a license or acquiring market power) to have the right to be the leader in a subsequent game - what we call the priority option.

Xiaolu Tan, CMAP, École Polytechnique

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 Sahim, 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 techniques. 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.

Jorge Zubelli, IMPA (with Vincent Guigues, Claudia Sagastizabal)

Evaluation of LNG contracts with cancellation options

For gas companies, liquefied natural gas (LNG) appears as a convenient complement to their own natural gas resources. A proper mix of natural gas and LNG contracts allows a gas company not only to diversify its portfolio, but to better hedge risk. In the gas sector, risk concerns are related to volatility of gas prices and also to the obligation of providing a faultless delivery, especially to “uninterruptible” clients, usually crucial customers for the business. LNG contracts offer the possibility to ship LNG loads at dates and volumes specified in the contract. Each shipment can be totally or partly cancelled, possibly paying a fee. Cancellation fees naturally increase as the shipment forecasted date approaches. Therefore, for a given LNG contract it is important to determine which loads might be cancelled. The introduction of LNG contracts in a gas portfolio brings into consideration two challenging issues. First, a company needs to determine a set of acceptable prices for the contracts. Second, on the basis of each contract’s features, a company needs to determine an optimal portfolio. We address these two points being complex and intertwined.

Bjarne Foss, NTNU (with Vidar Gunnarud)

Real-time production optimization based on decomposition techniques

This presentation focusses on Dantzig-Wolfe decomposition for real-time optimization of oil and gas systems with a decentralized structure. The idea is to improve computational efficiency and transparency of a solution. The contribution lies in the application of the Dantzig-Wolfe method which allows us to efficiently decompose an optimization problem into parts. Moreover, we show how the algorithm can be parallelized for even higher efficiency. The nonlinear system is modeled by piecewise linear models with the added benefit that error bounds can be computed. In this context alternative parameterizations are discussed.

Bjarte Foss, NTNU (with Vidar Gunnarud)

Optimization in energy systems

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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 intermittent sources. This is based on an on-going study of an offshore field outside Brazil.

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 - associated 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.

Optimization applications in industry III
Organizer/Chair Dietmar Hömberg, Weierstrass Institute for Applied Analysis and Stochastics - Invited Session
Roland Herzog, TU Chemnitz (with Christian Meyer, Gerd 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 linear 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 from a computational point of view. In this presentation, we therefore address tailor-made algorithmic techniques for optimization problems involving elastoplastic deformation processes.

Anton Schela, TU Berlin
An adaptive multilevel method for hyperthermia treatment planning
The aim of hyperthermia treatment as a cancer therapy is to destroy deeply seated 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 coping 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 very well conditioned and, indeed, can be solved by first-order methods, such as, OMP, FOCAS, 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 system is required and this system has computational complexity $O(n^3)$. We remove this disadvantage by employing the matrix-free interior point method with suitable preconditioners which cleverly exploit special features of compressed sensing problems. Spectral analysis of the preconditioners is presented. Computational experience with large-scale 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 - associated 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.

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Anton Schela, TU Berlin
An adaptive multilevel method for hyperthermia treatment planning
The aim of hyperthermia treatment as a cancer therapy is to destroy deeply seated 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 coping 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 very well conditioned and, indeed, can be solved by first-order methods, such as, OMP, FOCAS, 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 system is required and this system has computational complexity $O(n^3)$. We remove this disadvantage by employing the matrix-free interior point method with suitable preconditioners which cleverly exploit special features of compressed sensing problems. Spectral analysis of the preconditioners is presented. Computational experience with large-scale
one-dimensional signals ($n = 2^{20}$) confirms that the new approach is efficient and compares favorably with other state-of-the-art solvers.

Xiaowei Wang, Ningbo University (with Xiaoming Yuan)

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.

Sergiy Voronen, Princeton University

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 $ℓ_1$ minimization, and show that by replacing the non-smooth one norm $||x||_1 = \sum_{k=1}^{N} |x_k|$ 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: $||Ax - b||_2^2 + \sum_{k} \lambda_k ||x||_{q_k}$ for $1 \leq q_k < 2$ is desirable. We show that our proposed schemes extend to this more general case.

Vinayak Kamthe, Charles University in Prague, Faculty of Mathematics and Physics (with David Morton)

Risk-averse stochastic dual dynamic programming

We formulate a risk-averse multistage stochastic program using CVaR as the risk measure. The underlying random process is assumed to be stage-wise independent, and the stochastic dual programming (SDDP) algorithm is applied. We discuss the poor performance of the upper bound estimator in the risk-averse setting and provide a modified procedure, which improves the upper bound estimator. Only mild conditions and modest additional computational effort are required to apply the new upper bound estimator. The procedure saves a huge improvement in the terms of applying desirable stopping rules for the SDDP algorithm in the risk-averse setting. We give a numerical example with a simple multistage asset allocation problem using a log-normal distribution for the asset returns.

Jens Hübner, Leibniz Universität Hannover (with Marc Steinbach)

Structure-exploiting parallel interior point method for multistage stochastic programs

Highly specialized and structure-exploiting solvers for the primal-dual system are essential to make interior point methods competitively applicable to multistage stochastic programs. In the underlying sequential direct approach, depth-first based recursions over the scenario tree and usage of hierarchical problem structures are the key ingredients to achieve memory-efficiency and reduce computational costs. Our parallel approach is based upon a node-distributing pre-processing step that applies a depth-first based splitting of the scenario tree. The node-related problem data are statically distributed among participating processes. Proper computation orders lead to little idle times and communication overhead. This way only few communication routines are required to parallelize the sequential algorithm for distributed memory systems without losing its benefiting features. We use generic implementation techniques to adapt conforming data distributions to the entire IPM data. Thus, distributed memory systems can be used to solve even huge problems exceeding shared-memory capacities. Theoretical concepts and numerical results will be presented.

Anthony Man-Chu So, The Chinese University of Hong Kong (with Sin-Shun Cheung, Kuan-Cheng Wang)

Chance-constrained linear matrix inequalities with dependent perturbations: A safe tractable approximation approach

In the formulation of optimization models, the data defining the objective functions and/or constraints are often collected via estimation or sampling, and hence are only approximations of the nominal values. One approach to incorporate data uncertainty in optimization models is through chance constrained programming. Although such an approach often leads to computationally difficult optimization problems, one of the successes is the development of so-called safe tractable approximations (STAs) of chance constrained programs. Currently, the STA approach mainly applies to problems where the data perturbations are independent. However, in some applications (e.g., portfolio optimization), the data perturbations are not independent, and so existing results cannot be applied. In this talk, we will demonstrate how tools from probability theory can be used to develop STAs of chance constrained programs with dependent data perturbations. An advantage of our approach is that the resulting STAs can be formulated as SDPs or even SOCPs, thus allowing them to be solved easily by off-the-shelf solvers. If time permits, we will also discuss some other applications of our approach.

Vaclav Kozmik, Charles University in Prague, Faculty of Mathematics and Physics (with David Morton)

Algorithmic trade-off analysis for multistage asset allocation

We give a numerical example with a simple multistage asset allocation problem using a log-normal distribution for the asset returns. Many resource-scheduling applications require the construction of a model with predictive capabilities. The model is used to generate demand information as a function of historic data, resource constraints, sensory data, and other elements. Our research is directed towards the online construction and tuning of a semi-Markov model representing a stochastic process of demand. An optimization algorithm based on the optimal conditional probability measure associated with the stochastic process drives the construction. The conditional residual entropy entropy associated with the historic data gives the criterion: Maximization of residual entropy. The conditional probability measure associated with this model represents the demand at the current time, given the state information at the previous interval. The unique features of our approach are that a realization process in which the conditional probability is updated every time new information becomes available constructs the conditional probability. Another unique feature is that there is no apriori assumptions made about the associated probability space. This space is constructed and tuned as new information becomes available.

Matsgorn Srisung, Thai TEMCO Technical University

Risk aversion in stochastic combinatorial optimization

We characterize the dual feasible bases, in connection with univariate discrete moment problem for new classes of objective functions and its applications

We characterize the dual feasible bases, in connection with univariate discrete moment problem for new classes of objective functions and its applications.

Chair Mariya Naumova, Rutgers University

Scheduling, control and moment problems

Maggie von Raartman, imec (with Wolf Kohn)

Probabilistic realization resource scheduler with active learning

Many resource-scheduling applications require the construction of a model with predictive capabilities. The model is used to generate demand information as a function of historic data, resource constraints, sensory data, and other elements. Our research is directed towards the online construction and tuning of a semi-Markov model representing a stochastic process of demand. An optimization algorithm based on the optimal conditional probability measure associated with the stochastic process drives the construction. The conditional residual entropy entropy associated with the historic data gives the criterion: Maximization of residual entropy. The conditional probability measure associated with this model represents the demand at the current time, given the state information at the previous interval. The unique features of our approach are that a realization process in which the conditional probability is updated every time new information becomes available constructs the conditional probability. Another unique feature is that there is no apriori assumptions made about the associated probability space. This space is constructed and tuned as new information becomes available.

Jian Li, Tsinghua University (with Amit Deshpande)

Univariate discrete moment problem for new classes of objective functions and its applications

We characterize the dual feasible bases, in connection with univariate discrete moment problem for new classes of objective functions and its applications.

Chair Mariya Naumova, Rutgers University

Scheduling, control and moment problems

Partitions-requirements-matrices as optimal Markov kernels of special stochastic dynamic distance optimal partitioning problems

The stochastic dynamic distance optimal partitioning problem (SDDP problem) is a complex Operations Research problem. The SDDP problem is based on a problem in industry, which contains an optimal conversion of machines. Parts of integers as states of these stochastic dynamic programming problems involves combinatorial aspects of SDDP problems. Under the assumption of identical “basic costs” (in other words of “unit distances”) and independent and identically distributed requirements, we will show (in many cases) by means of combinatorial ideas that decisions for feasible states with least square sums of their parts are optimal solutions. Corresponding Markov kernels are called partitions-requirements-Matrices [PROM].

Optimal decisions of such problems can be used as approximate solutions of corresponding SDDP problems, in which the basic costs differ only slightly from each other or as starting decisions if corresponding SDDP problems are solved by iterative methods, such as the Howard algorithm.

Mariya Naumova, Rutgers University (with Andras Prekopa)

Univariate discrete moment problem for new classes of objective functions and its applications

We characterize the dual feasible bases, in connection with univariate discrete moment problem for new classes of objective functions and its applications.

Chair Mariya Naumova, Rutgers University

Scheduling, control and moment problems

Risk aversion in stochastic combinatorial optimization

Organizer Chair Evdokia Nikitova, Texas A&M University - Invited Session

Jian Li, Tsinghua University (with Amit Deshpande)

Maximizing expected utility for stochastic combinatorial optimization problems

We study the stochastic versions of a broad class of combinatorial optimization problems involving combinatorial aspect of SDDP problems. Under the assumption of identical “basic costs” (in other words of “unit distances”) and independent and identically distributed requirements, we will show (in many cases) by means of combinatorial ideas that decisions for feasible states with least square sums of their parts are optimal solutions. Corresponding Markov kernels are called partitions-requirements-Matrices [PROM].

Optimal decisions of such problems can be used as approximate solutions of corresponding SDDP problems, in which the basic costs differ only slightly from each other or as starting decisions if corresponding SDDP problems are solved by iterative methods, such as the Howard algorithm.
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 knapsack. 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. 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.

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 $\rho$. 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.

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 a class of algorithms that explicitly involve the trades the agent made in the past. 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.

Variational analysis

Nonsmooth variational inequalities: Theory and algorithms

We consider a general class of convex optimization problems in which one seeks to minimize a strongly convex function over a closed convex set which is by itself an optimal set of another convex problem through the D-gap function. We present a descent method for solving an equilibrium problem based on generalized D-gap function.
Approximation and online algorithms

Jose Soto, Universidad de Chile (with Jose Correa, Omar Larre)

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 $O(\log n)$. 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 a thm. 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

We consider 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 $O((|W| + |B|)^{2} \log n)$ 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 $O(n \log n)^{2} \log n$ time, while previous algorithms for these instances ran in time at least $O(n^{4})$.

Extended formulations in mixed-integer programming

We study 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 expanded 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 $b_{ij}$, $ij \in E$, let

$$S_{f}(G) = \{ x \in \mathbb{R}^{(U \cup V)}_{+} \mid x_{ij} \geq b_{ij}, ij \in E; x_{i} \in \mathbb{Z}, i \in f \}.$$ 

We show that the set $S_{f}(G)$ 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 $\text{conv}(S_{f}(G))$ and discuss cases in which the formulation is compact.

Our goal is to describe the polyhedron $\text{conv}(S_{f}(G))$ 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, BertGerards, LaurenceWolsey)

Mixed-integer bipartite vertex covers 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.

Abstract:

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 $O(\log n)$. 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 a thm. that solves this conjecture for MSTs in the amortized setting.

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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.
Combinatorial optimization

**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 of $S$ 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) polyhedral 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 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 $n$ 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 leaving that 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.

Rafael Barbosa, Universidade Federal do Ceará (with Yoshiko Wakabayashi)

**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, in 2009 Gibson and Varadarajan designed a polynomial-time algorithm which they 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.

Rafael Barbosa, Universidade Federal do Ceará (with Yoshiko Wakabayashi)

**Random synchronized prospecting: A new metaheuristic for combinatorial optimization**
In this contribution, we introduce Random Synchronized Prospecting (RSP), a new metaheuristic for solving NP-hard combinatorial optimization problems. This metaheuristic is presented as a swarm intelligence 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.

Abderrezak Guedous, ZAK Technology (with Ibtih Bourassid)
Combinatorial optimization

Assignment problems
Chair Ger Dahl, University of Oslo

Ger Dahl, University of Oslo (with Richard Brualdi)

Generalized Birkhoff polytopes and majorization

The notion of majorization plays an important role in matrix theory and other mathematical areas, like combinatorics, probability and physics. The basic notion is an ordering of vectors according to their partial sums, but several extensions exist. The purpose of this talk is to give a lively brief introduction to majorization theory and to present some recent work on a generalization of Birkhoff polytopes related to majorization. Recall that the Birkhoff polytope is the set of all doubly stochastic matrices of a fixed size (it also corresponds to the perfect matching polytope). Main results include a generalization of the Birkhoff–von Neumann theorem and a characterization of the faces of such generalized Birkhoff polytopes. This is joint work with Richard A. Brualdi (University of Wisconsin).

Olga Heissmann, Zuse Institute Berlin (with Ralf Borndörfer, Achim Hildenbrand)

The hypergraph assignment problem

The hypergraph assignment problem (HAP) generalizes the assignment problem on directed graphs to directed hypergraphs; it is motivated by railway scheduling applications. The HAP is NP-hard even for problems with small hyperarc sizes and hypergraphs with a special partitioned structure. We propose an integer programming approach to the HAP and investigate the associated polyhedron of feasible solutions. Further, we develop combinatorial procedures that provide heuristic approximation results.

Combinatorial optimization

Graph partitioning and clustering

Organizers/Chairs Renato Wernecke, Microsoft Research Silicon Valley - Invited Session

Renato Wernecke, Microsoft Research Silicon Valley (with Daniel Dellin, Andrew Goldberg, Ilya Razenshteyn)

Exact combinatorial branch-and-bound for graph bisection

We present an overview over our graph partitioners KaFFPa (Karlruhe Fast Flow Partitioner) and KaFFPaE (KaFFPa Evolutionary). KaFFPa 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.

Christian Schulz, Karlsruhe Institute of Technology (with Peter Sanders)

High quality graph partitioning

We present an overview over our graph partitioners KaFFPa (Karlruhe Fast Flow Partitioner) and KaFFPaE (KaFFPa Evolutionary). KaFFPa 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.

Henning Meyerhenke, Karlsruhe Institute of Technology (with David Bader, Jason Riedy)

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 optimization

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 illustrate how to approximate the following values for mathematical programs with quasi-variational inequality constraints

\[ \omega = \inf_{x \in X} \sup_{u \in \Omega(x)} f(x,u) \text{ and } \varphi = \inf_{x \in X(\Omega)} \sup_{u \in \Omega(x)} f(x,u), \]

where

\[ \Omega(x) = \{ u \in S(x,u) : A(x,u,u-w) \leq 0 \ \forall \ w \in S(x,u) \} \]

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

\[ X = \{ x : \varphi(s) \leq 0, i = 1, \ldots, m \} \]

\[ S(x,u) = \{ w : \varphi(s,x,u,w) \leq 0, j = 1, \ldots, n \} \].

Using suitable regularizations for quasi-variational inequalities, we determine classes of functions \( f, \varphi, h \) allowing to obtain one-sided (from above and below) approximation of \( \varphi \) and \( \omega \), and classes of functions providing a global approximation.

Fabio Raciti, University of Catania (with Francesca Faraci)

On generalized Nash equilibrium problems: The Lagrange multipliers approach

We study a class of generalized Nash equilibrium problems and characterize the solutions which have the property that all players share the same Nash multipliers. Nash equilibria of this kind were introduced 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.

Joachim Gwinner, Universität der Bundeswehr München

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 general 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.

Invited Session

Semidefinite programming and geometric representations of graphs

Organizers/Chairs Monique Laurent, CWI, Amsterdam and U Tilburg; Christoph Helmberg, TU Chemnitz - Invited Session

Susanna Reiss, Chemnitz University of Technology (with Frank Gürgen, 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

\[ \min \{ \lambda_{\max}(L_w(G)) - \kappa_2(L_w(G)) \} \]

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 Tunçel)

**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 Tunçel.

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 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 provide 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 Verdière-type graph invariants.

Deanna Needell, Claremont McKenna College

**Randomized projection algorithms for overdetermined linear systems**

In this talk we discuss variations to projection onto convex sets (POCS) type methods for overdetermined linear systems. POCS methods have found many applications ranging from computer tomography to digital signal and image processing. The Kaczmarz method is one of the earliest possible methods for overdetermined systems of linear equations due to its speed and simplicity. Here we introduce and analyze extensions of this method which provide exponential convergence to the solution in expectation which in some settings significantly improves upon the convergence rate of the standard method.

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.

Antonio Márquez-Velázquez, Universidad de Málaga (with Júlia Viana)

**Vibration-based structural health monitoring based on a derivative-free global optimization approach**

Structural health monitoring (SHM) of critical parts is assuming a relevant role in several engineering fields such as civil, aeronautical and
aerospatial. Several SHM techniques are able to determine the presence of structural damage. However, the location and damage severity estimation are more difficult to determine.

In this talk, a new SHM approach based on optimization techniques is shown. This method is capable of, simultaneously, locate, determine the type of damage and output its severity. The considered objective function measures how well structural damage simulated data (obtained by using finite element models) compares with the observed data from the un(damaged) part in service. For 2D parts, four damage spatial variables and three material properties variables are considered. Due to the simulation process involved, objective function and derivatives are unavailable and the objective function evaluations are costly. Numerical results also show that, in order to properly determine the damage location and severity, the optimization problem has to be solved globally. We present some successful numerical results using the PSwarm solver.

Per-Magnus Olsson, Linköping University (with Holmberg Kaj, Olsson Per-Magnus)

Parallelization of algorithms for derivative-free optimization

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.

Cristina Fulga, 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 the log-returns of the portfolio are normally distributed and according 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 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.

Wei Xu, Tongji University (with Zhou 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 Curran’s sampling strategy when the number of points at each time 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 indicate that the willow tree algorithm is much more efficient than the least square Monte Carlo method and binomial tree method.

Asaf Shupo, Mena Canada TD Bank Group (with Dragos Calitxu, Hasan Mykoli)

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 optimal 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 but 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.

Wei Xu, Tongji University. Invited Session

Optimization methodologies in computational finance

In this talk we present optimization 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.

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Analysis of auction mechanisms
Organizer/Chair Yangelis Markakis, Athens University of Economics and Business - Limited Session

Renato Paes Leme, Cornell University (with Gagan Goel, Vahab Mirrokni)

Polyhedral clinching auctions and the AdWords polytope
A central issue in applying auction theory in practice is the problem of designing welfare-maximizing mechanisms. The desirable goal in practice is to design incentive compatible, individually rational, and Pareto optimal auctions while respecting the budget constraints. Achieving this goal is particularly challenging in the presence of nontrivial combinatorial constraints over the set of feasible allocations. Toward this goal and motivated by AdWords auctions, we present an auction for polyhedral environments satisfying the above properties. Our auction employs a novel clinching technique with a clean geometric description and only needs an oracle access to the submodular function defining the polyhedron. As a result, this auction not only simplifies and generalizes all previous results, it applies to several new applications including AdWords Auctions, bandwidth markets, and video on demand. In particular, our characterization of the AdWords auction as polyhedral constraints might be of independent interest. This allows us to design the first mechanism for Ad Auctions taking into account simultaneously budgets, multiple keywords and multiple slots.

Ioannis Caragiannis, University of Patras & CTI (with Christos Kaklamanis, Panagiotis Kanellopoulos, Maria Kyropoulou, Brendan Lucier, Renato Paes Leme, and Eva Tardos)

Welfare and revenue guarantees in sponsored search auctions
In sponsored search auctions, advertisers compete for a number of available advertisement slots of different quality. The auctioneer decides the allocation of advertisers to slots using bids provided by them. Since the advertisers may act strategically and submit their bids in order to maximize their individual objectives, such an auction naturally defines a strategic game among the advertisers. We consider generalized second price and generalized first price auctions in settings where the advertisers have incomplete information and present bounds on the social welfare over Bayes-Nash equilibria compared to the optimal social welfare. We also consider auctions that use a single reserve price and provide similar bounds on the revenue. Even though the above auctions are inferior to variations of the well-known VCG auction mechanism, both in terms of welfare and revenue, our results provide explanations for their adoption by the sponsored search industry.

Vasillis Syrgkanis, Cornell University (with Renato Paes Leme, Eva Tardos)

Efficiency in sequential auctions
In many settings agents participate in multiple different auctions that are not necessarily implemented simultaneously. Future opportunities affect strategic considerations of the players in each auction, introducing externalities. Motivated by this consideration, we study a setting of a single market of buyers and sellers, where each seller holds one item, bidders have combinatorial valuations and sellers hold item auctions sequentially. We examine both the complete and incomplete information version of the setting. For the complete information setting we prove that if sellers hold sequential first price auctions then for unit-demand bidders (matching market) every subgame perfect equilibrium achieves at least half of the optimal social welfare, while for submodular bidders or when second price auctions are used, the social welfare can be arbitrarily worse than the optimal. For the incomplete information setting we prove that for the case of unit-demand bidders any Bayesian equilibrium achieves at least 4/9 of the optimal welfare.

Global optimization
Global optimization methods and applications
Organizer/Chair Sergey Gortyev, Texas A&M University - Invited Session

Panos Panditopoulos, University of Florida, USA & IHE Moscow, Russia (with Panos Georgiev)

Global optimality conditions in non-convex optimization
In this talk we are going to present recent results regarding global optimality conditions for general non-convex optimization problems. First motivated by AdWords complex issues regarding the existence of points satisfying optimality conditions and the connection to complementarity problems. In addition, we are going to discuss surprising connections between optimality conditions and continuous formulations of discrete optimization problems. In the second part of the talk we are going to discuss our recent result regarding optimality conditions of locally Lipschitz functions.

Erick 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 not-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-feedback-vertex-set and the multiple-genome alignment problems. 

Austin Buchanan, Texas A&M University (with Sergiy Butenko, Anar Vayva)

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
Exact MIP/LP solvers
Organizer/Chair Daniel Steffy, Oakland University - Invited Session

Sebastian Hoffmann, Johannes Gutenberg-Universität Mainz (with Ernst Althaus, Bernd Becker, Daniel Dumitru, Stefan Kupferschmid)

Integration of an LP solver into interval constraint propagation
In this talk we describe the integration of a linear program (LP) solver into iSAT, a Satisfiability Modulo Theories (SMT) solver that can solve Boolean combinations of linear and nonlinear constraints. iSAT is a tight integration of the well-known DPLL algorithm and interval constraint propagation (ICP) allowing it to reason about linear and nonlinear constraints. As interval arithmetic is known to be less efficient on solving linear programs, we will demonstrate how the integration of an LP solver can improve the overall solving performance of iSAT.

Kari Woite, Zuse Institute Berlin (ZIB) (with William Cook, Thorsten Koch, Daniel Steffy)

An exact rational mixed-integer programming solver
We present an exact rational solver for mixed-integer programming that avoids the numerical inaccuracies inherent in the floating-point computations used by existing software. This allows the solver to be used for establishing theoretical results and in applications where correct solutions are critical due to legal and financial consequences. Our solver is a hybrid symbolic/numeric implementation of LP-based branch-and-bound, using numerically-safe methods for all binding computations in the search tree. Computing provably accurate solutions dynamically choosing the fastest of several safe dual bounding methods, our exact solver is only moderately slower than an inexact floating-point branch-and-bound solver. The software is incorporated into the SCIP optimization framework. Computational results are presented for a suite of test instances taken from the MIPLIB and Mittelmann libraries and for a collection of numerically difficult instances.

Ojas Parekh, Sandia National Labs (with Robert Carr, Harvey Greenberg, Cynthia Phillips)

Computing certificates for integer programs
A certificate for a integer programming (IP) computation is information that allows an independent program to check that the output is correct, preferably far faster than the time required to compute the solution. The canonical example is the primal/dual certificate for a linear program (LP). Although solving an LP can take a large amount of time, checking a certificate requires two matrix vector multiplications and two dot products. A brute force certificate for an integer program branch-and-bound computation must prove that each branching operation, added cut, and fathoming operation is correct. We will discuss what this entails in the context of PCI0, our massively parallel integer programming solver. We give certificates for some general cut classes and discuss ways to prove the correctness of a general cut, which is equivalent to another integer program. These integer programs appear to be significantly easier than the original IP. Intuitively, they are equivalent to proving integer feasibility for the polytopes “cut off”. We will discuss numerical and other implementation issues and give computational results for moderate-size IPs.
In this presentation, we describe algorithms and software abstractions for a matrix-free code for PDE constrained optimization problems that contain both equality as well as cone constraints. The key to our discussion lies in the development of simple algebraic abstractions that allow us to build an efficient code and how these abstractions change between the 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 Pototschka, Heidelberg University (with Hans-Georg Boej)

**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 Method of Lines, Direct 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 Sollya 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.

**Unison Rooming HUS**

**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 compromise 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.

**Karin Thörnblad, Chalmers University of Technology (with Torgny Almgren, Michael Patriksson, Ani-Brith Strömberg)**

**Implementations & software**

**Wed.2.H 1054**

**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 contain both equality as well as cone constraints. The key to our discussion lies in the development of simple algebraic abstractions that allow us to build an efficient code and how these abstractions change between the 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.

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**Implementations & software**

**Wed.2.H 2032**

**Polyhedral theory**

Organizer/Chair Quentin Louveaux, University of Liège - Invited Session

Carla Michini, Sapienza Universitá di Roma (with Gerardo Cornuéjols, 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 related 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 Poirrier, University of Liège (with Quentin Louveaux, Domenico Salvagnin)**

**Valid inequalities for the single arc design problem with set-ups**

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 Doostmohammadi, University of Aveiro (with Agostinho Agra, Quentin Louveaux)**

**The strength of multi-row models**

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**Mohdi Doostmohammadi, University of Aveiro (with Agostinho Agra, 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 Wolsey)

**The structure of LLL-reduced kernel lattice bases: background and outline of the main result**

The so-called lattice reformulation 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 iden-
tity 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 Wolsey)

**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 Wolsey)

**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.

**Lattices and integer programming**

*Organizer/Chair: Karen Aardal, Delft University of Technology. Invited Session*

For all.

**Logistics, traffic, and transportation**

*Organizer/Chair: Heiko Schilling, TomTom International B.V.*

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

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 signific-
antly 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 naviga-
tion 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 algo-
rithmic game theory. We will conclude with some research challenges and their practical relevance.

Arne Keiting, TomTom International B.V.

**The dynamics of traffic jams – How data and models help to understand the principles of traffic 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 traf-
icjam 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.

Tobias Marschall, Centrum Wiskunde & Informatica (with Markus Bauer, Stefan Canzar, Ivan Costa, Gunnar W. Klau, Alexander Schlip, Alexander Schönhuth)

**CLEVER: Clique-enumerating variant finder**

Next-generation sequencing techniques have for the first time fa-
cilitated a large scale analysis of human genetic variation. However, de-
spite the advances in sequencing speeds, achieved at ever lower costs, the computational discovery of structural variants is not yet standard. It is likely that a considerable amount of variants have remained undis-
covered in many sequenced individuals. Here we present a novel inter-
nal segment size based approach, which organizes all, including also concordant reads into a read alignment graph where max-cliques rep-
resent maximal contradiction-free groups of alignments. A specifically engineered algorithm then enumerates all max-cliques and statistically evaluates them for their potential to reflect insertions or deletions (in-
dels). We achieve highly favorable performance rates in particular on indels of sizes 30–500 bp and predict a considerable amount of correct, but so far undiscovered variants.

Suzanne Page, FAU Erlangen-Nürnberg, Discrete Optimization (with Alexander Martin)

**Computational complexity of the multiple sequence alignment problem**

During the last decades, continuing advances in molecular bioinfor-
matics (for example the Human Genome Project) have led to increased understanding about biological sequences like protein or DNA sequences. Multiple alignments of these sequences play an important role in de-
tecting conserved subregions, inferring evolutionary history, or predict-
ing protein structure and function. We study the computational com-
plexity of two popular problems in multiple sequence alignment: multi-
ple alignment with SP-score and multiple tree alignment - two prob-
lems that have indeed received much attention in biological sequence comparison. From a mathematical point of view, both problems are dif-
ficult to solve and often remain hard, even if we restrict the problems to instances with scoring matrices that are a metric, a binary alphabet, or a gap-0-alignment (i.e. sequences can be shifted relative to each other, but no internal gaps are allowed). Here, we give an overview of some re-
cent results about NP-completeness and Max-SNP-hardness, analyze the computational complexity of some restricted versions of this prob-
lem, and present some new complexity and approximation results.

Susanne Page, FAU Erlangen-Nürnberg, Discrete Optimization (with Alexander Martin)

**The structure of LLL-reduced kernel lattice bases: background and outline of the main result**

The so-called lattice reformulation 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 ker-

nel 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 re-
duced kernel lattice bases. More specifically, a lattice basis will contain an iden-
tity 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 presen-
tation 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 Wolsey)

**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 Wolsey)

**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.

**Life sciences & healthcare**

*Organizer/Chair: Gunnar Klau, CWI; Alexander Schönhuth, Centrum Wiskunde & Informatica, Amsterdam. Invited Session*

Stefan Canzar, Johns Hopkins University (with Sandro Andreotti, Gunnar Klau, Knut Reinert, David Weese)

**Transcriptome reconstruction using delayed column generation**

Through alternative splicing, fragments of an RNA transcript of a gene, the exons, are recombined in different ways to generate different mRNA molecules, which in turn code for proteins. Determining the set of transcript variants and their abundance from millions of short se-
quence reads from the RNA complement of a cell is referred to as the transcriptome reconstruction problem. The main difficulty is that differ-
ent mRNA variants transcribed from the same gene may share a consid-
erable fraction as a common subsequence. Deciding from which variant a short read originates can thus be intricate and has to be done interde-
pendently, based on the global information provided by high-throughput transcriptome sequencing data.

We present an algorithm that implicitly explores the entire space of all possible transcriptomes by using a delayed column generation ap-

proach. We show that the pruning problem is a variant of the longest path problem in directed acyclic graphs, which we can solve efficiently.

Tobias Marschall, Centrum Wiskunde & Informatica (with Markus Bauer, Stefan Canzar, Ivan Costa, Gunnar W. Klau, Alexander Schlip, Alexander Schönhuth)

**CLEVER: Clique-enumerating variant finder**

Next-generation sequencing techniques have for the first time fa-

Auction theory and recent work on pricing with strategic consumers, we consider that arrivals over time according to a random process. Combining mechanisms to sell a single item when the number of bidders is random will be explored. Optimal continuous pricing with strategic consumers

Maxime Cohen, MIT (with Ruben Labab, Georgia Perakis)

Designing consumer subsidies with industry response for green technology adoption

The recent developments in green technologies would not have been possible without the subsidies offered by the government to consumers. While the government designs subsidies to stimulate adoption of new technologies, the manufacturing industry responds to these policies with the goal to maximize profits. In this talk, we study how government should set subsidies when considering the industry’s response.

An interesting problem in mechanism design is that of finding Nash equilibria of a logit choice model. The true parameters of the logit model are assumed to be unknown, and we represent the set of likely parameter values by a compact uncertainty set. The objective is to find an assortment that maximizes the worst case expected revenue over all parameter values in the uncertainty set. We give a complete characterization of the optimal policy in both settings, show that it can be computed efficiently, and derive operational insights. We also propose a family of uncertainty sets that enables the decision maker to control the tradeoff between increasing the average revenue and protecting against the worst case scenario. Numerical experiments show that our robust approach, combined with our proposed family of uncertainty sets, is especially beneficial when there is significant uncertainty in the parameter values.

Pavithra Harsha, IBM Research (with Ramesh Natarajan, Dharmashankar Subramanian)

Demand-response in the electricity smart grid: A data-driven pricing and inventory optimization approach

Demand response schemes based on dynamic pricing are of considerable interest in the emerging smart grid. For instance, an electric utility can optimize its operational objectives by providing certain “price incentive signals” to consumers, so as to minimize generation, spinning reserve and salvage costs, and revenue shortfalls, while simultaneously satisfying the resulting stochastic responsive demand. Although perhaps not well known and widely used, this demand-management problem can be formulated as a classical price-sensitive, newsvendor model, but with several enhancements to make it applicable to the smart grid context. A major concern is the interaction of multiple drivers of demand, including weather, time-of-day, and seasonality, in addition to the type and form of the incentive signals. We consider a novel approach that is based on the use of quantile and mixed quantile regression to jointly estimate the optimal stocking level and pricing signals. This approach is data-driven, distribution-free, and makes best use of the sparse, high-dimensional demand data. We illustrate its efficacy, robustness and accuracy over possible alternatives with computational examples.

Pavithra Harsha, IBM Research (with Ramesh Natarajan, Dharmashankar Subramanian)

New algorithms for new pricing models

Organizer/Chair Hamid Nazerzadeh, Marshall School of Business - Invited Session

Logistics, traffic, and transportation

An interesting problem in mechanism design is that of finding mechanisms to sell a single item when the number of bidders is random. In this paper we take a step further to the static situation and derive an optimal pricing scheme when selling a single item to strategic consumers that arrive over time according to a random process. Combining auction theory and recent work on pricing with strategic consumers, we derive the optimal pricing mechanism in this situation under reasonable conditions.

Achish Goel, Stanford University (with Bahman Bahmani, Goel Dandekar, 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 will first describe a model of networked trust that functions by exchange of IOUs among nodes. Informally, every node acts as a bank and prints its own currency, which is then used to purchase services within the network. Such “trust networks” are robust to inflation, 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.

Azarakhsh Malekian, Massachusetts Institute of Technology (with saeed alaei, hu fu, nima haghpanah, 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 challenge areas 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.

Toni Lastusilta, GAMS Software GmbH (with Michael R. Bussieck, Stefan Emel)

Structured MINLP and applications

Organizer/Chair Noam Goldberg, Mathematics and Computer Science Division, Argonne National Laboratory - Invited Session

Noam Goldberg, Mathematics and Computer Science Division, Argonne National Laboratory (with Sven Leyffer, Ilya Safro)

Cover inequalities for nearly monotone quadratic MINLPs

Cover Inequalities for nearly monotone quadratic 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 Ono)

Hilbert’s Nullstellensatz and the partition problem: An infeasibility algorithm via the partition monomial 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 refutations, or certificates of infeasibility when the underlying set of integers W is non-partitionable. We present an algorithm for 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 $W$.

MOPVC and establish relationships among various constraint qualifications which ensure that GGCQ holds for the MOPVC.

Ingrida Steponavičė, University of Jyväskylä (with Kaisa Miettinen)

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.

Luís Lumbarda Perez, Federal University of Goias (with Jose Vitorino Belo Cruz)

A modified subgradient algorithm for solving $K$-convex inequalities

Thirty years ago, Robinson proposed a subgradient method for solving $K$-convex inequalities in finite dimensional spaces. In this work, we propose a modification of this method that allows to solve systems of $K$-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.

Michael Engelhart, Interdisciplinary Center for Scientific Computing (IWR), Uni Heidelberg (with Joachim Funke, Sebastian Sager)

A new test-scenario for analysis and training of human decision making with a tailored decomposition approach

In the real domain complex problem solving in psychology, where the aim is to analyze complex human decision making and problem solving, computer-based test-scenarios play a major role. The approach is to evaluate the performance of participants within microworlds and correlate it to certain attributes, e.g., the participant's capacity to regulate emotions. In the past, however, these test-scenarios have usually been defined on a trial-and-error basis to realize specific requirements for the testee. The more complex models become, the more likely it is that unforeseen and unwanted characteristics emerge in studies. To overcome the previously important problem, we propose to use mathematical optimization methodology on three levels: first, in the design stage of the complex problem scenario, second, as an analysis tool, and third, to provide feedback in real time for learning purposes. We present a novel test scenario, the IWR Tailorshop, with functional relations and model parameters that have been formulated based on optimization results, as well as a tailored decomposition approach to address the resulting nonconvex nonlinear mixed-integer programs.

Michael Engelhart, Interdisciplinary Center for Scientific Computing (IWR), Uni Heidelberg

Chair

Optimal resource allocation in survey designs

Resource allocation is a relatively new research area in survey design and has not been fully addressed in the literature. Survey organizations across the world are considering the development of new mathematical models in order to improve the quality of survey results while taking into account optimal resource planning.

The resource allocation problem for survey designs has specific features that lead to a formulation as a nonconvex integer nonlinear problem, which prohibits the application of many algorithms that are found in the literature. Current global optimization tools that address general nonconvex integer problems suffer from long computational times and limitations in the problem size. Moreover, implementing solutions from convex approximations of the problem may result in major errors in survey results.

We present an algorithm that solves the problem to optimality using Markov decision theory. Additionally to optimal resource planning, the algorithm can handle various practical constraints that aim at improving the quality of survey results. The algorithm is implemented in C++, it achieves short computational times and it can handle large-scaled problems.

Available online at: IWR Tailorshop www.iwr.uni-heidelberg.de/tailorshop

Topics in mixed-integer nonlinear programming II

Chair Michael Engelhart, Interdisciplinary Center for Scientific Computing (IWR), Uni Heidelberg

Melania Calinescu, VU University Amsterdam (with Sandi Banjac, Barry Shotton)

Optimal resource allocation in survey designs

Michael Engelhart, Interdisciplinary Center for Scientific Computing (IWR), Uni Heidelberg (with Joachim Funke, Sebastian Sager)

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linear least-squares problems and bound-constrained convex quadratic programming.

Serge Gratton, ICTE-CEMEACS (with Selima Gued, Philippe Toint, Jean Tomienga)

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 non-linear 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 10^9. 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.

Applications of optimization I

Chair: Marc Steinbach, Leibniz Universität Hannover

Makoto Yamashita, Tokyo Institute of Technology (with Zh-Zin 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 hoping 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. The main difficulty of this 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, break-point and quasi-Newton classes of methods, for sizes up to about 10^6 variables. Establishing a new implementation of a relaxation algorithm utilizing a blended evaluation of the relaxed problem performs the best in general, having linear practical convergence even for very many variables.

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 problems and constrained optimization 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 model-redundancy and a covariance computation based on an SVD or a QR decomposition with pivoting.

Applications of nonsmooth optimization

Chair: Amirhossein Sadeghi, Frankfurt School of Finance & Management

Ann-Britt Strömberg, Chalmers University of Technology (with Emil Gustafsson, Torbjörn Larsson, Magnus Önnheim, 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 solution 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 finitely 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 Claudio Gesteira, Vinciquera 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 p-hub median problem consists in finding the least expensive HS network, locating a given number of p 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.

Amirhossein Sadeghi, Frankfurt School of Finance & Management (with Oleg Burdakov, Anders Grimvall)

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 priory 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 recently developed Generalized Pool-Adjacent-Violators (GPAV) algorithm.

Optimization in energy systems

Chair: Amirhossein Sadeghi, Frankfurt School of Finance & Management

Wim van Ackooij, EDF R&D (with René Henrion, Claudia Sagastizabal)

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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.

András Müller, Weierstrass Institute Berlin (WIAS) (with René Henrion, Vin Van Ackooij, Riadh 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 behaviour of these quantities we consider optimization problems with joint probabilistic constraints of the type

$$\min_{x} \mathbb{E}[c^T x] \mid P(A(x) \xi \leq b(x)) \geq p, x \in X$$

where $p \in (0, 1)$ is the required probability level.

The treatment of this optimization problem requires the computation of function values and gradients of $g(x) := P(A(x) \xi \leq b(x))$. 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 Kovacevic, University of Vienna (with Alois 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 Pligung and Pichler [2011]: The process-distance used is based on the process’ law, accounts for increasing information over time and generalizes the Wasserstein distance, which itself is a distance for probability measures. In this framework we implement an algorithm for improving the Wasserstein distance, which itself is a distance for probability law, accounts for increasing information over time and generalizes the Pichler (2011): The process-distance used is based on the process’

...
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.

Fiorian Bruno, Universitätsbibliothek (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 aspects of the problem are affected by uncertainty.

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/INRIA (with Alain Billionet, 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 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 storage 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.

Organizer/Chair Shiqian Ma, University of Minnesota - Invited Session

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 minor second order term is needed for the efficient and capability of solving very large problems. The global convergence result of the proposed algorithm is established. Numerical results on both synthetic data and gene expression data are shown to demonstrate the efficiency of the proposed method.

Organizer/Chair Fiorian Bruno, Universitàtisbibliothek (with Marc Goerigk, Sajid Knust, Anita Schöbel)

Sparse approximation via penalty decomposition methods

In this talk we consider sparse approximation problems, that is, general $l_p$ minimization problems with the $l_q$-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 $O(1/\epsilon)$ iterations to obtain an $\epsilon$-optimal solution and the ALB algorithm reduces this iteration complexity to $O(1/\sqrt{\epsilon})$ 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.

Efficient first-order methods for sparse optimization and its applications

Organizer/Chair Shiqian Ma, University of Minnesota - Invited Session

Recently, Nemirovski et al. established the tractability of a class of convex stochastic programs in the randomized setting. This talk describes classes of convex stochastic programs that are tractable in the stronger, worst case setting.

Jitima Desai, Nanyang Technological University (with Sun Yujie, Sen)

A mathematical programming framework for decision tree analysis

One of the most important analytical tools often used by management executives is decision tree analysis. Traditionally, the solution to decision tree problems has been accomplished using backward recursion or more specifically stochastic dynamic programming techniques, but such methods have been shown to suffer from a number of shortcomings. In this research effort, we present a mathematical programming formulation for solving decision tree problems that not only alleviates the difficulties faced by traditional approaches but also allows for the incorporation of new classes of constraints that were hitherto unsolvable in this decision-making context. We begin by presenting a mathematical representation of decision trees as a (path-based) polynomial programming problem, which can be efficiently solved using a branch-and-bound method. Recognizing the exponential increase in problem size for large-scale instances, we extend this basic characterization to a compact path-based relaxation and exploit the special structure of this formulation to design an efficient globally optimal branch-price-and-cut algorithm.

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Efficient first-order methods for sparse optimization and its applications

Organizer/Chair Shiqian Ma, University of Minnesota - Invited Session

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 minor second order term is needed for the efficient and capability of solving very large problems. The global convergence result of the proposed algorithm is established. Numerical results on both synthetic data and gene expression data are shown to demonstrate the efficiency of the proposed method.

Zhaoqiong Lu, Simon Fraser University (with Yong Zhang)
Stochastic optimization

Large-scale stochastic programming
Organizer/Chair Mihai Anitescu, Argonne National Laboratory - Invited Session
Andreas Grotthey, 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 warmed-started from the previous one. We analyse the resulting algorithm, argue that it yields improved complexity over either the coldstart or a naive two-stage scheme, and give numerical results.

Miles Lubin, Massachusetts Institute of Technology (with Mihai Anitescu, J. A. Julian Hall, Kipp Martin, Cosmin Petra, Barbara Banhegyi, Sanddor Szedon)

Parallel and distributed solution methods for two-stage stochastic (M)ILPs
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 interior point relaxation of the problem akin to Carøe 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 the effectiveness on a stochastic power grid unit commitment problem as well as problems from the literature.

Werner Römisch, Humboldt-University Berlin (with Helge Heitsch, Henner Longy)

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 $O(n^{-1+\epsilon})$ for $\epsilon \in (0,1/2)$ 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.

Andreas Bley, TU Berlin (with Janik Matuschke, Benjamin Müller)

Capacitated facility location with length bounded trees
We consider a generalization of the Capacitated Facility Location problem, where clients may connect to open facilities via trees shared by multiple clients. The total demand of clients served by a single tree must not exceed a given tree capacity. Furthermore, the length of the path between a client and its facility within the corresponding tree must not exceed a given length bound. The task is to choose open facilities and shared service trees in such a way that the sum of the facility costs and the tree costs is minimal. This problem arises, for example, in the planning of optical access networks in telecommunications, where multiple clients may share a fiber tree if both fiber capacity and signal attenuation on the resulting connection paths permit. We show that the problem is as hard as Set Cover in general and approximable with a constant factor for metric edge lengths that individually do not exceed the length bound. For the latter case, we present a general approximation algorithm and discuss several modifications of this algorithm that yield better approximation ratios or additional solution properties in special cases.

Organizer/Chair Markus Leitner, Vienna University of Technology (with Luis Gouveia, Ivana LJubic)

Layered graph models for hop constrained trees with multiple roots
We consider a network design problem that generalizes the hop constrained Steiner tree problem as follows. Given an edge-weighted undirected graph whose nodes are partitioned into a set of root nodes, a set of terminals and a set of Steiner nodes, find a minimum-weight subtree that spans all the roots and terminals such that the number of hops between each relevant node and an arbitrary root does not exceed a given hop limit. The set of relevant nodes may be equal to the set of terminals, or to the union of terminals and root nodes. We first introduce a natural mixed integer programming formulation using edge and node decision variables based on jump cuts. We then propose models utilizing one layered graph for each root node. Possibilities to relate solutions on the layered graphs and additional strengthening inequalities are discussed. Furthermore, theoretical comparisons between these models and previously proposed flow-based and path-based models are given. To solve the problem to optimality, we implement branch-and-cut algo-

Organizer/Chair Stephen Robinson, University of Wisconsin-Madison - Invited Session
Bart Morshuikhov, 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 applicability 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 characterize 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 generally, 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 SVI. 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 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.

Bara Saha, AT& T Shannon Research Laboratory (with Bernhard Haeupler, Aravind Srinivasan)
The constructive aspects of the Lovász Local Lemma: finding needles in a haystack

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 an 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.

Aravind Srinivasan, University of Maryland

Dependent rounding and its applications

Randomized rounding is a well-known and powerful tool in rounding solutions to relaxations of optimization problems. Starting with the work of Ageev and Sviridenko, the notion of dependent randomized rounding has led to significant progress in a variety of approximation algorithms: one carefully defines dependencies between several basic random variables in the rounding process. We will present a brief survey of this area, including works of the speaker and those of Calinescu, Chekuri, Pal and Vondrak.

Viswanath Nagarajan, IBM Research (with Anupam Gupta, R. Ravi)

The bounded sequential multiple knapsack problem

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. This problem is known in the literature as Bounded Sequential Multiple Knapsack Problem (BSMKP). Several authors have addressed the Bounded Sequential Knapsack Problem (BSKP). Pochet and Weismantel provided a description of the bounded sequential single-knapsack polytope. Polynomial time algorithms for BSKP and BSMKP are also proposed in the literature. This work basically extends the study of Pochet and Weismantel to BSMKP. Specifically, problem transformations are proposed for BSMKP that allow a characterization of the optimal solutions and the description
of the BSMKP polytope. Keywords: bounded sequential multiknapsack, optimal solutions, polytope description.

Joachim Schauer, University of Graz (with Ulrich Pferschy)

Knapscack 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 enforce 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.

Noriyoshi Sukegawa, Tokyo Institute of Technology (with Yoshitsugu Yamamoto, Liyuan 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

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 a semidefinite programming relaxation 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-allocated room assignments. These relaxations can be solved efficiently using alternating direction augmented Lagrangian methods (ALM). We present an ALM, which exploits the structure of the matrices involved and is essentially “matrix-free” except for a projection on the cone of positive semidefinite matrices. It can be shown the rate of convergence of ALMs with a given error bound is asymptotically the best possible, among first-order methods. The computational results suggest this may turn out to be the method of choice in practical timetabling.

Polina Kononova, 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 NP-hard. We present some ILP-reformulations to get lower bounds and VNS-heuristic to find optimal or near optimal solutions. The Kernighan-Lin neighborhoods and job-window neighborhoods are used in the VNS framework. For experiments we generate large scale instances with known global optimal. Computational results and some open questions are discussed.

Beyran Ceyl, Aándose University (with Nil Aksu)

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

Combinatorial optimization

Combinatorial optimization
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 warehouse 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

Wed.3.H 3013

Polyhedra in combinatorial optimization
Chair Shunco Koichi, Nanzan University

Shunco Koichi, Nanzan University

A note on ternary semimodular polyhedra

A ternary semimodular polyhedron associated with a submodular function on \{0, 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\} 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\} 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.

Aleskandr 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, Matsui 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 show also that the graph of a double covering polytope is a superpolynomial clique number. The same is true for the mentioned families of polytopes.

Shaheli 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 \(X_{SNF}\) respectively, are well-known relaxations of the capacitated facility location polytope \(X_{FL}\). In earlier studies specific classes of facets for \(X_{K}\) and \(X_{SNF}\) have been proved to be facets also for \(X_{FL}\), and the computational effectiveness of these classes have also been demonstrated for \(X_{FL}\). In this presentation we prove more general relationships between the polytopes \(X_{K}\), \(X_{SNF}\), and \(X_{FL}\). We also prove results in the spirit of Goemans’ worst-case comparison of valid inequalities.

Combinatorial optimization

Wed.3.H 3021

Routing in road networks
Organizer/Chair Andrew Goldberg, Microsoft Research - Invited Session

Peter Sanders, Karlsruhe Institute of Technology (with Yelt Batz, Robert Geigerber, Monir Kobitzsch, Dennis Luers, Dennis Schierendecker)

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 Itti Abraham, Daniel Delling, Ames Fait, 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 sets 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 does not 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.
to the penalty IPDE converges to that of the variational inequality problem 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.

**Conic programming**

**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 optimization methods, we measure the computational cost based on the oracle 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 properties of the resulting PEP for various black-box first order schemes. This allows us to prove a new tight analytical bound for the classical gradient method, as well as to derive numerical bounds that can be efficiency computed for a broad class of first order schemes. Moreover, we derive 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 Optimization) as an extension to Nemirovski-Yudin’s algorithm. CGSO is a conjugate gradient type algorithm that benefits from the optimal complexity bound Nemirovski-Yudin’s algorithm achieves for the class of unconstrained convex problems. In this talk, we discuss CGSO for convex problems with polyhedral constraints. We study the theoretical properties as well as the practical performance of CGSO for this class of problems.

**Conic and convex programming in statistics and signal processing IV**

Organizer/Chair Punitkirti Shah, University of Wisconsin - Invited Session

Defeng Sun, National University of Singapore (with Weinan Min)

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 cannot be applied to achieve this goal in the noisy setting. Here, we propose a new convex optimization approach by using a linear regularization term based on the observation matrix to represent the rank information. This convex optimization problem can be easily written as an $H$-weighted least squares semidefinite programming problem, which can be efficiently solved, even for large-scale cases. Under certain conditions, 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—namely, strong convexity and smoothness conditions—that underlie much of classical optimization analysis. We define appropriately restricted versions of these conditions, and show that they are satisfied with high probability for various statistical models. Under these conditions, our theory guarantees that composite gradient descent has a globally geometric rate of convergence up to the statistical precision of the model, meaning the typical distance between the true unknown parameter $\theta$ and an optimal solution $\hat{\theta}.$ 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 solving 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 system identification problem, the gradient projection method (accelerated by Nesterov’s extrapolation techniques) 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.

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 renewable 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 maximize 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 minimization problem and has associated algorithmic design challenges when we require a mechanism that can support the elicitation of preferences from potentially tens of thousands of agents in public auctions.

René Schinzel, Federal University of Lübeck (with Martin Lückner)

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 general and to account for special properties of EVs in particular. Besides the geometry of the route, one could be interested in additional parameters into the route, such as altitude maps, congestion probabilities, the weather forecast, multi-modality, the energy consumption of a fleet or 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 conditional expectation value of the energy use (given that a minimal success rate is satisfied). By adapting an algorithm from Uludag et al., we developed an algorithm to approach the mentioned energy-optimal path.

**Computational sustainability**

Organizer/Chair Alan Holland, University College Cork - Invited Session

Alan Holland, University College Cork (with Barry O’Sullivan)

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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 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 point of view, we wish to extract mathematical relationships to be modeled as constraints. In order to extract significant information from simulations, they should be run on 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 Scalay-Ile-de-France (with Michela Milano, Fabrizio Riguzzi)

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Anne Auger, INRIA Scalay-Ile-de-France (with Michela Milano, Fabrizio Riguzzi)

A continuous GRASP for global optimization with general linear constraints

A new variant of the global optimization method Continuous GRASP (C-GRASP) is presented. The new variant incorporates general linear constraints in addition to box constraints. C-GRASP solves continuous global optimization problems subject to box constraints by adapting the greedy randomized adaptive search procedure [GRASP] of Feo and Revented (1989) for discrete optimization. It has been applied to a wide range of continuous optimization problems. We consider the box constraints as implicit and handle the general linear equality/inequality constraints explicitly. If we are given an \( m \times n \) matrix \( A \), with \( m < n \), then all basic variables can be eliminated from the global optimization problem. A Reduced Problem in \( n - m \) independent variables will be subject only to the box constraints. The C-GRASP solver is a derivative-free global optimization method yielding an optimal or near-optimal solution to the Reduced Problem. The basic variables can be computed by solving a system of linear equations. If all basic variables are inside the box, the algorithm stops. Otherwise a change-of-basis procedure is applied, and a new Reduced Problem is solved.

Sebastian Stich, ETH Zürich (with Bernd Gärtner, Christian Müller)

Convergence of local search

We study unconstrained optimization of convex functions. Many algorithms generate a sequence of approximate solutions to this optimization problem. Usually, these algorithms are analyzed by estimating the (expected) one-step progress. However, in case of randomized algorithms it is often difficult to obtain bounds on the variance of the whole process. We present a general framework to analyze local search algorithms. Suppose that an algorithm proposes in each iteration exactly one new feasible solution that sufficiently improves the last iterate, i.e., a local decrease condition is satisfied. Karmakov (1974) presented a genuine method to analyze such a local search algorithm for differentiable convex functions. We extend his approach to strongly convex functions where linear convergence rates can be established with high probability. This approach can be used to analyze deterministic as well as randomized optimization algorithms. We show that for instance the Random Gradient method (Nesterov 2011), as well as Random Pursuit (Stich et al. 2011) can be analyzed by this framework. We conclude with another interesting example, namely derivative-free local metric learning.

Anne Auger, INRIA Scalay-Re-de-France (with Yuichi Akimoto, Nikolai 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 when determining candidate solutions. Hence they are invariant when transforming \( f \) or \( g \) of where \( g : \mathbb{R} \rightarrow \mathbb{R} \) is monotonically increasing. Recently, some adaptive ESs where shown to be stochastic approximations of a natural gradient algorithm in the manifold defined by the family of probability distributions. An ODE is naturally associated to this natural gradient algorithm when the step-size goes to zero. Solutions of this ODE are continuous time models of the underlying algorithms.

In this talk we will present convergence results of the solutions of this ODE and prove their local convergence on monotonic \( C^2\)-composite functions towards local optima of the function. We will also present global convergence of the corresponding algorithm on some scale-invariant functions as defined as functions such that \( f(x) < f(y) \) if \( f(sx) < f(sy) \) for all \( s > 0 \).

Marco Savarelli, University of Ferrara (with Michela Milano, Fabrizio Riguzzi)

Optimization and simulation 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 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 point of view, we wish to extract mathematical relationships to be modeled as constraints. In order to extract significant information from simulations, they should be run on 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 Scalay-Ile-de-France (with Michela Milano, Fabrizio Riguzzi)
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, LRI

The complexity of approximate Nash equilibrium in congestion games with negative delays

The extended study of the complexity of computing an \( \epsilon \)-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 \( \alpha \)-bounded jumps the \( \epsilon \)-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 to compute Nash equilibria of games with increasing delay functions and \( \alpha \)-bounded jumps when the delays can be both positive and negative: in that case computing an \( \epsilon \)-Nash equilibrium becomes \( \text{PLS} \)-complete, even if each delay function is of constant sign or of constant absolute value.

Wed.3.AA 042

Solving cooperative games

Chair Kazutoshi Ando, Shizuoka University

Tri-Dung Nguyen, University of Southampton

Finding solutions of large cooperative games

The nucleus 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 nucleus is very challenging because this involves lexicographical minimization of an exponentially large number of excess values. We present a method for computing the nucleus 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 nucleus 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 Hong Kong (with Chueyng 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 whether core existences, 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 \( \text{NP} \)-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: \( \text{NP} \)-hardness and polynomial cases

We show that computing the Shapley value of minimum cost spanning tree games is \( \text{NP} \)-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 \( \text{NP} \)-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 \( O(n^2) \) time, where \( n \) is the number of players.

Global optimization

Wed.3.JH 2053

Nonconvex optimization: Theory and algorithms

Organizer/Chair Evrim Dalkiran, Wayne State University - Invited Session

Evrim Dalkiran, Wayne State University (with Hande 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 bond 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 randomly 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 Kedong 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 Schaber, 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 investigated 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 stability region of the solutions 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.

Thorstien Koch, ZIB (with Gerald Gamrath, Hans Mittelmann)
Any progress one year after MIPLIB 2010?
It has been a little more than one year after the release of MIPLIB
2010. How much progress has there 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. Modelers 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.

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
simulators 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)
Fi OroDs: A Matlab toolbox for C-code generation for first-order
methods
Fi OroDs is the first toolbox for automated C-code generation for
first-order methods. It considers the class of multi-parametric convex
programs 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
respectively. Thus, solver code for problems beyond quadratic program-
ning can be generated. If required, the solution approach is based on
Lagrangian relaxation which uses the gradient or the fast gradient method
at a lower level. Additional toolbox features include optimal precondi-
tioning and the automatic certification of the iteration count for a re-
stricted set of problems. The generated C-code can be compiled for
any platform and can be made library-free. Fi OroDs 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.
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 using decomposition-based techniques for solving linear and mixed-integer linear programs. Using the modeling language provided by the OPTMODEL procedure in SAS/OR software, a user can easily experiment with different decompositions simply by modifying the partition of constraints in the original compact problem. All algorithmic 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 applications where DECOMP was successfully used, including results in both shared and distributed memory parallel environments.

José María Ucha, Universidad de Sevilla (with F. Castro, J. Gago, M. Hartillo, J. Puerto)
Applications of discrete optimization to numerical semigroups
In this talk we will show some connections between discrete optimization and commutative algebra. In particular we analyze some problems in numerical semigroups, which are sets of nonnegative integers, closed under addition for which their complement is finite. In this algebraic framework, we will prove that some computations that are usually performed by applying brute force algorithms can be improved by formulating the problems as (single or multiobjective) linear integer programming. For instance, computing the omega invariant of a numerical semigroup (a measure of the primality of the algebraic object), decompositions into irreducible numerical semigroups (special semigroups with simple structure), homogeneous numerical semigroups, or the Kunz-coordinates vector of a numerical semigroups can be done efficiently by formulating the equivalent discrete optimization problem.

Víctor Blanco, Universidad de Granada (with Justo Puerto)
Algebraic tools for nonlinear integer programming problems 1: Getting started
In this first talk we revisit a classical approach for obtaining exact solutions of some nonlinear integer problems. We treat the case of linear objective function with linear and nonlinear constraints. Besides the test-set of some linear subpart of the problem, calculated via Grobner bases (sometimes obtained explicitly without computation), we propose some extra ingredients. We show how to use information from the continuous relaxation of the problem, add quasi-tangent hyperplanes and use penalty functions as a guide in the search process.

José-Martía Ucha, Universidad de Sevilla (with F. Castro, J. Gago, M. Hartillo, J. Puerto)
Algebraic tools for nonlinear integer programming problems 2: Applications
In this second talk of the series we present how the methodology works in some real problems, namely construction of integer portfolios and redundancy allocation problems in series-parallels systems. Only in the first case the nonlinear part is of convex type. We analyze how the ideas introduced in the first talk provide promising results in computational experiments. On the other side, the combination of using test-sets and heuristics techniques opens a new approach for getting good solutions in facing huge problems.

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Radiation therapy treatment planning
Organizer/Chair: Edwin Romeijn, University of Michigan - Invited Session
Tony Long, University of Michigan (with Hildred Rameijn)
Beam orientation optimization in radiation therapy treatment planning
A characterization of robust radiation therapy optimization methods
A key aspect of external beam radiation therapy is the calibration 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 Xun Jin, Xun Jia, Steve Jiang, Fei Peng, Edwin Romeijn)
A column generation-based algorithm for Volumetric Modulated Arc Therapy (VMAT) treatment plan optimization
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 individual beam 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 Froiland, University of New South Wales, Australia
Vehicle and crew planning
Chair: Gary Froiland, University of New South Wales, Australia
Gary Froiland, University of New South Wales, Australia (with Michelle Dunbar, Cheng-Lung Wu)
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
transferred between late-running aircraft and crew, it is important that aircraft routing and crew pairing decisions are made together. The propagated delay may then be accurately estimated to minimise the overall propagated delay for the network and produce a robust solution for both aircraft and crew. We introduce a new scenario-based approach to accurately calculate and minimise the cost of propagated delay, in a framework that considers aircraft routing, crew pairing, and re-timing, and uses delay information from multiple scenarios.

Elmar Swarat, Zuse Institute Berlin (with Ralf Borndörfer, Guillaume Safir)

Modeling and solving a toll enforcement problem

We present the Toll Enforcement Problem to optimise 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.

Guenc Sahin, Sabanci University (with Fardin Dastghiy Sadirang, A. Cetin Soyapbatmaz)

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 considers 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.

Amini Toosi Vahid, Industrial Engineering Dept. of Amirkabir University of Tehran (with Najjar Vazifedan Aha)

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 model to design a BRT network. The model attempts to maximize the coverage of public transportation demand. The model has been implemented to the design of BRT network in Mashhad, the second largest city in Iran. The required actual data have been collected and fed to the model. The resulting network determines the BRT routes, the BRT stations and the schedules.

Weng Hei Tou, The Chinese University of Hong Kong (with Jimmy M. Y. Leung)

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 transit 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.

Marie Schmidt, Universität Göttingen

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 ones, leading to an over-concentration 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.

Convex piecewise quadratic integer programming

We consider the problem of minimizing a function given as the maximum of finitely many convex quadratic functions having the same Hessians. A fast algorithm for minimizing such functions over all integer vectors is presented. This algorithm can be embedded in an extended outer approximation scheme for solving general convex integer programs, where suitable approximations are used to underestimate the original objective function instead of classical linear approximations. Our algorithm is based on a fast branch-and-bound approach for convex quadratic integer programming proposed by Buchheim, Caprara and Lodi (2011). The main feature of the latter approach consists in a fast incremental computation of continuous global minima, which are used as lower bounds. We explain the generalization of this idea to the case of k convex quadratic functions. The idea is implicitly used to reduce the problem to at most $k^2$ convex quadratic integer programs. Each node of the branch-and-bound algorithm can be processed in $O(n^{2k})$. Experimental results for increasing sizes of $k$ are shown. Compared to the standard MIQCP solver of CPLEX, running times can be improved considerably.

Hyemin Jean, University of Wisconsin-Madison (with Jeffrey Linderoth, Andrew Miller)

Convex quadratic programming with variable bounds

The set $X = \{ (t, x, y) \in \mathbb{R}_+^n \times \mathbb{R}^n \times \mathbb{R}^n \mid (t \geq 0, x \leq y, y \geq 0)\}$ for some matrix $Q \geq 0$ is used as such in many applications including portfolio management and data mining. In the reformulated set $S = \{ (t, y, z) \in \mathbb{R}^n \times \mathbb{R}^n \times \mathbb{R}^n \mid (t \geq 0, y = z, y \geq 0)\}$, the problem of finding $Q = LL^T$. Experimental results for increasing sizes of $k$ show that the convex piecewise quadratic integer programming problem can be solved efficiently.

Long Trieu, TU Dortmund (with Christoph Buchheim)

Nonconvex underestimators for integer quadratic optimization

Recently, fast branch-and-bound algorithms for both convex and nonconvex integer quadratic optimization problems have been proposed that use lattice-point free ellipsoids for deriving lower bounds. In the convex case, these bounds improve those obtained from continuous relaxation. The ellipsoids are often chosen as axis-parallel ellipsoids centered in the stationary point of the objective function. In our work, we show that in this case the resulting lower bound can be interpreted as the integer minimum of a separable quadratic nonconvex global underestimator of the objective function with the same stationary point. The best such underestimator can be computed efficiently by solving an appropriate semidefinite program. This approach can be applied to mixed-integer quadratic programming problems with box constraints, where the separable underestimator can be minimized easily, and to combinatorial optimization problems with quadratic objective functions whenever the underlying linear problem can be solved efficiently.

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Crystof Buchheim, TU Dortmund (with Emiliano Traverso)

Nonconvex underestimators for integer quadratic optimization

Recently, fast branch-and-bound algorithms for both convex and nonconvex integer quadratic optimization problems have been proposed that use lattice-point free ellipsoids for deriving lower bounds. In the convex case, these bounds improve those obtained from continuous relaxation. The ellipsoids are often chosen as axis-parallel ellipsoids centered in the stationary point of the objective function. In our work, we show that in this case the resulting lower bound can be interpreted as the integer minimum of a separable quadratic nonconvex global underestimator of the objective function with the same stationary point. The best such underestimator can be computed efficiently by solving an appropriate semidefinite program. This approach can be applied to mixed-integer quadratic programming problems with box constraints, where the separable underestimator can be minimized easily, and to combinatorial optimization problems with quadratic objective functions whenever the underlying linear problem can be solved efficiently.

Hyemin Jean, University of Wisconsin-Madison (with Jeffrey Linderoth, Andrew Miller)

Convex piecewise quadratic integer programming

We consider the problem of minimizing a function given as the maximum of finitely many convex quadratic functions having the same Hessians. A fast algorithm for minimizing such functions over all integer vectors is presented. This algorithm can be embedded in an extended outer approximation scheme for solving general convex integer programs, where suitable approximations are used to underestimate the original objective function instead of classical linear approximations. Our algorithm is based on a fast branch-and-bound approach for convex quadratic integer programming proposed by Buchheim, Caprara and Lodi (2011). The main feature of the latter approach consists in a fast incremental computation of continuous global minima, which are used as lower bounds. We explain the generalization of this idea to the case of k convex quadratic functions. The idea is implicitly used to reduce the problem to at most $k^2$ convex quadratic integer programs. Each node of the branch-and-bound algorithm can be processed in $O(n^{2k})$. Experimental results for increasing sizes of $k$ show that the convex piecewise quadratic integer programming problem can be solved efficiently.

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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, Xiaojin Zheng)
MIOQ 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 MIOQ reformulations of the problem show that the proposed SDP approach can help to improve the performance of the standard MIOQ solvers for cardinality constrained quadratic programs.

Vikas Sharma, Thapar University (with Kalpana Dahiya, Vanita Vema)
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.

Gupta 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 Löhne, Martin-Luther-Universitat Halle-Wittenberg - Invited Session
Sonja Radjef, University USOD of Oran (with Mehdi Ouamer Bida)
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 Ifni Dairy.

Andreas Löhne, Martin-Luther-Universität Halle-Wittenberg
BENSOLVE – A solver for multi-objective linear programs
BENSOLVE is a MOLP 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.

Firdevs Ulus, Princeton University (with Andreas Löhne, 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.

Line-search strategies
Organizer/Chair José Martínez 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-Ruggiers, 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. 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.

Natasja Krijc, University of Nove Sad (with Natasja Kričk)
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 search methods can improve the convergence speed of 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 solution. After that the maximal sample size is used so the variable sample size strategy generates the solution of the same quality as SAA method but with significantly smaller number of functional evaluations.
Applications of optimization II
Chair Alina Fedossova, Colombian National University

Thea Gollner, 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 models are of great interest in modeling shipbuilding processes, but they are also of importance in industrial production process, where the geometry of such sheet metal parts is 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.

Alina Fedossova, Colombian National University (with Valery Fedosov)
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 lots of virtual sources with a total capacity 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 later in the numerical experiment. Objective function of semi-infinite program minimizes costs of pollution control with wind shifts.

Variational methods in optimization
Organizers/Chairs Pandos Georgiou, University of Florida; Julian Revalski, Bulgarian Academy of Sciences - Invited Session
Nina Ovcharova, 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 minorized 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). These 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 Georgiou, University of Florida (with Pason Parotadis)
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 second order of the non-smooth function is enough to determine the global minimizer of a locally Lipschitz function under constraints can be used to obtain 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 on the 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.

Nonlinear programming

Nonsmooth optimization

Optimization in energy systems

Stochastic programming in energy
Organizer/Chair: Amir Tomagrand, NTNU - Invited Session
Gerardo Perez Valdes, NTNU (with Launero Escudero, Marte Fredstad, Adela Pages-Beiras, Gloria Perez, Amir Togrand)
Parallel computational implementation of a branch and fix coordination algorithm
Branch and fix coordination is an algorithm designed to solve large scale multi-stage stochastic mixed integer problems, based on the notion that the particular structure of such problems makes it so that they can be broken down into scenario groups with smaller subproblems, solvable almost independently. With this in mind, it is possible to use parallel computing techniques to solve the subproblems created: each processor solves the subproblems pertaining to a particular cluster, and then the solutions are reported to a master routine. To satisfy non-anticipativity in the master problem’s binary variables, the values of the binary variables in the subproblem solutions are coordinated the entire process. The treatment of the original problem this way not only makes it faster to solve, but also allows us to solve otherwise intractable instances, where the number of binary variables is too large to be efficiently computed in a single processor. In this work, we present details and results about our computational implementation of the branch and fix coordination algorithm.

Xiong Li, Queen’s University (with Paul Barton, Amir Tomagrand)
Stochastic nonconvex MINLP models and global optimization for natural gas production network design under uncertainty
Scenario-based stochastic nonconvex MINLP models are developed to facilitate the design of natural gas production networks under uncertainty. Here the nonconvexity comes from bilinear, quadratic and power functions involved in the equations for tracking the gas qualities and pressures. As a gas network involves large investments, a small performance gain made in the design can translate into significant increase in profits; it is desirable to solve the nonconvex MINLPs to global optimality. An extension of generalized Benders decomposition (GBD), called nonconvex generalized Benders decomposition (NGBD), is developed for the global optimization of the stochastic MINLPs. As it takes advantage of the decomposable structure of the problem, NGBD has significantly computational advantages over state-of-the-art global optimization solvers (such as BARON). The advantages of the proposed stochastic nonconvex MINLP models and NGBD are demonstrated through case studies of an industrial gas production system.

Lars Hellem, NTNU (with Paul Barton, Amir Tomagrand)
Stochastic programming with decision dependent probabilities
We propose an investment problem modeled as a stochastic program with decision dependent probabilities. In addition to the available production technologies, we assume there is an activity or technology that results in a follower. We propose an investment problem modeled as a stochastic program with decision dependent probabilities. In addition to the available production technologies, we assume there is an activity or technology available that will alter the probabilities of the discrete scenarios occurring. By investing in such technology or activity, it is possible to increase the probability of some scenarios, while reducing the probability of the remaining scenarios, or vice versa. We also demonstrate the use of a specialized decomposition algorithm for this class of problems, using generalized Benders decomposition and relaxation of algorithms/McCormick relaxations. We illustrate the potential usefulness and the performance of the decomposition algorithm on this class of problems through an application from the Energy business.

Models for large consumer peak shaving and the impact on line pricing
We will present a mathematical programming model for a price responsive electricity user with an option to self generate. We will discuss the properties of this model and time permitting use it in a Stackelberg game where a lines company setting its tariffs is the leader and the user is a follower.

Gauthier de Marre, FEEM and CMCC (with Yves Smets)
Modelling market liquidity in restructured power systems by stochastic Nash and generalized Nash equilibrium
The volatility of electricity prices makes its financial derivatives important instruments for asset managers. Even if the volume of derivat-

Optimization in energy systems

Nonlinear programming
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 convex risk measures and show that the futures prices obey a risk neutral valuation property. We then 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 equilibria 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 Ehrenmånder, GDF Suez (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.

Wed.3.MA 415

Optimization applications in industry V

Organizer/Chair Diethelm Himmelberg, Wiener Institut for Applied Analysis and Stochastics - Invited Session

Amd Roesch, University Duisburg-Essen (with Hendrik Feldhorst)

A shape and topology optimization method for inverse problems in tomography

We propose a general shape optimization approach for the resolution of different inverse problems in tomography. For instance, in the case of Electrical Impedance Tomography (EIT), we reconstruct the electrical conductivity while in the case of Fluorescence Diffuse Optical Tomography (FDOT), the unknown is a fluorophore concentration. These problems are in general severely ill-posed, and a standard cure is to make additional assumptions on the unknowns to regularize the problem. Our approach consists in assuming that the functions to be reconstructed are piecewise constants.

Thanks to this hypothesis, the problem essentially boils down to a shape optimization problem. The sensitivity of a certain cost functional with respect to small perturbations of the shapes of these inclusions is analyzed. This may not be easy to accommodate in an optimization context. We then reconstruct the shape of the inclusions by modifying their boundaries with the help of the so-called shape derivative.

Stephania Hokenmaier, Linde AG (with Barbara Kaltenbacher)

Optimization with discontinuities and approximations in process engineering

Process simulators are indispensable in the daily work of process engineers. The Engineering Division of The Linde Group, which is one of the world leading companies in planning and building process plants, has been developing the in-house process simulation pro-

gram OPTISIM® for the simulation and optimization of chemical processes. Increasing demands on the optimizer concerning problem size, efficiency and robustness, especially with the occurrence of discontinuities and the use of approximations during simulation and optimization, lead to a closer look towards new optimization methods. In this context the global convergence result of Biegler and Wächter, used in the optimizer IPOPT, was considered under the assumption of perturbed equality constraints and derivatives, which models their approximative evaluation as well as to some extent also the discontinuities. Furthermore some numerical results will be shown.

Rodolphe Jenatton, CNRS - CMAP (with Francis Bach, Julien Mairal, Guillaume Obozinski)

Structured models in sparse optimization

Organizer/Chair John Duchi, University of California, Berkeley - Invited Session

Proximal methods for hierarchical sparse coding and structured sparsity

Sparse coding consists in representing signals as sparse linear combinations of atoms selected from a dictionary. We consider an extension of this framework where the atoms are further assumed to be embedded in a tree. This is achieved using a recently introduced tree-structured sparse regularization norm, which has proven useful in several applications. This norm leads to regularized problems that are difficult to optimize, and we propose in this paper efficient algorithms for solving them. More precisely, we show that the proximal operator associated with this norm is computable exactly via a dual approach. We also discuss extensions of this dual approach for more general settings of structured...
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 Ruszczynski]
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 Duchi, 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.

Wed.3.MA 141
Algorithms and applications for stochastic programming
Organizer/Chair Yongpei Guan, University of Florida - Invited Session
Zhihui Zhu, 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.

Ruowei Jiang, University of Florida [with Yongpei Guan]
Optimization under data-driven chance constraints
Chance constraint is an effective and convenient modeling tool of decision making in uncertain environment. Unfortunately, the solution obtained from a chance-constrained optimization problem might be questionable due to the accessibility of the probability distribution of the random parameters. Usually, decision makers have no access to the distribution itself, but can only observe a series of data sampled from the true (while ambiguous) distribution. In this talk, we develop exact approaches to deal with the data-driven chance constraints (DCC). Starting from the historical data, we construct two types of confidence sets for the ambiguous distribution through statistical estimation of its moments and density functions, respectively. We then formulate DCC as a robust version of chance constraints by allowing the ambiguous distribution to run adversely within its confidence set. By deriving equivalent reformulations, we show that DCC with both (moment- and density-based) confidence sets can be efficiently solved. In addition, we depict the relation between the risk level of DCC and the sample size of historical data, which can a priori determine the robustness of DCC.

Gustin Bayrakian, University of Arizona [with David Morton, Peggy Pierre-Louis]
A deterministic bounding method for a class of two-stage stochastic programs
In this talk, we present an algorithm for two-stage stochastic programming with a convex second stage program and with uncertainty in the right-hand side. The algorithm draws on techniques from deterministically-valid bounding and approximation methods as well as sampling-based approaches. In particular, we sequentially refine a partition of the support of the random vector and, through Jensen’s inequality, generate deterministically-valid lower bounds on the optimal objective function value. An upper bound estimator is formed through a simple Monte Carlo bounding procedure that includes the use of a control variate variance reduction scheme. We present stopping rules that ensure an asymptotically valid confidence interval on the quality of the proposed solution and illustrate the algorithm via computational results.

Wed.3.MA 144
Network design, reliability, and PDE constraints
Chair Olga Mnydyuk, New Jersey State University Rutgers
Olga Mnydyuk, New Jersey State University Rutgers
Stochastic network design under probabilistic constraint with continuous random variables.
Stochastic network optimization problem is formulated, where the demands at the nodes are continuously distributed random variables. The problem is to find optimal node and arc capacities under probabilistic constraint that insures the satisfaction of all demands on a high probability level. The large number of feasibility inequalities is reduced to a much smaller number (elimination by network topology), equivalent reformulation takes us to a specially structured LP. It is solved by the combination of an inner and 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, traffic, transportation, evacuation and other networks.

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 decomposition of the problem formulation phase before the realization of the uncertainty. We solve our problem with raw discretization, decompose it into overlapping parts of the domain, and solve it again iteratively by PHA with finer discretization – using values from the raw discretization as boundary conditions – until a given accuracy is reached.

The spatial decomposition is applied to a civil engineering problem: design of beam cross section dimensions. The algorithms are implemented in GAMS and the results are evaluated by width of overlap and computational complexity.

Rasool Tahmasbi, Amirkabir University of Technology [with S. Mehdi Rashedi]
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 must 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 if we allow implementing a maximum flow value before the realization of 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.

Stefan Gollnitzer, University of Vienna (with Bernard Gendron, Ivana Ljubic)

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 network design problem (CNDP) with the single-source capacitated facility location problem (SSCFLP). We will refer to it as the Capacitated connected 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 several (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.

Mohsen Rezapour, Technical University of Berlin (with Andreas Bley, S. Mehdi Hashemi)

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 addition 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 approximation algorithm for the problem with the rank of 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 information algorithm for the problem with benchmark instances.

Ashwin Arulselvan, TU Berlin (with Olaf Maurer, Martin Skutella)

An algebraic algorithm for the facility location problem

We are given an instance of a facility location problem. We provide an algebraic 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 facilities 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.

Radek Cibulka, University of Limoges (with Samir Adly, Jií Outrata)

Quantitative stability of a generalized equation: Application to non-regular electrical circuits

We study a network design problem that arises in the design of last mile telecommunication networks. It combines the capacitated network design problem (CNDP) with the single-source capacitated facility location problem (SSCFLP). We will refer to it as the Capacitated connected 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 several (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.

Variational analysis

Th effect of calmness on the solution set of nonlinear equations

We address the problem of solving a continuously differentiable nonlinear system of equations under the condition of calmness. This property, called also upper Lipschitz continuity in the literature, can be described as a local error bound, and is being widely used as a regularity condition in optimization. Indeed, it is known to be significantly weaker than classic regularity assumptions, which imply that solutions are isolated. We prove that under this condition, the rank of the Jacobian of the function that defines the system of equations must be locally constant on the solution set. As a consequence, we conclude that, locally, the solution set must be a differentiable manifold. Our results are illustrated by examples and discussed in terms of their theoretical relevance and algorithmic implications.

On some calmness conditions for nonsmooth constraint systems

Amos Uderzo, University of Milano-Bicocca

On some calmness conditions for nonsmooth constraint systems

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 homeomorphy invariance of the solution set under small perturbations of the defining functions. We discuss the gap between the nonsmooth versions of implicit and inverse function theorems in the complementarity 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 nonsmooth analysis.
Approximation algorithms
Chair Naonori Kakimura, University of Tokyo

David Williamson, Cornell University (with James Davis)
A dual-fitting $\frac{1}{2}$-approximation algorithm for some minimum-cost graph problems
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 components 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.

Stanos Kallipolitis, University of Athens (with Ido 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 $O(k)n^{O(1)}$.

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 integer $\alpha$, we are given $\alpha$-robust knapsack solutions, this result provides a sharp approximation for the knapsack problem. For the knapsack problem and a positive integer $\alpha$, 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.

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Thu.1 3010
Approximation & online algorithms

Thu.1 3005
Robust network design
Organizer/Chair Michael Jünger, Universität zu Köln - Invited Session
Manuel Kotrcha, RWTH Aachen University (with Grit Clallen, Arie Koster, Hsuan Taih)
Robust metric inequalities for network design under demand uncertainty
In this talk, we generalize the metric inequalities for the classical network design problem to its robust counter-part. Furthermore, we show that they describe the robust network design problem completely in the capacity space, where a straight-forward generalization of the classical metric inequalities is not sufficient. We present a polynomial algorithm to separate robust metric in-equalities as model inequalities for the capacity space formulation of the robust network design problem.

In computational experiments, we analyze the added value of this new class of valid inequalities within a branch-and-cut approach to solve the robust network design problem.

Daniel Schmidt, Universität zu Köln (with Eduardo Alvarez-Miranda, Valentina Cacchiani, Tim Dorneth, Michael Jünger, Frauke Liers, Andrea Lodi, Tiziano Parrini)
Single commodity robust network design: Models and algorithms
We study a model that aims at designing cost-minimum networks that are robust under varying demands. Given an underlying graph $G$, a finite number of scenarios and a cost function, we want to find the cheapest possible capacity installation on the edges of $G$ such that the demands of all scenarios can be satisfied by a single-commodity flow. This problem is known in the literature as single commodity robust network design problem. In computational experiments, we analyze the added value of this new class of valid inequalities within a branch-and-cut approach to solve the robust network design problem.

Thu.1 3008
Resource placement in networks
Organizer/Chair David Johnson, AT&T Labs - Research - Invited Session
David Johnson, AT&T Labs - Research (with Lee Breslau, Ilias Diakonikolas, Nick Duffield, Yu Gu, MohammadTaghi Hajiaghayi, Howard Karloff, Mauricio Resende, Subhajata Sen)
Disjoint path facility location: Theory and practice
The Steiner tree problem is one of the most fundamental NP-hard problems: given a weighted undirected graph and a subset of terminal nodes, find a minimum-cost tree spanning the terminals. In a sequence of papers, the approximation ratio for this problem was improved from $2$ to $1.55$ [Robins,Zelikovsky-05]. All these algorithms are purely combinatorial. In this talk we present an LP-based approximation algorithm for Steiner tree with an improved approximation factor. Our algorithm is based on a, seemingly novel, iterative randomized rounding technique. We consider an LP relaxation of the problem, which is based on the notion of directed components. We sample one component with probability proportional to the value of the associated variable in a fractional solution: the sampled component is contracted and the LP is updated consequently. We iterate this process until all terminals are connected. Our algorithm delivers a solution of cost at most $\ln(4) + \epsilon < 1.39$ times the cost of an optimal Steiner tree.

Thu.1 3034
Optimization and enumeration
Organizers/Chairs Jarekowd Neestett, Charles University Prague; Martin Leeb, Charles University - Invited Session
Patrice Ossona de Mendez, CNRS (with Jarekowd Neestett)
Large structured induced subgraphs with close homomorphism statistics
A particular attention has been recently devoted to the study of the graph homomorphism statistics. Let $\operatorname{hom}(F,G)$ denote the number of homomorphisms of $F$ to $G$. The problem we address here is whether a graph $G$ contains an induced subgraph $G[A]$ such that:

- for every small test graph $F$, $\operatorname{hom}(F,G[A])$ is not “too different” from $\operatorname{hom}(F,G)$:

$$|F| \leq \rho \implies \log \operatorname{hom}(F,G[A]) > (1 - \epsilon) \log \operatorname{hom}(F,G),$$

- the subgraph $G[A]$ is highly structured in the sense that it is obtained from a small graph $H$ of order at most $c(\rho, \epsilon)$ by applying some blow-up-like operations.

We prove that classes of graphs which are nowhere dense (meaning that for every integer $p$ there is a $p$ subdivision of a finite complete graph that is isomorphic to no subgraph of a graph in $\mathcal{C}$) have the property that for every integer $p$ and every $\epsilon > 0$ every sufficiently large graph in the class has such an induced subgraph.

Michael Chertkov, Los Alamos National Laboratory (with Adam Yedidia)
Computing the permanent with belief propagation
We discuss schemes for exact and approximate computations of permanents, and compare them with each other. Specifically, we analyze the Belief Propagation (BP) approach and its Fractional BP generalization to computing the permanent of a non-negative matrix. Known bounds and conjectures are verified in experiments, and some new theoretical relations, bounds and conjectures are proposed.

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 $2^{1-\epsilon}\log k$ in the random $k$-NAESAT problem, one of the standard benchmarks in the theory or random CSPs. This is joint work with Konstantinos Panagiotou.
Experiments show that our semidefinite branch-and-cut approach is a common branch-and-cut framework for linear and semidefinite relaxations of the minimum graph bisection problem. Extensive numerical experiments within 2% of optimal with no constraint violated by more than 1%. However, even for moderately large instances (20,000 videos, 50 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 La-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%.

Global optimally clustered regression by branch and bound optimization with heuristics, sequencing and ending subset

Global optimally clusterwise regression by branch and bound optimization with heuristics, sequencing and ending subset. Clusterwise regression is a clustering technique which fits multiple linear or hyperplane models to 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.

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 inaccuracies 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 methodology 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.
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.

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**Smoothed analysis of algorithms**

Tobias Brunsch, University of Bonn (with Heiko Röglin)

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 bridge between the worst case and average case, to understand good behavior of 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 ratio 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.

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**Improved smoothed analysis of multiobjective optimization**

We present several new results about smoothed analysis of multiobjective optimization problems. Particularly, we consider problems in which the linear and one arbitrary objective function are to be optimized over a set $S \subseteq \{0,1\}^n$ 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 $\phi$. We improve the previously best known bound for the smoothed number of Pareto-optimal solutions to $O(n^{2d}d^3)$ for natural perturbation models. Additionally, we show that for any constant $\epsilon$ the $\epsilon$-th moment of the smoothed number of Pareto-optimal solutions is bounded by $O((n^{2d}d^3)^{\epsilon})$. 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.

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**The power of constraint reduction in interior-point methods**

André Tits, University of Maryland, College Park (with Pierre-Antoine Absil, Mayun He, Ming-Tao Luai, Dianne O’Leary, Sungsyoung Park, Luke Winters)

We consider approximation algorithms for the shortest common superstring problem (SCS). It is well-known that there is a constant $f > 1$ such that there is no efficient approximation algorithm for SCS achieving a factor of at most $f$ in the worst case, unless $\text{P}=\text{NP}$. We study SCS on random inputs and present an approximation scheme that achieves, for every $\epsilon > 0$, a $1+\epsilon$-approximation in expected polynomial time. This result applies to the letters 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 Frieze and Szpankowski.
Several NP-complete problems can be turned into convex problems by formulating them as optimization problems over the copositive cone. Unfortunately, checking membership in the copositive cone is a co-NP-complete problem in itself. To deal with this problem, several approximation schemes have been developed. One of them is the hierarchy of linear semi-infinite programming (LSIP). We will provide an overview of error bound for these approximation schemes in terms of the mesh size. Examples will illustrate the structure of the programs.

Luuk Gijben, Rijksuniversiteit Groningen (with Peter Dickinson, Mirjam Dür, Roland Hildebrand)
Scaling relationship between the copositive cone and Parrilo’s first level approximation

### Conic programming: Genericity results and order of minimizers

In this presentation we will discuss about the connections between conic programming (CP) and Linear Semi-Infinite Programming (LSIP). We will view copositive programming as a special instance of linear semi-infinite programming. Discretization methods known for solving LSIP (approximately). The connection between CP and LSIP will leads us to interpret certain approximation schemes for CP as a special instance of discretization methods for LSIP. We will provide an overview of error bound for these approximation schemes in terms of the mesh size. Examples will illustrate the structure of the programs.

Faizan Ahmed, University of Twente (with Georg Stijl)
On connections between conic programming and semi-infinite programming

### Constraint programming

#### Instance-specific tuning, selection, and scheduling of solvers

Organizer/Chair Meinolf Sellmann, IBM Research - Invited Session

Minonft Sellmann, IBM Research (with Yuni Malitsky, Aristosh Sabralov, Horst Samulowitz)
Solver 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 (S5) and its parallel counterpart, p3S:

Yuni Malitsky, University College Cork (with Meinolf Sellmann)
Instance-specific algorithm configuration

The presentation focuses on a method for instance-specific algorithm 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 representative 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 explored 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 improvements are shown over the existing state-of-the-art solvers.

Lin Ku, 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 solver 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 draw two main conclusions from the results that we obtained. First, automatically-constructed portfolios of sequential, non-portfolio competition 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 without them.

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Mechanisms for resource allocation problems

Carmine Ventre, 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.

Game theory

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 on the value that every agent can have. We focus on a algorithmic and mechanism design aspects of this problem. In the work of [Hill1987], 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.

Ammari 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 make-span 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 a 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.

Mean-field approaches to large scale dynamic auctions and mechanisms

Karthik Srikantaiah, 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 unbiased amount that is exactly the expected effect of 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. Using this characterization we study the extent to which we can learn 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 Prokopenko, KTH (with Ranbir Gummadi, 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.
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 the number of facilities is small.

Pål Buri, TU 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 differentiability of the objective function and its bidual [the latter is known from convex analysis].

Robert Fourer, AMPL Optimization (with Jared Erickson)

Strategies for using algebraic modeling languages to formulate second-order cone programs

A surprising variety of optimization applications can be written as convex quadratic problems that linear solvers can be extended to handle effectively. Particular interest has focused on conic constraint regions and the “second-order cone programs” [or SOCPs] that they define. Whether given quadratic constraints define a convex cone can in principle be determined numerically, but of greater interest are the various combinations of sums and maxima of Euclidean norms, quadratic-linear ratios, products of powers, p-norms, and log-Chebychev terms that can be identified and transformed symbolically. The power and convenience of algebraic modeling language may be extended to support such forms, with the help of a recursive tree-walk approach that detects and converts arbitrarily complex instances – freeing modelers from the time-consuming and error-prone work of maintaining the equivalent SOCPs explicitly. These facilities moreover integrate well with other common linear and quadratic transformations. We describe the challenges of creating the requisite detection and transformation routines, and report computational tests using the AMPL language.

Vinicius Forte, Universidad Federal de Rio de Janeiro

Polyhedral combinatorics

Chair Vinicius Forte, Universidad 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 (M2CDSP) asks for a least cardinality 2-connected D. The problem has applications in the design of ad-hoc wireless telecommunications 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 M2CDSP 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 one 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 Marenco)

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 matrix methods via primal dual 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.

**Integer & mixed-integer programming**

**Branch-and-price II: Column and row generation**

Organizer/Chair Marco Lübbecke, RWTH Aachen University - Invited Session

Pedro Murari, 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.

Kerem Bülbül, Sabancı University (with S. Iker Bribiesca, Ibrahim Muter)

**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 these 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 a new 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 Vanderbeck)

**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 new closure. Most notably we prove that the new closure is polyhedral, 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 6158 (with Clément de la Rionière)

**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 neuroimaging and cognitive research, where brain connectivity and graph theory are increasingly important concepts for understanding and for computation. We investigate functional brain connectivity and graph analysis methodology applied to the aging brain at two quite different time scales. The study involves whole-brain BOLD fMRI measurements, conducted at time 1 and 2 years later, defining binary functional connectivity graphs \( G_1 \) and \( G_2 \) for subjects \( i = 1, 2 \). We computed local and global nodal network metrics to assess functional connectivity 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) that maintain the binary graphs. Several perspectives are proposed by these preliminary results, eg in the context of test-retest reliability and reproducibility of graph metric.

Engbert Mephu Ngoufo, LIMOS, Clermont University, UBP, CNRS (with Sabour Aribi, 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 ma-
chine learning tools to perform data mining tasks such as classification.
Previous works described motif extraction methods for sequences clas-
sification, but none discussed the 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.

Romain Popesculcne, UMS3- CNRS (with Anne Berry, Ameign Weyer)

Clustering separator decomposition and applications to biological data

The study of gene interactions is an important research area in biol-
ygy. Nowadays, high-throughput techniques are available to obtain
gene expression data, and clustering is a first mandatory step towards a bet-
ter understanding of the functional relationships between genes. We
propose a new approach using graphs to model this data, and decom-
pose the graphs by means of clique minimal separators. A clique sep-
parator 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 lat-
ter enables us to visualize the data by a meta-graph where two clus-
ters are adjacent if they intersect. In addition, clique separators help to
identify special genes, called fusion genes, in sequence similarity net-
works, in the context of evolutionary history. Our first results applying
this approach to transcriptomic data are promising.

Daniela Saban, Columbia University (with Nicolas Stier-Moses)

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 facili-
ties on vertices that capture the largest-possible market share. The com-
petitive 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 along the shore. It is well-known that a gener-
alization of that game on a tree always admits an equilibrium. Further-
more, 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.

Luyi Gui, Georgia Institute of Technology (with Ozlem Ergun)

A robustness analysis of a capacity exchange mechanism in
multicommodity networks under demand uncertainty

We study the coordination of a decentralized multicommodity net-
work system with individually-owned capacities by designing a capacity
exchange mechanism under which capacity is traded according to pre-
determined unit prices. The goal is to maximize the social efficiency,
measured by the total routing revenue, of the flow composed by individ-
ual players’ selfish routing of their own commodities motivated by the
mechanism. A practical challenge to achieve this is that the network
varies from uncertainties in demand, as in many cases the mechanism is designed before
the demand is revealed. Hence, it is desirable that the capacity exchange
mechanism is robust, i.e., it can effectively coordinate the network un-
der all potential demand scenarios using a fixed set of exchange prices.
In this paper, we perform the following subproblems to study the robustness
of the capacity exchange mechanism under demand uncertainty.
First, we characterize how network structure affects the robustness of the me-
chanism. Second, we investigate the computational side of designing a ro-
bust capacity exchange mechanism in any given network. We propose a

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Techniques for convex MINLPs

Organizer: Chad Jeff Liberti, University of Wisconsin Madison - Invited Session

Pierre Bonami, CNRS - Aix Marseille (Institut

On disjunctive cuts for mixed integer convex programs

We study the separation of disjunctive cuts for mixed integer non-
linear programs where the objective is linear and the relations between
the decision variables are defined by a convex set. We derive cuts that
generate cuts are typically not more complicated than the original con-
tinuous relaxation. In particular they do not require the introduction of
additional variables and maintain the properties of the nonlinear func-
tions describing the feasible region. We propose several strategies for
using the technique and present computational evidence of its practi-
cal 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.

Arash Ashouri, Argonne National Lab (with Svend Leyffer)

Algorithms for solving convex MINLPs with MINOTAUR

MINOTAUR is an open-source software toolkit for implementing al-
gorithms for mixed-integer nonlinear optimization problems. We will
describe the design features of the toolkit and present two new al-
gorithms. The first is a new tree-search algorithm for solving convex
MINLPs. Rather than relying on computationally expensive nonlinear
solves at every node of the branch-and-bound tree, our algorithm solves
a quadratic approximation at every node. We show that the resulting al-
gorithm retains global convergence properties for convex MINLPs, and
we present numerical results on a range of test problems. The second is an
algorithm for presolving MINLPs. In order to improve the formulation
of a MINLP in the presolve, we directly manipulate the computational
graph of nonlinear functions. Extensive computational results showing
effects of presolving on different algorithms for convex MINLPs are pro-
vided using what we call ‘extended performance-profiles’. We show im-
provements of up to two orders of magnitude in running time for some
classes of problems.

Andrew Miller, Université Bordeaux 1 (with Hyemim Jeon, Jeff Linderoth)

Valid inequalities for a nonseparable quadratic set

We describe approaches for finding strong valid inequalities for the
convex hull of a quadratic mixed integer nonlinear set containing two
integer variables that are linked by linear constraints. This study is mo-
tivated by the fact that such sets appear can be defined by a convex
quadratic program, and therefore strong inequalities for this set may help
to strengthen the formulation of the original problem.

A number of the inequalities that we define for this set are nonlinear
(specifically conic). The techniques used to define strong inequalities in-
clude not only ideas related to perspective reformulations of
MINLPs, but also disjunctive and lifting arguments. Initial computational
experiments will be presented.
**Mixed-integer nonlinear programming**

**MINLP theory and algorithms**  
Organizer/Chair Giacomo Nannicini, Singapore University of Technology and Design - Invited Session

Emilioa, 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 problem 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 Pasquale Margali)  
**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 \( \mathbf{w} \in \mathbb{R}^n \) and hyperplane with parameters \((w, y) \in \mathbb{R}^{n+1}\), their distance is \(|\mathbf{w}^T \mathbf{w} - y|\) 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 [sBB] methods employ not tight relaxations which yield nontrivial bounds only after many iterations. Then, we propose a novel sBB method where the complement of the unit ball is approximated with the complement \(P\) of polyhedron \(P\). We represent \(P\) as a disjunction with a subproblem for each facet of \(P\) and, at each sBB iteration, we refine it by adding a new vertex to \(P\) which corresponds to the new infeasible solution. Compared to a standard sBB 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%.

**Multi-objective optimization**  
Organizer/Chairs César Gutiérrez, Universidad de Valladolid; Vicente Novo, UNED - Invited Session

María Beatriz Hernández-Jiménez, Universidad Pablo de Olavide (with Manuel Arana-Jiménez, Rafaela Durán-Gómez, Gabriel Ruiz-Garaico)  
**Characterization of efficient solutions for non-regular multibjective problems with inequality-type constraints**  
For multibjective 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 \(\varepsilon\)-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. It is necessary to introduce generalized convexity notions. In the multibjective nonregular case we give the notion of \(\varepsilon\)-KKT-pseudoinvex-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 Bienvenida Jiménez, Vicente Nova)  
**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 solutions 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.

**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 Akke, ICERM Stanford University (with Michael Saunders)  
**Preconditioning for iterative computation of search directions within interior methods for constrained optimization**  
Our primal-dual interior-point optimizer PDCO has found many applications for optimization problems of the form  
\[
\min \varphi(x) \quad \text{st} \quad Ax = b, \quad 1 \leq x \leq u,
\]

in which \(\varphi(x)\) 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  
\[
AD\Delta y = r, \quad D \text{ diagonal and positive definite.}
\]

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 LSQR.

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 Moulines)  
**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 those 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.

**Nonlinear programming**  
Organizer/Chair Ganesh Perumal, Infosys Limited / International Institute of Information Technology, Bangalore

Stefan Stefanov, Neelof Rishi South-Western University  
**Convex separable minimization with box constraints**  
In this talk, we consider 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 “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 for solving these three problems are proposed and convergence of algorithms is proved. Some particular problems of the form under consideration as well as numerical results are presented.

Ganesh Persam, Infosys Limited / International Institute of Information Technology, Bangalore (with G. N. Srinivasa Prasanna)

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 subspace 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.

Anna-Laura Wickström, Universität Zürich

Generalized derivatives of the projection onto the cone of positive semidefinite matrices

We are interested in sensitivity and stability analysis of solution sets of nonlinear optimization problems under set or cone constraints. A main motivation behind our work is the analysis of semidefinite programs (SDPs). We wish to explore the sensitivity analysis of SDPs with help of generalized derivatives.

In order to study critical points and solutions of SDPs we construct a Kojima kind of locally Lipschitz functions of the Karush-Kuhn-Tucker conditions for $C^2$-optimization problems over the space of symmetric matrices. We will study generalized derivatives of this Kojima function in order to show regularity of our problem. The Kojima-function is the product of a continuously differentiable and a nonsmooth function. The latter contains the projection function onto the cone of positive semidefinite matrices. We shall look at the construction of it’s Thibault derivatives (strict graphical derivatives). Moreover, we examine the relations between Thibault derivatives and Clarke’s generalized Jacobians of these projections.

Alain B. Zemkoho, TU Bergakademie Freiberg

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.

Waltraud Huyer, Universität Wien (with Arnold Neumaier)

Minimizing functions containing absolute values of variables

We propose an algorithm for the minimization of the function $f(Ax-b, |x|)$ on a box $x \in \mathbb{R}^n$ 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 $q(x) = y + c^T x + \frac{1}{2}(b x - c)^T F (b x - c)$, $F$ a diagonal matrix, is developed.

Finally, MINABS is applied to problems of the above kind in order to demonstrate the applicability of the algorithm.

Christine Hayn, FAU Erlangen-Nürnberg, Discrete Optimization (with Lars Schewe)

Optimal allocation of capacities in gas 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 modelled 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.

Lars Schewe, FAU Erlangen-Nürnberg, Discrete Optimization (with Björn Geißler, Alexander Martin, Antonio Monreal)

Mixed-integer-programming methods for gas network optimization

We present methods to formulate and solve MINLPs originating in stationary gas network optimization. To this aim we use a hierarchy of MIP-relaxations. With this hierarchy we are able to give tight relaxations of the underlying MINLP. The methods we present can be generalized to other non-linear network optimization problems with binary decisions. We give computational results for a number of real world instances. The underlying optimization problem can be adapted to give operating limits for the network in fixed scenarios. These results can be used as the basic building block for further study of the allocation of capacities in the network.

Benjamin Hiller, Zuse Institute Berlin (with Heiman Leovey, Arndt Möller, Werner Römisch)

An automated method for the booking validation problem

We propose an automated approach to solve the booking validation problem faced by gas network operators. Given a set of transmission capacity contracts [a booking], check whether all balanced gas flows that may result from those contracts are technically realizable. Our approach is based on MINLP methods for checking gas flow realizability complemented by a method for generating a representative subset of the gas flows that may arise. This generation method combines a stochastic model for gas fortnights and a deterministic model for the contractual limitations of both injections and offtakes.

Optimization in energy systems

Thu.1 MA 560

Gas and electricity networks

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.

Paul Todenh, University of Edinburgh (with Wagquas Bolkhit, Andreas Grotthe, Ken McKinnon)

MILP-based islanding of large electricity networks using an aggregated model of power flows

Wide-area blackout 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 islands large, real networks.

Ken McKinnon, Edinburgh University [with Waqquas Bukhsh, Andreas Grothey, Paul Todten] 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 isolated while an island’s load shed is minimized. 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.

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

Thu.1 MA 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 chemotherapry treatment through its corresponding PDE in different frameworks.

Thu.1 MA 011

Thu.1 MA 015

Optimization applications in industry VI
Organizer/Chair Dietmar H"{o}mberg, Weierstrass Institute for Applied Analysis and Stochastics - Invited Session

Eulantes 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.

Georg Vossen, University of Applied Sciences [with Axel Hack, Andreas Pitter]
Optimization and model reduction methods for heat source determination in welding

Thu.1 MA 044

Thu.1 MA 004

Robust optimization, estimation and machine learning
Organizer/Chair Aharon Ben-Tal, Technion – Israel Institute of Technology - Invited Session

Shimrit Shimron, 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 inflected 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.

Elad Hazan, Technion – Israel Institute of Technology
Sublinear optimization for machine learning

Linear classification is a fundamental problem of machine learning, in which positive and negative examples of a concept are represented in Euclidean space by their feature vectors, and we seek to find a hyperplane separating the two classes of vectors. We’ll present the first
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 Aadirun 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 statistics of the uncertainty. The formulation in general is non-convex, but in several cases of interest it reduces to a convex program. To address the non-convexity issue we propose a robust optimization based procedure. Specifically the uncertainty is modeled as a positive affine combination of given positive semi definite kernels, with the coefficients ranging in a norm bounded uncertainty set. Subsequently using the Robust Optimization methodology, the SVM problem 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 an $O(1/T^2)$ reduction of the initial error after $T$ iterations. A comprehensive empirical study on both synthetic data and real-world protein structure databases shows that the proposed formulations achieve desired robustness.

Fatma Kilinc Karzan, Carnegie Mellon University (with Anatoli Juditsky, Arkadi Nemirovski)

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 bilinear 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.

Alexandre D'Aspremont, CNRS – Ecole Polytechnique

High-dimensional geometry, sparse statistics and optimization

This talk will focus on a geometrical interpretation of recent results in high dimensional statistics and show how some key concepts controlling model selection performance can be approximated using convex relaxation techniques. We will also discuss the limits of performance of these methods and describe a few key open questions.

Fatma Kilinc Karzan, Carnegie Mellon University (with Anatoli Juditsky, Arkadi Nemirovski)

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 bilinear 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, LIM, Université J. Fourier - Invited Session

Computable bounds for sparse recovery

Organizer/Chair: Vincent Guigues, UFRJ - Invited Session

Alexandre D'Aspremont, CNRS – Ecole Polytechnique

High-dimensional geometry, sparse statistics and optimization

This talk will focus on a geometrical interpretation of recent results in high dimensional statistics and show how some key concepts controlling model selection performance can be approximated using convex relaxation techniques. We will also discuss the limits of performance of these methods and describe a few key open questions.

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Anatoli Juditsky, LIM, Université J. Fourier - Invited Session

Accuracy guarantees and optimal $\ell_1$-recovery of sparse signals

We 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 certitudes 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.

Stochastic optimization

Thu.1 MA 141

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

Deviation 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 which 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.

Shef Mannon, 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 are more simple and incorporate a robust optimization methodology, 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.

Thu.1 MA 144

Decomposition methods for multistage stochastic programs based on extended polyhedral risk measures

Organizers/Chair: Vincent Guigues, UFRJ - Invited Session

Vincent Guigues, UFRJ (with Werner Römisch)

Sampling-based decomposition methods for multistage stochastic programs

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 new class of multistage 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.

Wajdi Tekaya, Georgia Institute of Technology (with Joari Da Costa, Alexander Shapiro, Murilo 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.

Suvejajeet Sen, University of Southern California (with Zhitong 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 prescribes knowledge of the mode, but not the 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.

Sabine Böttner, University of Kaiserslautern

Online network routing amongst unknown obstacles

We consider variants of online network optimization problems connected to graph exploration. In the process-collecting travelling salesman problem, we are given a weighted graph $G = (V,E)$ with edge weights $\ell : E \rightarrow \mathbb{R}_{+}$, a special vertex $s \in V$, penalties $p : V \rightarrow \mathbb{R}_{+}$, and the goal is to find a closed tour $T$ such that $s \in V(T)$ 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 or to pay 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.

Thomas Worth, TU Kaiserslautern (with Sven Krumke, Helke Spotter)

Bottleneck routing games

We consider Nash and strong equilibria in weighted bottleneck routing games in single commodity networks. In such a game every player chooses a path from the common source vertex to the sink vertex in a graph with directed edges. The cost of an edge depends on the total weight of players choosing it and the personal cost every player tries to minimize is the cost of the most expensive edge in her path, the bottleneck value. To derive efficient algorithms for finding equilibria in unweighted games, we generalize a transformation of a bottleneck game into a special congestion game introduced by Caragiannis et al. (2005).

For weighted routing games we show that Greedy methods give $O(1)$-competitive algorithms for special networks. We also relate the problem to other (classical) online network and routing problems.

Networks in production, logistics and transport

Organizer/Chair Sven Krumke, University of Kaiserslautern - Invited Session

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Thu.1.H 3503

Allocation problems

Chair Anders Gullqvist, NTNU (Trondheim)

Hasan Tarun, University of Talca (with Nitak Kasap)

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

Cloud computing and its Software-as-a-Service (SaaS) model has made a big impact on the way ICT services are being delivered to the users, and gives providers more flexibility in scaling the services according to the demand. In the provisioning, a SaaS provider needs to focus on cost and energy-efficient operation of its private cloud, and ensure that the services deployed on the nodes in the cloud have a QoS satisfying the agreed requirements. In this talk, we mainly focus on decisions of a SaaS provider related to the management of his services and cloud data centers, but also acknowledge decisions related to bursting services into public clouds. A service is modeled as a collection of distinct components, and increased QoS is obtained by adding active or passive copies of these, leading to several ways to satisfy the QoS requirements. We will present MIP models of a problem where the goal is to minimize the cost of running services in private and public clouds, while ensuring satisfactory QoS. Firstly a direct formulation is created, and then we reformulate the model, utilizing column generation techniques with pregeneration of node patterns, by which we achieve better results.

Arend Gullqvist, NTNU (Trondheim) (with Bjar Nyeen)

Service deployment in cloud data centers regarding quality of service (QoS) requirements

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Deepak Carg, Panjab University (with Harindra Kumar, Mariushi Sharma)

Heuristic mathematical models for solving dynamic task assignment problem in distributed real time systems

Efficient task scheduling is a crucial step to achieve high performance for multiprocessor platform remains one of the challenging problems despite of the numerous studies. In a distributed real time systems (DRTS) the tasks of a program must be assigned dynamically to the heterogeneous processors, so as to utilize the computational capabilities and resources of the system efficiently. This paper deals with dynamical task assignment problem for allocating the m tasks of distributed program to n heterogeneous processors (m > n) to minimize the total cost of the program, which permits each task to be migrated from one processor to another during the execution of the program. To design the mathematical model, phase wise execution cost (EC), inter-task communication cost (ITCC), migration cost (MC) and residence cost (RC) of each task on each processor has been taken in the form of matrices.
corresponding stationary indices) of the original problem and those with the feasible set $\mathcal{M}^*$.

Helmut Geißen, Johannes Kepler Universität 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 polyhedral 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 Fucík, 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 an 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 coherently oriented $B$-subdifferentials. This class is broad enough to include the Kojima function corresponding to the nonlinear semidefinite programming problem.

Karl-Franzens-Universität Graz . Invited Session

Optimization methods for nonsmooth inverse problems in PDEs

Barbara Kaltenbacher, Alpen-Adria University of 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. Therewith, convexity of the Newton step subproblems is preserved while often nondifferentiability might be introduced, which results in the requirement of solving a PDE with non-smooth linearity 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.

Christian Clason, Karl-Franzens-Universität Graz

Approximation & online algorithms

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the cycle packing number and outline the structure of one optimal cycle packing of such graphs.

Peter Rechtx, TU Dortmund (with Eva-Marie Sprengel)

A “min-max-theorem” for the cycle packing problem in Eulerian graphs

This lecture deals with the problem to determine a set \( Z^* = \{ C_1, C_2, \ldots, C_{|Z^*|}\} \) of edge-disjoint cycles of maximum cardinality \( \nu(G) \) 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 tree 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 trees are not uniquely defined but their packing numbers \( \nu(T(v)) \) are.

We prove that if \( G \) is 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 case, 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 Boumedien (U.S.T.H.B) (with Meznane Adler)

4-cycle polytone 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 \( V_1 = \{ x \} \) and \( V_2 = \{ y \} \) and a weight function \( w : \{ x \} \rightarrow \mathbb{R} \). The minimum weighted 4-cycle problem consists on finding a 4-cycle \( C \in \mathbb{C} \) such that \( \sum_{v \in V} w_C \) 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 \( \mathbf{x}^{(C)} \) denote the incidence vector of \( C \) defined by: \( \mathbf{x}^{(C)}(e) = 1 \) and \( \mathbf{x}^{(C)}(e) = 0 \) if \( e \notin \mathbb{C} \). The 4-cycle polytone \( PC_{4,n}^m \), is the convex hull of the incidence vectors of the 4-cycles of \( K_{m,n} \), i.e. \( PC_{4,n}^m = \text{convex hull} (\{ \mathbf{x}^{(C)} | C \text{ is a 4-cycle of } G \} ) \). 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 \( PC_{4,n}^m \).

Solving the discretizable molecular distance geometry problem by multiple realization trees

The Discretizable Molecular Distance Geometry Problem (MDGP) is a subclass of the MDGP, which can be solved using a discrete method called Branch-and-Prune (IBP) algorithm. We present an initial study of showing that the BP algorithm may be used differently from its original form, which fixes the initial atoms of a molecule and then branches the BP tree until the last atom is reached. Particularly, we show that the use of multiple BP trees may explore the search space faster than the original BP.
auxiliary variables replace the quadratic monomials, yields an exact LP formulation, but the resulting LP bounds are weak in general. For BQPs 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.

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 expediously zone protected areas. Zoning problem was mathematically modeled as a combinatorial problem with quadratic objective and non-convex quadratic constraints. Numerical results on real life instances are given.

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Inverse problems

Chair Peter Gritzmann, TU München

Natalia Skalkovics, University of Leeds (with Peter Brucker)

On general methodology for solving inverse scheduling problems

The talk will provide a summary of the results developed for solving inverse optimisation problems in application to scheduling. For an inverse scheduling problem, a target (non-optimal) solution is given and the objective is to find problem parameters (e.g., job weights, processing times or due dates) so that the target solution is optimal while the deviation from the original parameters is as small as possible. The common methodology for solving inverse scheduling problems consists of the following two steps: (1) formulating necessary and sufficient optimality conditions which characterize optimal schedules and (2) developing efficient procedures for adjusting problem parameters in order to achieve optimality of a given solution. In the talk we provide new results for the necessary and sufficient optimality conditions.

We show that the formulated conditions allow reformulating some in-verse scheduling problems as dual network flow problems defined on networks of a special structure.

Daniele Catanzaro, Université Libre de Bruxelles (with Roberto Aringhieri, Marco Di Summa, Raffaele Pandi)

An exact algorithm to reconstruct phylogenetic trees under the minimum evolution criterion

We investigate one of the most important $\mathcal{NP}$-hard versions of the phylogeny estimation problem, called the Minimum Evolution Problem (MEP). Specifically, we investigate the theoretical foundation of the MEP and its relationships with the Balanced Minimum Evolution Problem. Moreover, we present a new exact approach to solution of the MEP based on a sophisticated combination of both a branch-price-and-cut approach and a non-isomorphic enumeration of all possible phylogenies for a set of $n$ taxa. This peculiar approach allows to break symmetries in the problem and to improve upon the performances of the best-so-far exact algorithm for the MEP. Hopefully, our findings will provide new perspective on the mathematics of the MEP and suggest new directions on the development of future efficient exact approaches to solution of the problem.

Peter Gritzmann, TU München (with Andreas Alpers, Barbara Langfeld, Markus Wiegandmeier)

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

Discrete Tomography is concerned with the retrieval of finite or finitely presented sets in some $\mathbb{B}^d$ from their X-rays in a given finite number of directions. In the talk we focus on recent results on unique reconstruction problems. In particular, we give new conditions when a subset $J$ of possible positions is already determined by the given data that allow us to settle conjectures of Kuba [1997] and of Brunetti & Daurat [2005]. Further, we indicate how new challenges in refraction tomography relate to issues in computational convexity.
Conjectures is derived, and a qualitative analysis of the model is conducted. The equilibrium conditions are first derived, and then the governing variables of its influence upon the prices of instruments are determined. Each sector is assumed to be quadratic, and constraints and computational errors are bounded from above by a constant.

Finding a conjectural variations equilibrium in a financial model by solving a variational inequality problem

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.

Vycheslav Kalashnikhov, ITESM, Campus Monterrey - Invited Session

Extended systems of primal-dual variational inequalities

A system of variational inequalities with general mappings, which can be regarded as an extension of Lagrangean 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 - Israel Institute of Technology

The extragradient method for solving variational inequalities in the presence of computational errors

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. This fact creates certain difficulties for providing convergence of many existing iterative methods.

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Vycheslav Kalashnikhov, ITESM, Campus Monterrey (with Yasmín Acosta Sanchez, Nataliya Kalashnykova)
Optimization and economic applications
Organizer/Chair: Kenneth Judd, Hoover Institution - Invited Session
Sebastian Cerezo, University of Seville
Choosing the best partner for a horizontal cooperation
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.

Xiaoguo Meng, City University of Hong Kong (with Chunyan Dang)
An interior-point path-following method for computing equilibria of an exchange economy with linear production technologies
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 comput-

Derivative-free & simulation-based opt.
Thu.2.H.3093A
Addressing noise in derivative-free optimization
Organizer/Chairs: Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory - Invited Session
Stefan Wild, Argonne National Laboratory
Computational noise in simulation-based optimization
Efficient simulation of complex phenomena often results in computational noise. Noise destroys underlying smoothness that otherwise would benefit optimization algorithms. We present a non-intrusive method for estimating computational noise and show how this noise can be used to derive finite-difference estimates with provably good approximation guarantees. Building upon these results, we show how step sizes for model minimization and improvement can be selected. These techniques can also be used to determine when to transition from interpolation-based to regression-based surrogate models in derivative-free optimization.

Stephen Billups, University of Colorado, Denver
Managing the trust region and sample set for regression model based methods for optimizing noisy functions without derivatives
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 regenerative methods 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.

Arie Ilachinski, CERFACS Toulouse (with Serge Gratton, Philippe Joubert)
A model-based trust-region algorithm for derivative-free optimization and its adaptation to handle noisy functions and gradients
Optimization algorithms are crucial to solve industrial 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 gradient information. 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.

Thu.2.H.3027
Optimization and economic applications
Organizer/Chair: Kenneth Judd, Hoover Institution - Invited Session
Vasilis Gkatzelis, Courant Institute, NYU (with Richard Cole, Gagan Goel)
Truthful mechanisms for proportionally fair allocations
We study the problem of designing mechanisms to allocate a heterogeneous set of divisible goods among a set of agents in a fair manner. We consider the well known solution concept of proportional fairness that has found applications in many real-world scenarios. Although finding a proportionally fair solution is computationally tractable, it cannot be implemented in a truthful manner. To overcome this, in this paper, we propose mechanisms which are truthful and achieve proportional fairness in an approximate manner. We use a strong notion of approximation, requiring the mechanism to give each agent a good approximation of its proportionally fair utility. A motivating example is provided by the massive privatization auction in the Czech republic in the early 90s.

Giorgos Christodoulou, University of Liverpool (with Kurt Mehlhorn, Evangelia Pyrga)
Coordination mechanisms for selfish routing games
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.

Francesco Paccautie, Università degli Studi di Salerno (with Vincenzo Audetel, Diodato Ferrari, Paolo Perra, Giuseppe Persanne)
Logit dynamics: Expected social welfare, mixing time, and metastability
Logit dynamics [Blume, Games and Economic Behavior, 1993] is a randomized best response dynamics for strategic games: at every time step a player is selected uniformly at random and she chooses a new strategy according to a probability distribution based toward strategies promising higher payoffs. This process defines an ergodic Markov chain over the set of strategy profiles, whose unique stationary distribution we regard as the long-term equilibrium concept for the game. We are interested in the stationary performance of the game (the expected social welfare when the profiles are random according to the stationary distribution) and in the time it takes to get close to the stationary distribution (mixing time). When the mixing time is large the stationary distribution loses its appeal as equilibrium concept and we look for ’regularities’ at time-scales shorter than mixing time (metastability). In this talk we give an overview of our recent results on stationary expected social welfare, mixing time, and metastability of logit dynamics for some classes of games.
Game theory in supply chain management
Chair Tiru Arthanari, The University of Auckland

Tiru Arthanari, The University of Auckland (with Nagarajan Krishnamurthy)

Game theory and supply chain management: A survey
Recent years have seen an increasing interest in the applications of Game Theory in Supply Chain Management (SCM), and allied areas. We survey some of these results. These include applications of Non-cooperative Games to SCM where, for example, there are competing entities and Nash equilibrium is sought. We also survey applications of Cooperative Games where, for example, the Shapley value is used to share costs (or profits). Examples are [Thun, 2000] where the author discusses applications of Cooperative Game Theory to apportion profit among partners. [Cachon and Netessine, 2003] discuss non-cooperative as well as cooperative game theoretic concepts that have potential for applications to analyzing supply chains. [Emaelli, Aranjehad and Zeephongsekul, 2009] propose several seller–buyer supply chain models which incorporate elements of competition as well as cooperation between buyer and seller. [Shuyong et al., 2008] use game theoretic tools to analyze the cost allocation problem in supply chain coordination. Stochastic Games, Bayesian Games etc. have been finding increasing applications in SCM too, and we discuss some of these as well. Illustrative applications are discussed.

David Carli, University of California at Riverside (with Tiru Arthanari)

Game theoretic modeling of supply chain cooperation among growers
Cooperation in supply chains is studied, by Lincoln (2010), using qualitative research methodology, based on case studies done in New Zealand. Recently, in the Horticultural New Zealand conference, the speakers explained how cooperation was working for their industries [Farmers Weekly, 2010]. In this paper we examine the cooperation phenomenon from a game theoretic perspective and give a model that brings out the trajectory of equilibria that will lead to optimal participation among the coalition partners. The model considers a set of growers who can choose to form a cooperative alliance to market their produce in some external markets, while competing within the internal regions.

By means of the general analytical framework of competition, studied by Carli (2010 and 2011), and others, we show the strategies that could produce cooperative solutions for these growers, where these feasible solutions aim at offering a win-win outcome for the growers, letting them share the pie fairly within a growth path represented by a family of non-zero sum games. The strategy requires determining the proportion of their resources they will use and how the gain will be shared.

Ravindran Gomadam, Indian Statistical Institute (with Jyengar Sudhanan)

Centrality in social networks
Centrality captures the intuitive notion of importance of nodes in a network. In the recent past there has been a flurry of activities in the science of Networks and its applications in diverse field of study thus making it a hot topic of interdisciplinary research.

In this paper we review and propose different approaches to finding influential nodes in complex networks particularly from a game theoretic point of view.

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. Simplifications are crucial to implement such optimization models into some business process 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 Beradier, Frederic Delhumeau)

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 based on ILOG optimization and SPSS. The presentation will showcase the synergy of these two worlds. The key integration piece will be presented, that is, the connector between prescriptive (optimization) and predictive analytics (SPSS Modeler), existing in the OPL language, integrated in the CPLEX Studio Integrated Development Environment. With this connector 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 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.

Lee 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. With PROC 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 program 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.
Currently used methods are reported.

It is of interest in several fields, for example in sociology, economy, or biology. Classes can hence be visualized by a graph, the so-called role graph. It is defined as a cycle packing problem, in computational biology. For our approach, we discuss both combinatorial algorithms and a mixed-integer linear programming (MIP) formulation for solving the pricing problems. In order to further improve the dual bound, cutting planes from the literature are separated during the solution process and their integration in the pricing problems is explained. Furthermore, we highlight a novel application for detecting structures in constraint matrices of MIPs and user heuristics tailored to this application for finding solutions during the branch-and-price algorithm. Finally, we present computational results both on graphs from the literature as well as from our approach and discuss the peculiarities of these instances.

An exact approach for aggregated formulations

Aggregating formulations is a powerful trick for transforming problems into more tractable forms. An example is Dantzig-Wolfe decomposition, which characterizes the relative errors in weights and threshold of strict separating systems: the tolerance (Hu 1962) 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 attains 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.

Cycle free flows in large-scale metabolic networks

Using a specific branching strategy combined with a primal heuristic, genome-scale metabolic networks only contain few internal circuits. 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. 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 30–300 to previous methods.

Column generation alternately solves a master problem and a pricing subproblem to add variables to the master problem as needed. The method is known to suffer from degeneracy, exposing what is known as the so-called row-reduction for the number of variables n and the number of types of distinguished variables k.

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Organizer/Chair Marco Lübbecke, RWTH Aachen University. Invited Session

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A column generation scheme alternately solves a master problem and a pricing subproblem to add variables to the master problem as needed. The method is known to suffer from degeneracy, exposing what is known as the so-called row-reduction. In this presentation, we propose a general method for solving aggregated formulations, such that the solution is optimal to the original problem. The method is based on applying Benders' decomposition on a combination of the original and aggregated formulations. Put in a branch-and-bound context, branching can be performed on the original variables to ensure optimality. We show how to apply the method on well-known optimization problems.

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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 Widdows, CORE, Université Catholique de Louvain (with Mathias Van Vyve, Hilde Tuyman)

The one warehouse multiple retailer problem with start-ups and constant capacities

For the uncapacitated OWMR problem with \( K \) clients and \( T \) periods, a multi-commodity reformulation solves instances with \( K, T = 100 \) to optimality. We consider a new relaxation motivated by the Wagner-Whitin relaxation that is effective for single level problems. The relaxed solution set \( X \) decomposes into \( X = X_1^*, Y_1^* \), each set \( Y^* \) having the same structure, denoted \( Y \).

(i) When \( K = 1 \) and uncapacitated at warehouse and client, we give a tight and compact extended formulation for con\((Y)\), an inequality description in the original space, and an \( O(T^2) \) separation algorithm.

(ii) A similar result with start-up costs at both levels.

(iii) With multiple clients (\( K > 1 \)), the convex hull of \( Y^* \) is essentially the intersection of the convex hulls for each client individually, providing an \( O(KT^2) \) formulation for OWMR.

(iv) When uncapacitated at the warehouse and constant capacity for each retailer, we give an extended formulation for \( Y^* \) that is conjectured to be tight.

For OWMR with start-ups, our formulation improves computationally on the multicommodity formulation, and with capacities it solves to optimality instances with \( K, T = 25 \).

Scheduling, assignment and matching in healthcare

Chair Sarah Kitcher, RWHU Aachen

Andrea Trautschlamm, University of Natural Resources and Life Sciences, Vienna (with Patrick Hirschl)

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 of medium term time consuming. 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. Jalilzadeghain, 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 by 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 age difference, and minimize the stroke severity index difference. We applied our models for two data sets EPITHET 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 Kitcher, RWHU Aachen (with Marco Lubbecke)

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 patient care pathway. This problem can be seen as a new 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 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.

Olga Perederieieva, The University of Auckland

Solving the time surplus maximisation bi-objective user equilibrium problem in a travel assignment model

The conventional approach to model traffic assignment assumes that all users have the same objective, i.e., to minimize their travel time or generalised cost, which usually represents a linear combination of time and monetary cost. In a tolled road network, this assumption cannot be adequate to represent real systems. Inspired by the multi-objective definition of optimality, we reformulate the problem with a bi-objective user equilibrium (BUE) condition, which allows multiple solutions. More specifically, we propose a time-surplus maximisation model (TSMaxBUE) as a possible way to represent route choice behaviour in tolled road networks. In case of multiple user classes, this model can be solved by multiuser equilibrium methods. To solve it we adopt path-based optimisation algorithms used for conventional traffic assignment, compare their performance and study how the solution space depends on the parameters of the model. In case of multiple user classes generally it is not possible to derive an equivalent optimisation formulation. Therefore, we propose to use a non-linear complementarity problem formulation to solve the TSMaxBUE model.

Alexander Gashnikov, Moscow Institute of Physics and Technology (with Ergun Gashnikova)

Stochastic optimization in the model of correspondences matrix calculation and traffic flow distribution

We considered two problems connecting to each other. The first problem is to interpret a gravitational matrix correspondence model and its proper generalization for Moscow city according to the conception of equilibrium of macro system. We propose an ergodic stochastic Markov dynamic of natural behavior of the residents. At the large values of time this dynamic leads to the stationary distribution measure. And when the number of residents tends to infinity this measure is concentrated in a small vicinity of the most probable macro state. To find this state we have to solve an entropy optimization problem. For this problem we use proper dual barrier-multiplicative stochastic subgradient descent in dual spaces. The second problems consist in finding traffic flow (stochastic) assignment according to the BMW model and Nesterov–de Palma model. We show that substantially interpreted evolutionary games dynamic in this games theory models can be considered to be the mirror descent subgradient (with prox-function Kullback–Leibler distance). We also investigate the logit(Gibbs) best responses dynamic (Nash–Vardrop equilibrium isn’t assumed unique).
We present new separation algorithms for the ATM by horizontal maneuvers. A ranked multiobjective MINLO problem

A mixed 0—1 nonlinear optimization approach is presented to solve the aircraft collision avoidance problem for the Air Traffic Management. Given the flight plans configuration, the problem consists of deciding a strategy such that every conflict situation is avoided. For this aim, we consider two possible maneuvers: velocity and angle changes, in a high nonconvex mixed integer nonlinear optimization (MINLO) approach that is based on a geometric construction. In order to determine which maneuvers will be followed, a ranked multiobjective approach is presented optimizing one of them by appending to it the constraint that satisfies the optimal objective function value of the other one with higher rank allowing an epsilon violation, such that the optimal solution of the higher rank objective can be used as a hot start for optimizing the other one. Some preliminary computational results will be presented by using a state-of-the-art nonconvex MINLO engine at each iteration, where a MINLO submodel is solved.

In logistics applications, transport requests are conducted in parallel by several vehicles moving along a fixed shared pathway. Examples include cranes mounted on a common rail, like gantry cranes parallel by several vehicles moving along a fixed shared pathway. Existing solutions consider two possible maneuvers: velocity and angle changes, in a high nonconvex mixed integer nonlinear optimization (MINLO) approach that is based on a geometric construction. In order to determine which maneuvers will be followed, a ranked multiobjective approach is presented optimizing one of them by appending to it the constraint that satisfies the optimal objective function value of the other one with higher rank allowing an epsilon violation, such that the optimal solution of the higher rank objective can be used as a hot start for optimizing the other one. Some preliminary computational results will be presented by using a state-of-the-art nonconvex MINLO engine at each iteration, where a MINLO submodel is solved.

Convex approaches for quadratic integer programs

Organizers/Chairs: Adam Letchford, Lancaster University; Samuel Burer, University of Iowa — Invited Session

Adam Letchford, Lancaster University (with Michael Soerensen)

A new separation algorithm for the Boolean quadric and cut polytopes

A separation algorithm is a procedure for generating cutting planes. We present new separation algorithms for the Boolean quadric and cut polytopes, which are the polytopes associated with zero-one quadratic programming and the max-cut problem, respectively. Our approach exploits a non-trivial way, three known results in the literature: 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 \((p, 2)\)-circuit inequalities.

Anja Fischer, Chemnitz University of Technology

The asymmetric quadratic traveling salesman problem

In the asymmetric quadratic traveling salesman problem (AQTSP) the costs are associated to any three nodes that are traversed in succession and the task is to find a directed tour of minimal total cost. The problem is motivated by an application in biology and includes the antimetric TSP and the TSP with reload costs as special cases. We study the polyhedral structure of a linearized integer formulation, present several classes of facets and investigate the complexity of the corresponding separation problems. Some facets are related to the Boolean quadric polytope and others forbid conflicting configurations. A general strengthening approach is proposed that allows to lift valid inequalities for the asymmetric TSP to improved inequalities for AQTSP. Applying this for the subtour elimination constraints gives rise to facet defining inequalities for AQTSP. Finally we demonstrate the usefulness of the new cuts. Real world instances from biology can be solved up to 100 nodes in less than 11 minutes. Random instances turn out to be difficult, but on these semidefinite relaxations improved by the cutting planes help to reduce the gap in the root node significantly.

John Mitchell, Rensselaer Polytechnic Institute (with Lijie Bai, Jong-Shi Pang)

Quadratic programs with complementarity constraints

We examine the relationship between a quadratic program with complementarity constraints (QPCC) and its completely positive relaxation. We show that the two problems are equivalent under certain conditions, even if the complementary variables are unbounded. We describe the use of semidefinite programming to tighten up the quadratic relaxation of a QPCC when the quadratic objective function is convex. When the variables are bounded, a QPCC can be expressed as a mixed integer nonlinear program.

Mixed-integer nonlinear programming

Organizers/Chairs: Peter Keskinen, Linköping University; Kaj Holmberg, Torbjörn Larsson, Kristian Lundberg

Scheduling multiple cranes on a shared pathway

In many logistics applications, transport requests are conducted in parallel by several vehicles moving along a fixed shared pathway. Examples include cranes mounted on a common rail, like gantry cranes parallel by several vehicles moving along a fixed shared pathway. In theory, assigning transport requests to the vehicles of such systems and scheduling their execution amounts to finding a tour on a common line, where tours may never cross each other in time — dynamic collision constraints need to be respected. The goal is to minimize the total time for a given set of transport requests. This problem contains other challenging tasks like partitioning jobs and assigning starting times.

We present a model capturing the core challenges in transport planning problems of this type and prove NP-hardness for the problem. The structural properties can be used to formulate a mixed integer program with starting time variables, but without any assignment of jobs to vehicles. Furthermore, we show some special cases where an optimal solution can be found in polynomial time.

Nonlinear programming

Organizer/Chair: Yu-xiang Yuan, Chinese Academy of Sciences — Invited Session

Coralia Cartis, University of Edinburgh (with Nicholas Gould, Philippe Toint)

On the evaluation complexity of constrained nonlinear programming

We present a short-step target-following algorithm for smooth and nonconvexly constrained programming problems that relies upon approximate first-order minimization of a nonsmooth composite merit function and that takes at most \(\mathcal{O}(\varepsilon^{\frac{3}{2}})\) problem-evaluations to generate an approximate KKT point or an infeasible point of the feasibility.
measure. This bound has the same order as that for steepest-descent methods applied to unconstrained problems. Furthermore, complexity bounds of \(O(n^{3.5/2})\) 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.

Xia 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-Shapeley 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.

Luciana Casacio, UNICAMP - University of Campinas (with Christiano Lyra, Aurelio Oliveira)

**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 behavior on medium-scale problems from the Netlib collection.

Luiz-Rafael Santos, IMECC/Unicamp (with Aurelio Oliveira, Clovis Perin, Fernando Villas-Blas)

**A polynomial optimization superproblem 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 methods, combines three types of directions to generate a better one by making an extensive use of real-valued polynomials on variables \((a, \mu, \sigma)\), where \(a\) is the step length, \(\mu\) defines a more general central path, and \(\sigma\) models the weight that a predictor direction should have. We develop a merit function that is a polynomial in \((a, \mu, \sigma)\) 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.

Xiao Wang, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (with Ya-xiang Yuan)

**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.

Zhijun Wu, Iowa State University (with Yiping Hao, Wen Zhou)

**Interior-point methods for linear programming**

Luiz-Rafael Santos, IMECC/Unicamp (with Aurelio Oliveira, Clovis Perin, Fernando Villas-Blas)

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Xia Wang, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (with Ya-xiang Yuan)
Optimization in energy systems

Thur. 2 MA 547
Optimization in the natural gas markets
Organizer/Chair Guillaume Erts, GDF SUEZ - Invited Session
Guillaume Erts, GDF SUEZ (with Romain Apparigliato)
Application of stochastic dual dynamic programming to the analysis of natural gas markets

For the evaluation of the natural gas markets, the transactional simulation models 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 (pipelines or LNG), and storage. In this presentation, we make the assumption of perfect competition and we focus on the uncertainty of supply (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.

Abada 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.

Argoir Tamgangard, NTNU (with Lars Hellamo, Kjetil Midtnes, Adrian Werner)
Multi-stage stochastic programming for natural gas infrastructure design

We present a multi-stage stochastic model that analyzes investments in a 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-bound coordination is summarized.

Optimization in energy systems

Thur. 2 MA 550
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 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 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 disconnected. We will illustrate 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’ 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) what degree does the abstraction of the temporally dynamic technological operations in separate LP, MILP, and MINLP formulations impact upon the optimisation’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.

Optimization in energy systems

Thur. 2 MA 551
PDE-constrained opt. & multi-level/multi-grid meth.

PDE optimization in medicine II
Organizer/Chair Anton Schiela, TU Berlin - Invited Session
Martin Frank, RWTH Aachen University (with Richard Barnard, 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 a 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.

Chamakur Najagha, 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 optimal control approach is based on minimizing a properly chosen cost functional $J(v, l)$ depending on the extracellular current $I_e$ 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.

Optimization in energy systems
of the Lagrange-Newton-Krylov method in a parallel environment will be shown.

Malik Kirschner, Zuse Institut 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 Metric 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.

Theresa Kolhs, Technische Universität München

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Florian Kruse, Technische Universität München (with Michael Ulbrich)

An infesiable 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 minimizers and the solution of the problem. Moreover, we report on numerical experiments to illustrate the efficiency and the mesh independence of this algorithm.

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Florian Kruse, Technische Universität München (with Michael Ulbrich)
Linearly 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 this algorithm results in a naturally generalized version 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 energy, 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 energy, 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 $\delta_p < 1$, 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

Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen - Invited Session

Dimitri Drakunov, 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 problems with order constraints (active/passive) in the first and second stage. 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 bivector 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 Wallenberg, University of Duisburg-Essen (with Uwe Clausen, Rüdiger Schultz, Sascha Wohlgemuth)

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.

Anna Timonina, 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 meditatively. 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 conditional distributions at each stage, that allows to approximate a large class of processes.

Jose Nino-Mora, Carlos III University of Madrid (Q-218109-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.

Alois 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, scenarios, 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 reliable 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.

Jose Nino-Mora, Carlos III University of Madrid (Q-218109-G)

Stochastic optimization

Large-scale and multi-stage stochastic optimization

Chair Alois Pichler, University of Vienna

Organizer/Chair Sergiy Butenko, Texas A&M University - Invited Session

Michael Ovelgönne, University of Maryland (with Andreas Geyer-Schulz)

Ensemble learning for combinatorial optimization: Modularity maximization and beyond

Ensemble learning clustering method with very high operational performance, such as 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 Schumm, Karlshue 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 qualitative behavior 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-movement is superior to one based on merging. We further reveal that the former approach generally outperforms alternative setups and reference algorithms from the literature in terms of its own objective, while a modularity-based algorithm competes 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 improve the communication capacity. For a K-user MIMO interference channel, we propose a low complexity interference alignment algorithm to solve the desired signal power maximization problem which is a nonconvex complex matrix optimization problem. First we use a courant 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 Householder transformation, the matrix problem becomes vector optimization 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.

Thu.2.H 223

Stability of constraint systems

Organized/Chair Réne Henrion, Weierstrass Institute Berlin - Invited Session

Alexey Izmailov, Moscow State University [with Alexey Kurennoy]

Strong regularity and abstract Newton schemes for nonsmooth generalized equations

We suggest the inverse function theorem for generalized equations, unifying Robinson’s theorem for strongly regular generalized equations and Clarke’s inverse function theorem for equations with locally Lipschitzian mappings. This theorem is further applied in the context of very general Newton schemes, covering, among others, some methods which are usually not regarded as Newtonian. In particular, we derive new local convergence results for the augmented Lagrangian methods applied to optimization problems with locally Lipschitzian derivatives.

Réne Henrion, Weierstrass Institute Berlin [with Alexander Kruger, Jiří Outrata, Thomas Surowiec]

On (co-)derivatives of the solution map to a class of generalized equations

This talk is devoted to the computation of (co-)derivatives of solutions maps associated with a frequently arising class of generalized equations. The constraint sets are given by (not necessarily convex) inequalities for which we do not assume the linear independence of gradients. On the basis of the obtained generalized derivatives, new optimality conditions for a class of mathematical programs with equilibrium constraints are derived, and a workable characterization of the isolated calmness of the considered solution map is provided. The results are illustrated by means of examples.

Marco A. López, Alacant University [with A. Daniilidis, M. A. Goberna, R. Luke]  

Lower semicontinuity of the feasible set mapping of linear systems relative to their domains

The talk deals with stability properties of the feasible set of linear inequality systems having a finite number of variables and an arbitrary number of constraints. Several types of perturbations preserving consistency are considered, affecting respectively, all of the data, the left-hand side data, or the right-hand side coefficients. Our analysis is focused on lower semi-continuity properties of the feasible mapping confined to its effective domain, dimensionality of the images and relations with Slater-type conditions. The results presented here are established in a joint paper with A. Daniilidis, M. A. Goberna, and R. Luke.
Variational analysis of optimal value functions and set-valued mappings with applications

Organizer/Chair: Muu Num Nguyen, University of Texas-Pan American - Invited Session

Messaoud Bounkhel, King Saud University (with Chong Li)

Regularity concepts of perturbed distance functions at points outside of the set in Banach spaces

In this talk, I will present some new results on the (Fréchet, proximal, Clarke, Mordukhovich) subdifferential of the perturbed distance function \( d_{\alpha}(.) \) determined by a closed subset \( S \) and a Lipschitz function \( f(.) \). Using these results, I will establish some important relationships between the regularity of the set and the perturbed distance function at points outside of \( S \) in arbitrary Banach space.

Sangho Kum, Chungbuk National University

A geometric mean of parameterized arithmetic and harmonic means of convex functions

Recently, Bauschke et al. (2008) introduced a new notion of proximal average, and studied this subject systematically from various viewpoints. The proximal average can be an attractive and powerful alternative to the classical arithmetic and epigraphical averages in the context of convex analysis and optimization problems. The present work aims at providing a further development of the proximal average. For that purpose, exploiting the geometric mean of convex functions by Attiea and Ras-soulii (2001), we develop a new algorithmic self-dual operator for convex functions termed "the geometric mean of parameterized arithmetic and harmonic means of convex functions", and investigate its essential properties.

Nguyen Dong Yen, Institute of Mathematics, Vietnam Academy of Science and Technology (with Gue Myung Lee)

Coderspectives of a Karush-Kuhn-Tucker point set map and applications

The trust-region subproblem corresponding to the triple \( \{A, b, \alpha\} \), where \( A \in \mathbb{R}^{m \times n} \) is a symmetric matrix, \( b \in \mathbb{R}^m \) a given vector, and \( \alpha > 0 \) a real number, is the optimization problem

\[
\min \left\{ f(x) : \frac{1}{2} x^T A x + b^T x : \|x\|^2 \leq \alpha^2 \right\}. \tag{P}
\]

One often encounters with \((P)\) in the development of trust-region methods for nonlinear programs. Since the feasible region of \((P)\) is a convex compact set with an infinite number of extreme points, the structure of its solution set (resp. of its Karush-Kuhn-Tucker point set) is quite different from that of quadratic programs with linear constraints. By using some tools from Variational Analysis, this paper investigates the stability of \((P)\) with respect to the perturbations of all the three components of its data set \(\{A, b, \alpha\}\).

Thu.2.MA 649

Variational methods in inverse problems

Organizer/Chair: Elena Nesimenta, Alpian-Adria University - Invited Session

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). The sought-after function is modeled as a piecewise constant function. Hence, it consists of \( n \) sets \( \Omega_i \) and the corresponding values \( c_i \). The sets and values together with their number are found as minimizers of a Mumford-Shah-type functional. We present a level-set based minimization algorithm for this functional as well as theoretical results regarding the existence of minimizers, stability and regularization properties. We also present numerical results for tomography problems with limited data [limited angle, region of interest and electron tomography].

Mihaiu Praicu-Beckstadt, Leibniz Institute for Farm Animal Biology (with Norbert Reinsch)

Genomic selection and iterative regularization methods

In genomic selection it is expected that genetic information contributes to selection for difficult traits like traits with low heritability, traits which are hard to measure or sex limited traits. The availability of dense markers covering the whole genome leads to genomic methods aiming for estimating the effect of each of the available single nucleotide polymorphism. Hence, we propose a semiparametric method and an iterative regularization approach for high-dimensional but small sample-sized data. Numerical challenges like model selection, the estimation of the predictive ability and the choice of the regularization parameter are discussed and illustrated by simulated and real data examples.

Christian Pischel, Alpen-Adria Universität Klagenfurt (with Vicent Caselles, Matteo Navaglia)

TV-denoising and evolution of sets

Let \( S \subset \mathbb{R}^2 \) be the union of two convex sets with smooth boundary. We connect the levelsets of the minimizers \( u_j \) of

\[
\frac{1}{2} \| u - x \|_2^2 + \lambda \| u \|_{TV}
\]

to the minimizers of a (simpler) set-minimization problem in order to obtain a geometrical characterization of the levelsets of \( u_j \). Moreover, we calculate explicit minimizers of \((1)\), when \( S \) is the union of two non-intersecting circles/squares, using simple morphological operators. We also show how to construct the solutions for the more general case when \( S \) is nonconvex, starshaped set.

Thu.2.R 3010

Online algorithms

Organizer/Chair: Lisa Fleischer, Dartmouth College - Invited Session

Aleksander Madry, EPFL (with Nikhil Bansal, Noa Buchbinder, Joseph Naor)

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.

We will present a new randomized algorithm for the \(k\)-server problem that is the first online algorithm for this problem that achieves poly-logarithmic competitiveness.

Umang Bhaskar, Dartmouth College (with Lisa Fleischer)

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 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.

We apply our techniques to solve two online fixed-charged problems with congestion, motivated by applications in machine scheduling and facility location. The linear program for these problems is more complicated than mixed packing and covering, and presents unique challenges. We show that our techniques combined with a randomized rounding procedure give polylogarithmic-competitive integral solutions. These problems generalize online set-cover, for which there is a poly-logarithmic lower bound. Hence, our results are close to tight.

Vahab Mirrokni, Google Research NC (with Shayan Oveisgharan, Moritz Madgiahad)
Combinatorial optimization
Thu.3.II 3094
Optimization methods for geometric problems
Organizer/Chair 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 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 (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 Moemi, 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 the problem 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 - an upper bound - 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.

Thu.3.II 3098
Discrete structures and algorithms III
Organizer/Chair Satoru Fujishige, Kyoto University - Invited Session
Yuusuke 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, 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 $K_{t,t}$, we consider the problem of finding a maximum $t$-matching. We 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 Katoh)
Rooted-tree decompositions with matroid constraints and the infinitesimal rigidity of frameworks with boundaries
As an extension of classical tree-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 $R = \{r_1, \ldots, r_k\}$ 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 $G_{i_1}, \ldots, G_{i_t}$ such that (i) for each $i \leq t$, $G_{i}$ is a tree with $r_t \in V$, and (ii) for each $v \in V$, the multiset $\{r_i \in R \mid v \in V_i\}$ 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 d-rigidity of body-bar frameworks.

Kiyohito Nagano, University of Tokyo (with Kazuyuki Aihara, Yoshitomo Kawaharada)
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.

Combinatorial optimization

Thu.3 H 2012
Arborescences
Chair Attila Bernáth, Warsaw University
Attila Bernáth, Warsaw University (with Gyuho Pap)
Covering minimum cost arborescences

Given a digraph $D = (V, A)$ with a designated root node $r \in V$ and arc-costs $c : A \rightarrow \mathbb{R}$, we consider the problem of finding a minimum cardinality subset $H$ of the arc set $A$ such that $H$ intersects every minimum cost $r$-arborescence. This problem is a special case of covering minimum cost common bases of two matroids, which is NP-complete even if the two matroids coincide, and the costs are all equal to 1. On the other hand we show that this special case is polynomially solvable: we give a polynomial algorithm for finding such an arc set $H$. The algorithm solves a weighted version as well, in which a nonnegative weight function $w : A \rightarrow \mathbb{R}_+$ is also given, and we want to find a subset $H$ of the arc set such that $H$ intersects every minimum cost $r$-arborescence, and $w(H)$ is minimum.

Mario Leston-Rey, Instituto de Matemática e Estatística da Universidade de São Paulo (with Yoshiko Wakabayashi)
Packing entering sets in kernel systems

In 1998, H. N. Gabow and K. S. Manu showed a strongly polynomial time algorithm to obtain – in a capacitated digraph with $m$ arcs and $n$ vertices – a maximum integral packing of at most the maximum integral packing entering sets in kernel systems (Wakabayashi).

Thu.3 MA 313
Algorithms for complementarity and related problems I
Chair Walter Morris, George Mason University
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 $B^D$-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.

Jacek Górska, Łódź Technical University (with Alexey Izmailov, Mikhail Solodov)
Global convergence of augmented Lagrangian methods applied to

Thu.3 H 2012
Scheduling and network flows over time
Organizer/Chair Kay Kaya, TU Berlin (with Imre Pósfai)
Alberto Marchetti-Spaccamela, Sapienza University of Rome (with Leah Epstein, Asaf Levin, Nicole Megow, Julian Mestre, Martin Skutella, Leon Stougie)
Universal sequencing on an unreliable machine

We consider scheduling on an unreliable machine that may experience peak-time load exceed or even full breakdowns. Our objective is to minimize the sum of weighted completion times for any non-decreasing, non-negative, differentiable cost function $f(C_i)$. We aim for a universal solution that performs well without adaptation for all cost functions for any possible machine behavior.

Combinatorial optimization

Wedesignadeterministicalgorithmthatfindsaunderialschedulingsequencewithasolutionvaluewithinfortimesthetheralueofanoptimalclairvoyantalgorithmthatknowsthemachinemachinebehaviorinadvance.Arandomizedversionofthisalgorithmattainsinexpectationaratioof$e$.Weshowthatbothperformanceguaranteesarebestpossibleforanyunboundedcostfunction.

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 $O(\log n/\log \log n)$ 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 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 [FACOS ’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-flow-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.
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 (MPCC). 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 MPCC, 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 MPCC (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, Georgia 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-Chung 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, which has previously found applications in compressed sensing (where all accounts are subject to global constraints) is also studied with satisfactory convergence property. A more general game problem with degenerate constraints, such as existence and uniqueness, and devise efficient algorithms for problems with degenerate constraints.

Senshan Ji, The Chinese University of Hong Kong (with Anthony Man-Chung So)

Semidefinite relaxation in wireless communications: Forefront developments, advances and challenges

- Semidefinite relaxation (SDR) is well-known to be an efficient high-performance technique for approximating a host of hard, nonconvex optimization problems. And one of its most recognized applications is probably MAXCUT. In fact, SDR has also made its way to signal processing and wireless communications, and the impact is tremendous -- today we see not only numerous applications, but also new fundamental concepts and theory driven by the applications themselves. This talk will focus on transmit beamforming, now a key topic in communications. I will provide an overview on its scope, which is quite broad (classical multiuser downlinks, unicastand multicasting, multicell cohered multiuser downlinks, cognitive radio, physical layer security, relaying, ...). I will then describe some latest advances that link up fundamental meaning to optimization studies, like chance-constrained optimizations, and rank-two SDR. This will be followed by an open discussion on some mysteries and challenges, noticed by researchers in simulations. For example, why does SDR give us a rank-one solution for some hard problems that involve semi-infinite quadratic constraints, seemingly all the time?

Wing-Kin Ma, The Chinese University of Hong Kong

Multi-portfolio optimization: A variational inequality approach

In this paper, we study the multi-portfolio optimization problem with square-root market impact model using a game-theoretic approach. Contrary to the linear market impact model, available tools such as potential game theory are not applicable for the square-root model. We approach this problem using Variational Inequality, and give a comprehensive and rigorous analysis on the properties of the Nash Equilibrium such as existence and uniqueness, and devise efficient algorithms with satisfactory convergence property. A more general game problem where all accounts are subject to global constraints is also studied under the framework of Variational Inequality.

Yang Yang, The Hong Kong University of Science and Technology (with Daniel Palomar, Francisco Rubio, Gesualdo Scutari)

Recent developments of theory and applications in conic optimization

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 symmetric 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.

Sébastien Le Digabel, Polytechnique Montréal (with Charles Audet, Andrea Lodi, Christophe Torbi)

The mesh adaptive direct search algorithm with reduced number of directions

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 positive 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.

JoséMarioMartínez, University of Campinas (with Luís 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

Roots of convex cones

Organizers/Chairs Hayato Waki, Kyushu University; Masakazu Muramatsu, The University of Electro-Communications - Invited Session

On the nonhomogeneity and the bilinearity rank of a completely positive cone

Muddapaka Gowda, University of Maryland, Baltimore County

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 small perturbation. When applied to a POP, it provides guarantees that the optimal value of the corresponding SDP relaxation with sufficiently large order is bounded below by \( f^* - \epsilon \) and from above by \( f^* + \epsilon + \delta \), where \( f^* \) is the optimal value of the POP, \( n \) is the number of variables, and \( \epsilon \) 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 positively 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 than the sparse SDP relaxation proposed by Waki et al. We present some applications and the results of our computational experiments.

Masakazu Muramatsu, The University of Electro-Communications (with Levent Tuncel, Hayato Waki)

Semidefinite programming applications

We present some applications and the results of our computational experiments.

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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
on the Inexact Restoration framework, by means of which each iteration is divided in two phases. In the first phase one considers only the constraints, in order to improve feasibility. In the second phase one minimizes a suitable objective function subject to a linear approximation of the constraints. The second phase must be solved using derivative-free methods. An algorithm introduced recently by Kolda, Lewis, and Torczon for linearly constrained derivative-free optimization is employed for this purpose. Under usual assumptions, convergence to stationary points is proved. A computer implementation is described and numerical experiments are presented.

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 of 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.

Mathias Barkhagen, Linköping University (with Jörgen Blomvall)

An optimization based method for arbitrage-free estimation of the implied risk neutral density surface

Accurate pricing of OTC derivatives which is consistent with noisy market prices presents a major challenge. The pricing accuracy will crucially depend on using arbitrage-free inputs to the pricing engine. To this end we develop a general optimization based framework for estimation of the option implied risk neutral density (RND) surface, while satisfying no-arbitrage constraints. The developed framework is a generalization of existing models such as the Heston model. Thus, the method considers all types of realistic surfaces and is hence not constrained to a certain function class. Instead the RND is discretized making it possible to use standard solvers for the problem. The approach leads to an optimization model where it is possible to formulate the constraints as linear constraints. The linear constraints and the form of the objective function leads to an inherent problem structure which may be utilized to speed up calculations. We show that our method produce smooth local volatility surfaces that can be used for pricing and hedging of OTC derivatives. Statistical tests demonstrate that our method gives better results than the Heston model in terms of yielding stable RNDs.

Jonas Mayer, University of Zurich (with Thorsten Hens)

Portfolio optimization with objective functions from cumulative prospect theory

We consider portfolio optimization problems with several assets, involving objective functions from the cumulative prospect theory (CPT) of Tversky and Kahneman (1992). These are numerically difficult optimization problems since the objective function to be maximized is neither convex nor smooth. We have implemented an adaptive simplex grid method for the solution of this type of problems and report on the results of a numerical study. Levy and Levy (2004) proved that under the assumption of normally distributed returns the CPT efficient set is a subset of the mean-variance (MV) frontier. In fact the authors state that there is no need for separate solution algorithms for CPT-optimization, since those problems are readily solvable by maximizing the CPT objective function along the MV frontier. We compare this suggestion with the direct CPT-optimization, for a real life data-set and for several investors and find that the two approaches lead to substantially different portfolios. This difference increases dramatically if we add a call option to our data-set and it diminishes almost completely for a data-set obtained by sampling from the corresponding normal distribution.

Eligius Hendrix, Málaga University (with Leocadio 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 maximise return and minimise risk, have been made explicit in terms of optimisation 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.

Mathias Barkhagen, Linköping University (with Jörgen Blomvall)

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Jonas Mayer, University of Zurich (with Thorsten Hens)

Portfolio optimization with objective functions from cumulative prospect theory

We consider portfolio optimization problems with several assets, involving objective functions from the cumulative prospect theory (CPT) of Tversky and Kahneman (1992). These are numerically difficult optimization problems since the objective function to be maximized is neither convex nor smooth. We have implemented an adaptive simplex grid method for the solution of this type of problems and report on the results of a numerical study. Levy and Levy (2004) proved that under the assumption of normally distributed returns the CPT efficient set is a subset of the mean-variance (MV) frontier. In fact the authors state that there is no need for separate solution algorithms for CPT-optimization, since those problems are readily solvable by maximizing the CPT objective function along the MV frontier. We compare this suggestion with the direct CPT-optimization, for a real life data-set and for several investors and find that the two approaches lead to substantially different portfolios. This difference increases dramatically if we add a call option to our data-set and it diminishes almost completely for a data-set obtained by sampling from the corresponding normal distribution.

Eligius Hendrix, Málaga University (with Leocadio 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 maximise return and minimise risk, have been made explicit in terms of optimisation 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.
Game theory

Software piracy and mastermind
Chair Carola Wiszniewski, Max-Planck-Institut für Informatik

Yael Perlman, Department of Management, Bar-Ilan University (with Konstantin Kogan, Yaacov Otzic):
Software piracy prevention 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 Wiszniewski, Max-Planck-Institut für Informatik (with Benjamin Deoer, Reita Spehoel, Renning 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 code-breaker 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 $k \leq n - \log n$ of colors, and it yields a winning strategy using $O(n \log k / \log(n/k))$ guesses.

Global optimization

Advances in global optimization III
Chair Duy Van Nguyen, Universität Trier

Tibor Csendes, University of Szeged (with Elekta Antal):
Symbolic simplification of nonlinear optimization problems

We present a Maple implementation of a symbolic algorithm that is capable to transform the original nonlinear global optimization problem into an equivalent form, that is simpler in the sense that it has less operations to be calculated. The algorithm can also recognize redundancies in the optimized variables, and in this sense it can decrease the dimensionality of the problem (if it is possible). The applied transformations can preserve the number of local minimizer points, and the solution of the transformed problem can easily be transformed back to the space of the original variables.

We have tested the code on the set of standard global optimization problems and on some custom made simplifiable problems. The results are convincing in terms that the algorithm concludes in almost all cases according to our knowledge on the problems. Csendes, T. and T. Rapsz: Nonlinear Coordinate Transformations for Unconstrained Optimization. I. Basic Transformations, J. of Global Optimization 3(1993) 213-221.

Chu Nguyen, Eastern Asian University of Technology (with Nguyen Chu, Pham Duong, Le Hue):
The interior exterior approach for linear programming problem

In this paper we present a new interior exterior algorithm for solving linear programming problems, which can be viewed as a variation of simplex method in combination with interior approach. With the assumption that a feasible interior solution to the input system is known, this algorithm uses it and appropriate constraints of the system to construct a sequence of the so called station cones whose vertices tend very fast to the solution to be found. The computational experiments show that the number of iterations of the interior exterior algorithm is significantly smaller than that of the second phase of the simplex method. Additionally, when the number of variables and constraints of the problem increase, the number of iterations of the interior exterior approach increase in a slower manner than that of the simplex method.

Duy Van Nguyen, Universität Trier:
Solving standard problem (STOP)

We consider the standard quadratic problem (STOP) which consists of globally minimizing an indefinite quadratic function over the simplex. We propose a a finite but exponential solution algorithm in which the main task of each iteration is to check semidefiniteness of $k \times k$ symmetric matrix with $k \leq n$. We show some illustrative examples and computational test results for the algorithm.

Implementation & software

Per Rutquist, Tomlab Optimization (with Marcus Edvall, Kenneth Holmström):
Trajectory optimization with TOMLAB/PROPT

We demonstrate an easy-to-use symbolic interface for trajectory optimization, and for general linear and nonlinear programming, using Matlab syntax. PROPT allows ordinary differential equations (as well as more general differential algebraic equations) to be converted into optimization constraints using pseudo-spectral collocation. Multi-phase problems and links to time-independent equations are also handled in a straightforward manner.

Equations are entered via the symbolic interface TOMSYM, which automatically generates the linear constraint matrix as well as derivatives of nonlinear functions. These are then integrated with the entire TOMLAB suite of solvers, which includes mixed-integer optimization with KNITRO and MINLPBB and global optimization with multiMin. As a result, we achieve very good results on many problems described as “hard” in literature. As illustration, we present solved examples from robotics, aerospace, process control and parameter estimation.

Optimization under uncertainty: Software tools for modelling and solver support

Algebraic modeling languages are now well established as a formulation tool used by practitioners and academics in the field of operational research. We describe an integrated modeling and solver platform for investigating stochastic and robust optimization models. We consider the following well known approaches: stochastic programming (SP) with recourse, chance constrained programming, integrated chance constrained programming, and robust optimization.

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 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 Beraudier, IBM Industry Solution (with Ferenc Katai, Arnaud Schulz):
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 integrated debugging mechanisms 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.
which relies on the Dantzig-Wolfe decomposition. The column generation procedure has proven to be a successful approach, and large neighborhood search and diving heuristics in column generation algorithms have been proposed in the literature. Numerical results presented compare the results obtained with the formulation proposed with the solutions obtained by the exhaustive algorithm supported by the freely available Bunch clustering tool, for benchmark problems.

Christian Puchert, RWTH Aachen University (with Marco Lübbecke)

Natural languages with the morphosyntactic distance as a topological space

The main aim of this paper is to give a proof of the computability of morphosyntactic space (M.D.) over an arbitrary set of data. Since here, M.D. (defined in the works of De Santos, Villa and Guillièn) can be defined over the elements of this group. Distance d induces a topological space, that we call morphosyntactic space. Based on this hypothesis, studying the properties of this space from a topological point of view. Let the associated lexical space built, that has a semigroup structure, and could be treated as a set, regardless of its algebraic properties. Using the fact that the meaning function is injective, it is possible to define on it the M.D. d.

In the first section, several topological properties of morphosyntactic space are proved: total disconnection, compactness and separability. Then a comparison is proposed between different structures and morphosyntactic space.

Under the latter theorem, reasonable time to implement algorithms can be assumed over morphosyntactic space. In these conditions, it is easy to conclude that the model designed to define the morphosyntactic space is computable, and therefore the algorithm of M.D. is solvable.

Inácio Andruski-Guimarães, UTFPR – Universidade Tecnológica Federal do Paraná

Comparison of techniques based on linear programming to detect separation

Separation is a key feature in logistic regression. In fact, it is well known that, in case of complete separation, iterative methods commonly used to maximize the likelihood, like for example Newton’s method, do not converge to finite values. This phenomenon is also known as monotone likelihood, or infinite parameters. Linear programming techniques to detect separation have been proposed in the literature for logistic regression with binary response variable. But, for polynomials response variable, the time required to perform these techniques can be greater than that for fitting the model using an iterative method. The purpose with this job is to develop and implement an alternative approach to detect separation for the parameter estimation in polynomials logistic regression. This approach proposes to use as covariates a reduced set of optimum principal components of the original covariates. Principal components analysis allows the reduction of the number of dimensions and avoiding the multicollinearity of these variables. Examples on datasets taken from the literature show that the approach is feasible and works better than other techniques, in terms of amount of computing.

Pedro Guillen, Universidad Politécnica de Madrid (UPTM), Natural Computing Group (with Juan Castellanos, Alejandro De Santos, Eduardo Villa)

A branch-and-price algorithm for rearranging a matrix into doubly bordered block-diagonal form

We consider rearranging the rows and the columns of a matrix into doubly bordered block-diagonal (a.k.a. arrowhead) form. For a given number of blocks and some given balance condition on the blocks, this becomes an optimization problem in which the total number of border rows and border columns is to be minimized. In this talk we present an exact branch-and-price algorithm to this optimization problem.

For us, this matrix form is particularly interesting because it may help us applying a Dantzig-Wolfe decomposition of the underlying mixed integer program.

We extend a naive assignment IP formulation [that has a weak LP relaxation] by an exponentially number of block pattern variables to strengthen the LP relaxation. Our branch-and-price algorithm first solves the pricing problem heuristically by exploiting its special structure. If the heuristic solution for the pricing problem does not yield variables with negative reduced costs the pricing problem is solved exactly by an IP. We present the improvement of the LP relaxation and discuss the practicability of the algorithm.

Michael Bastubbe, RWTH Aachen, Chair of Operations Research (with Martin Bergner, Alberto Ceselli, Marco Lübbecke)
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. 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 (and bounded-genus) graphs, for any constant $\epsilon > 0$. PCS, PCTSP, 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 PCSF 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.]

Mohammadhossein Bateni, Google Inc. (with Mohammadtaghi Hajiaghayi, Philip Klein, Claire Mathieu)

PTAS for planar multicut

Given an undirected graph with edge lengths and a subset of nodes (called the terminals), a multicut way cut (also called a multi-terminal cut) problem asks for a subset of edges with minimum total length and whose removal disconnects each terminal from the others. It generalizes the min st-cut problem but is NP-hard for planar graphs and APX-hard for general graphs. We give a polynomial-time approximation scheme for this problem on planar graphs. We prove the result by building a novel separator for multicut way cut on planar graphs which is of independent interest.

Thu.3 MA B24

Real-world applications
Chair Kaj Holmberg, Linköping University

Kaj Holmberg, Linköping University

Planning and routing in networks: Urban snow removal

We study the problem of planning service tasks in street networks, and use snow removal as a generic problem. Snow removal is (sometimes) an important problem. Drastic weather changes might become more frequent in the future, which indicates a need to handle unusual situations. Computerized optimization based tools for planning will be a help.

The goal is to find good a plan: When should each task be done, which vehicle should do the task and how should the vehicle travel between tasks. Different vehicles have different capabilities and tasks may have precedence requirements. The objective function may include finishing times, costs and environmental aspects.

The problem is too difficult to be solved by standard methods, but there are several usable structures in the problem, such as the Chinese postman problem, the rural postman problem, the asymmetric traveling salesman problem as well as scheduling with precedence constraints. We discuss solution methods containing several different heuristic parts building up and improving the solutions, using decomposition frameworks. Some preliminary conclusions from a real life example are mentioned.

Rodrigo Brachini, Universidade Estadual de Campinas – UNICAMP (with Víncula Armentano)

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 pickups and delivers client cargoes, etc., containers, along a pre-established route analogous to the hop-in and hop-off of passengers in a bus line. A tramp shipping company does not have a predefined route to follow, the route is constructed and executed as new demands arrive. Although the relevance of the types of decisions for each operation is different, for example daily routing decisions are more important to tramp than to liner companies, both operations share similar structure, such as the goal of profit maximization while fulfilling established contracts agreements, and may have part of the decision making process modeled and solved using a generic MIP formulation. The decisions addressed by the model are the definition of fleet size and mix e.g., which vessels to charter in/out or lay-up, the evaluation of spot voyages contracts and and the determination of vessel routes and schedules. The model was implemented with CPLEX and computational results are reported.

Thu.3 MA 427

Life sciences & healthcare

Chair Rujira Ouncharoen, Chiang Mai University

Ivan Savic, Faculty of Technology, University of Nis (with Ljubisa Nikolic, Vesna Nikolic, Ivana Savic, Mihajlo Stankovic)

Mathematical modeling of amygdalin isolation from plum kernel using response surface methodology

Amygdalin belongs in the group of anticancer agents. It has a high application in treatment of cancer, because of its selective impact on the tumor cells. The aim of this study was to model and optimize a process of amygdalin isolation from plum kernel (Nucleus Prunus Domestica) using 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 amygdalin as a dependent variable for central composite design. The second order polynomial model was successfully applied for mathematical modeling of this process. A correlation coefficient of 0.7768 indicates on a good fitting of observed with predicted data. By desirability function, the extraction process was optimized. The optimal amygdalin yield of 15.83 g/100 g d.e. was achieved after 120 min using 20% ethanol at the solution temperature of 78°C.

Rujira Ouncharoen, Chiang Mai University (with Thongchai Dumrongpokaphan, Siriwan Intawichai)

Stability of HIV aphaeresis model

The new approach in treating the human immunodeficiency virus (HIV) infection is aphaeresis. It is a method of collecting larger quantities of certain blood components that can safely be collected through a simple blood draw. In this paper, we investigate the effect of HIV aphaeresis in a model of HIV infection. Sufficient conditions are given to ensure the endemic equilibrium point is stable which mean the viral load is under control.

Thu.3 8104

Logistics, traffic, and transportation

Organization/Chair Arash Asadpour, New York University - Stern School of Business - Invited Session

Arash Asadpour, New York University - Stern School of Business (with Michel Goemans, Aleksander Madry, Shayan Oveis Gharan, Amin Saberi)

Rounding by sampling and an $O(\log n / \log \log n)$ approximation algorithm for ATSP

We study the relation between the integer linear programming models for a class of discrete optimization problems and their relaxations. I will introduce a new probabilistic technique for transforming the optimal solutions of these relaxed programs into the near-optimal solutions for the original discrete problems. The technique is based on sampling from maximum entropy distributions over combinatorial structures hidden in such problems.

In order to present the idea, I will go through a generalization of the Traveling Salesman Problem (Asymmetric TSP) and show how we can improve the worst-case performance guarantee for this problem after almost 30 years. We will also see other applications of this technique in assignment problems and fair resource allocation.

Nithish Korula, Google Research (with Mohammadhossein Bateni, Chandra Chekuri, Alina Ene, Mohammadtaghi Hajiaghayi, Daniel Marx)

Prize-collecting Steiner network problems on planar graphs

In this paper, we reduce Prize-Collecting Steiner TSP (PCSTP), Prize-Collecting TSP (PCSTP), Prize-Collecting Steiner Tree (PCCTT), 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. 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 (and bounded-genus) graphs, for any constant $\epsilon > 0$. PCS, PCTSP, 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 PCSF 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.]

Matthias Miltenberger, Zuse Institute Berlin

Advances in linear programming

The efficient and reliable solution of today's optimization problems remains an interesting and challenging task, especially when dealing with large-scale instances. A lot of these are formulated as mixed integer programs that rely on branch-and-cut to compute an optimal solution. In this process, several linear relaxations (LPs) have to be solved and the simplex method has proven successful in this task. We shed light on the impact of LP solving within the MIP context and present recent progress in the area, in particular with respect to the academic solvers SCIP and ScPoX.
Mixed-integer 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, multicommodity 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. Sotirov, De Loera, Hemmecke, Lee, Romanchuk, Rothblum and Weismantel.

Renata Sotirov, Tilburg University

SDP relaxations for the graph partition problem

In [R. Sotirov. 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 till 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.

The talk draws from my recent monograph on nonlinear discrete optimization and will show that this theory is universal and provides a new parametrization of all integer programming.

Preference structures in multi-objective optimization

Organizer/Chair Gabriele Eichfelder, TU Ilmenau - Invited Session

Gabriele Eichfelder, TU Ilmenau (with Markus Schweighofer, Universität Konstanz)

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 image space.

In this talk we present 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 subset 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.

Refat 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.

The new type of nonlinear scalarizing functions is introduced and their properties are discussed. These functions are used to characterize the properly nondominated elements.

Polyhedral Optimization

Organizer/Chair Jiawang Nie, University of California, San Diego - Invited Session

Li Hong, Zhi, Academy of Mathematics and Systems Science, Institute of Natural Sciences, Chinese Academy of Sciences

Computing real solutions of polynomial systems via low-rank moment matrix completion

We propose a new algorithm for computing real roots of polynomial equations or a subset of real roots in a given semi-algebraic set described by additional polynomial inequalities. The algorithm is based on using modified fixed point continuation method for solving Lasserre’s hierarchy of moment relaxations. We establish convergence properties for our algorithm. For a large-scale polynomial system with only few real solutions in a given area, we can extract them quickly. Moreover, for a polynomial system with an infinite number of real solutions, our algorithm can also be used to find some isolated real solutions or real solutions on the manifolds.

Jinyan Fan, Shanghai Jiaotong University

Optimizing inversion methods for semicracks 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.

Torsten Bosse, Humboldt Universität zu Berlin (with Levis Eneya, Andreas Griewank)

Limited memory updating and quadratic overestimation for NLOP

We pursue the approach of solving non-linearly 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 whose positive definiteness is ensured with the help of quadratic overestimation. We present theoretical arguments and numerical experiments.

Rohan Raniere, University of Konstanz

Symmetry in polynomial optimization

Solving polynomial optimization problems is known to be a hard task in general. In order to turn the recently emerged relaxation paradigms into efficient tools for these optimization problems 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.

Markus Schweighofer, Universität Konstanz (with Igor Klep)

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 dual 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.

Nonlinear multilevel and domain decomposition methods in optimization

Optimal massively parallel algorithms for large QP/QPC problems arising in mechanics

We first 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 qualifications. When applied to the class of convex QP or QPC 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 has an impact 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 topology 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 non-convex problem into many small, but also nonlinear, problems. In this way, strongly local nonlinearities or even heterogeneous 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 when 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 MILP framework we concentrate on the remaining nonsmooth nonlinear optimization problem (NSNLP). 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 a 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 NLP. This approach is successful when applied to real-world instances met in a meshed gas network of a German utility.

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

Thu.3 MA 415
Variational methods in image processing and compressed sensing
Organizer/Chair Weimin Han, Rice University - Invited Session

Qiyiu Dong, Helmholtz Zentrum München (with Tieyong Zeng)

A convex variational model for restoring blurred images with multiplicative noise

In this talk, we are concerned with a convex variational model for restoring blurred images with multiplicative noise. Based on the statistical property of the noise, a quadratic penalty technique is utilized in order to obtain a strictly convex model. For solving the optimization problem in the model, a primal-dual method is proposed. Numerical results show that this method can provide better performance of suppressing noise as well as preserving details in the image.

Hong Jiang, Bell Labs, Alcatel-Lucent (with Wu Dong, Zuowei Shen)

Surveillance video processing using compressive sensing

A compressive sensing model combined with decomposition of a matrix formed with image frames of a surveillance video into low rank and sparse matrices is proposed to segment the background and extract moving objects in a surveillance video. The video is acquired by compressive measurements, and the measurements are used to reconstruct the video by a low rank and sparse decomposition of matrix. The low rank component represents the background, and the sparse component is used to identify moving objects in the surveillance video. The decomposition is performed by an augmented Lagrangian alternating direction method. Experiments are carried out to demonstrate that moving objects can be reliably extracted with a small amount of measurements.

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

Adjoint-based methods and algorithmic differentiation in large scale optimization
Organizer/Chair Andreas Griewank, Humboldt University - Invited Session

Nikolaus Strogios, Humboldt-Universität zu Berlin (with Andreas Griewank)

A time-labeling approach for open pit mine planning

For open pit mine planning, integer or mixed integer programming approaches are well understood and investigated. In this talk a function space formulation will be presented. So called time labeling functions (TLF) assign the time of excavation to each spatial coordinate. An additional pointwise constraint replaces the predecessor relationship and ensures the physical stability of the resulting sequence of profiles. The capacity of the mine is expressed via a density function and is allowed to vary over time. In all points this approach allows a significantly more detailed modeling of the mining operation than the usual block model. We formulate the dynamic open pit mine planning problem in a suitable function space and present a stationarity condition. Moreover we discuss properties of the TLF.

Emre Özkaya, RWTH Aachen (with Nicolas Gauger, Armin Nemitz)

Automatic differentiation of an unsteady RANS solver for optimal active flow control

We present the development of a discrete adjoint solver for the optimal active flow control of viscous flows, governed by the unsteady incompressible Reynolds-averaged Navier Stokes (RANS) equations. The discrete adjoint solver is developed by applying automatic differentiation (AD) in reverse mode to the underlying primal flow solver. Employing AD for discrete adjoint code generation results in a robust adjoint solver, which gives accurate sensitivities for turbulent flows with separation. If AD is applied in a black-box fashion then the resulting adjoint code will have prohibitively expensive memory requirements. Further, a significant amount of CPU time is spent on storing and retrieving the data from the memory. In order to reduce the excessive storage and CPU costs, various techniques such as checkpointing and reverse accumulation are employed. Numerical results are presented for the test cases of optimal active flow control around a rotating cylinder and a NACA4412 airfoil.

Stephan Schmidt, Imperial College London

Large scale shape optimization

Shape optimization problems are a special sub-class of PDE constrained optimization problems. As such, they pose additional difficulties stemming from the need to compute derivatives with respect to geometric changes or variations of the domain itself. In addition to the standard joint methodology, this talk also considers how these derivatives with respect to the domain can be computed very efficiently. To this end, shape calculus is considered. The Hadamard theorem states that given sufficient regularity, the directional derivative of a shape optimization problem can be computed as a boundary scalar product with the normal component of the perturbation field and the shape gradient. Thus, knowledge of this shape gradient can be used to formulate an extremely fast optimization scheme, as tangential calculus can be used to derive gradient formulations that exist on the boundary of the domain only, thereby circumventing the need to know sensitivities of the mesh deformation inside the domain. Furthermore, approximate Newton methods can be employed in order to construct higher order optimization schemes. The Newton-type shape update can also be used to incorporate a desired boundary regularity.
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 uniqueness of Hessian is handled by a trust-region based regularization scheme. Finally, the associated model in function space is discussed.

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**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

Dongqian Shi, 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 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 Stantshukumar, Gah-Yi 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.

Jelena Uchanco, MIT (with Retael Levy, Georgia Perakis)

Regret optimization for stochastic inventory models with spread information

We study a minimax regret approach to the news-vendor problem. Using a distribution statistic, called absolute mean spread (AMS), we introduce new models 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.

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**Sparse optimization & compressed sensing**

**Thu.3 MA 108**

*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 show that our algorithm and some state-of-the-art methods are also reported.

Junfeng Yang, Nanjing University (with Xin Liu, 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.

Yilun 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 optimization**

**Thu.3 MA 141**

*Measures of uncertainty*

Organizer/Chair Marida Bertocchi, University of Bergamo - Invited Session

Francesca Maggioni, University of Bergamo (with Elisabetta Allevi, Marida Bertocchi)

Measures of information in multistage stochastic programming

Multistage stochastic programs, which involve sequences of decisions over time, are usually hard to solve in realistically sized problems. Providing bounds for their optimal solution, may help in evaluating whether it is worth the additional computations for the stochastic program versus simplified approaches. In this talk we generalize the problem of information gained from deterministic, pair solutions and rolling-horizon approximation in the two-stage case to the multistage stochastic formulation. With respect to the former we introduce the Multistage Expected Value of the Reference Scenario, MEVRS, the Multistage Sum of Pairs Expected Values, MSPEV and the Multistage Expectation of Pairs Expected Value, MEPEV by means of the new concept of auxiliary scenario and redefinition of pairs subproblems probability. We show that theorems proved for two stage case are valid also in the multi-stage case. With respect to the latter, the rolling time horizon procedure allows to update the estimations of the solution at each stage. New measures of quality of the average solution are of practical relevance. Numerical results on a case study illustrate the relationships.

Simone Garatti, Politecnico di Milano (with Marco Campi, Ago Cagi)

The risk of empirical costs in randomized min-max stochastic optimization

We consider convex min-max stochastic optimization. By sampling the uncertain parameter, the min-max solution that satisfies the sam-
pled instances of uncertainty can be constructed at low computational effort. This min-max solution incurs various costs, called "empirical costs", in correspondence of the sampled instances of the uncertain parameter. Our goal is to precisely characterize the risks associated to the empirical costs, namely to evaluate the probability that the various empirical costs are exceeded when a new uncertainty instance is seen. The main result is that the risks distribute as an ordered Dirichlet distribution, irrespective of the probability measure of the uncertain stochastic parameter. This provides a full-fledged characterization of the reliability of the min-max sample-based solution.

Alessio Giavonetti, Norwegian University of Science and Technology (with Paolo Piscicella)

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.

Jianqiang Cheng, LRI, University of Paris-Sud (with Abdel Lisser)

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.

Yongia Song, University of Wisconsin-Madison (with Sime Kirczukaziev, James (Ludwik))

Overall aircraft design based on chance-constrained programming

Preliminary Overall Aircraft Design (OAD) is classically carried out using a deterministic optimisation 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 policy against deviation to ensure requirement satisfaction. In the last decades, many researches have been done in the area of optimisation 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 optimisation 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.

Jessie Birman, AirBus Operation S.A.S.

Stochastic optimization

Thu.3.MA 144

Chance constrained stochastic optimization

Chair Yongia Song, University of Wisconsin-Madison

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Jianqiang Cheng, LRI, University of Paris-Sud (with Abdel Lisser)

Stochastic linear programming with joint chance constraints

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.

Viet Hung Nguyen, LIPA - Universite 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 \( O(n^3) \) time while the former, running in \( O(n^2 \log(n)) \) time, is less efficient. In this paper, we improve the time complexity by giving 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/LAMSAD (with Ali Ridha 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 (OMBN) 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 OMBN 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.

Rassasi Gataik, LAMSAD / Université Paris-Dauphine (with Sylvie Burke, Virginie Gabriel-Willemin, A. Ridha Mahjoub)

Models and algorithms for the survivable multilayer network design problem

We are interested with 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 polyhedral 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.

Grit Clffen, RWTH Aachen University (with Arie Koster, Anke Schmeink)

A branch-and-price approach for the robust wireless network planning

In this work, we consider the problem of base station location and traffic node assignment in wireless networks. The uncertainty by user behaviour is modelled by the well-known \( \Gamma \)-robustness approach by Bertsimas and Sim. We compare a straightforward ILP with a column generation approach. The direct ILP is divided into a restricted master problem and one pricing problem per base station. If a pricing problem finds an assignment variable with negative reduced cost fulfilling the capacity constraint, this variable is added to the restricted master problem. Since the pricing problems are robust knapsack problems, we can apply well-known techniques such as cover inequalities to improve the solving performance. Due to the integrality of all variables, we develop problem specific branching rules leading to a branch-and-price approach.
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 is still 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 dAndreagiovanni)

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 discredited 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 connections to the linear arrangement problem, and give first results on the hardness of approximation.

Andreas Hamel, Yeshiva University New York (with Andrea Ribeiro)

Dini derivatives for vector- and set-valued functions

We will introduce set-valued derivatives of Dini type for vector- and set-valued functions and provide basic calculus rules for these derivatives. Using a solution concept for multicriteria optimization problems introduced by Heyde and Löhne in 2008, we will provide a variational representation of the fibers in such a way, that the number of workers necessary in each period of the discredited 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 connections to the linear arrangement problem, and give first results on the hardness of approximation.

Samuel Drapeau, Humboldt University Berlin (with Andreas Hamel, Michael Kupper)

Complete duality for convex and quasiconvex set-valued functions

The Fenchel-Moreau theorem is a central result stating a one to one relation between l.s.c. convex functions and their conjugate. For quasiconvex functions, a dual representation has been achieved by Benoist, Volle. The complete duality, that is, the unique characterisation of the dual function, has been done by Cerreia-Voglio et al. on M-spaces and Drapeau, Kupper on l.s.c. functions. However, for vector valued convex functions problems appear for the existence of a Fenchel-Moreau theorem and the uniqueness is still open.

In this talk, we present a complete duality for quasiconvex and convex set valued functions. More precisely given a l.s.c. quasiconvex function $F: X \rightarrow \mathcal{P}(Z, K)$ where $\mathcal{P}(Z, K)$ is the set of monotone subsets of a vector space $Z$ with respect to a convex cone $K$, then, there exists a function $R: X^* \times X \rightarrow \mathcal{P}(Z, K)$ such that

$$F(x) = \sup_{\alpha \in X^*} R(\alpha, x).$$

Furthermore, $R$ is uniquely determined if $K \setminus (\text{int} K^\circ)$ $\neq \emptyset$. For convex functions we provide a set-valued pendant to the Fenchel Moreau theorem. As an illustration, we study the dual representation of non complete preference orders.
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.

Jenny Nossack, University of Siegen (with Erwin Pesch)

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 is simultaneously solved 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.

Erwin Pesch, University of Siegen (with Jenny Nossack)

A branch-and-bound algorithm for the acyclic partitioning problem

We focus on the problem of partitioning the vertex set of a directed, arc- and vertex-weighted graph into clusters, i.e. disjoint sets. Clusters are not determined such that the sum of the vertex weights within the clusters satisfies an upper bound and the sum of the arc weights within the clusters is maximized. Additionally, the graph is enforcing a partition into a directed, acyclic graph where the clusters define the vertices. This problem is known as the acyclic partitioning problem and has been proven to be NP-hard. Real-life applications arise at rail-rail transshipment yards. We propose new integer programming formulations for the acyclic partitioning problem and suggest an exact solution approach based on an integration constraint propagation into a branch-and-bound framework. Computational results are reported to confirm the strength of our approach.

Maurizio Pesant, Max-Planck-Institute for Computer Science (with Danny Hermelin, Erik Jan Oomen, Gerhard Woeginger)

Domination when the stars are out - Efficient decomposition of claw-free graphs

We algorithmize the recent structural characterization for claw-free graphs by Chudnovsky and Seymour. Building on this result, we show that several domination problems are fixed-parameter tractable, and even possess polynomial-sized kernels, on claw-free graphs. To complement these results, we establish these problems are not fixed-parameter tractable on the slightly larger class of graphs that exclude $K_{1,4}$ as an induced subgraph. Our results provide a dichotomy for $K_{1,2}$-
free graphs and characterize when the problems are fixed-parameter tractable.

Yuri Faenza, Università di Padova (with Gianpaolo Oriolo, Gautier Stauffer)

Separating stable sets in claw-free graphs through extended formulations

The stable set polytope in claw-free graphs (ssp-cf) 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 cannot 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 these extended formulations to propose 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.

Pavlo Nibili, 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 \( S \subseteq G \). Following Lovász, we say that two nodes \( u \in v \in V \setminus S \) are similar if \( N(u) \cap N(v) \setminus S \). Moreover, extending a definition due to Schrijver, we say that a node \( v \in S \) is clique-splittable in \( G \) with respect to \( S \) if the nodes in \( N(v) \setminus S \) can be partitioned into two cliques \( (X,v) \) with the property that each dissimilar pair of nodes \( z \in N(v) \setminus S \) is adjacent if and only if both belong to \( X \) or \( Y \). Our main result is that a claw-free graph \( G \) is a line graph if and only if each node \( v \in S \) is clique-splittable and \( S \) does not define two special structures in \( G \), namely a pair of cross-linked nodes or a free strip.

Maribel Montenegro, Escuela Politécnica Nacional

On the \( N \)-index of the stable set polytope related to antwebs

In this work we investigate the application of the \( N \) and \( N_\infty \) operators defined by Lovász and Schrijver [1979] to the edge relaxation of the stable set polytope related to antwebs. The first intermediate result is that these polytopes have \( N \)-index equal to 1.

Moreover, we have proved that if an antweb \( \mathcal{W}_k \) is such that \( n = qn + 1 \) and \( k = q(k+1) - 1 \) with \( n', q', q \in N \) and \( q \geq 2 \), it contains a subtantibweb which is isomorphic to the antweb \( \mathcal{W}_k \) and the rank constraint of this subtantibweb can be used to generate the rank constraint of \( \mathcal{W}_k \). Using this construction we obtain upper bounds on the \( N \)-index for some particular classes of antwebs.

Graciela Nasini, Universidad Nacional de Rosario

Lovász-Schrijver \( N_{\infty} \) relaxations on the fractional stable set polytope in a superclass of near-perfect graphs

\( N_{\infty} \) perfect graphs are those graphs for which its stable set polytope is achieved by applying Lovász and Schrijver’s \( N_\infty \) operator on its edge relaxation once. They define a proper superclass of perfect graphs where the Maximum Weight Stable Set Problem is solvable in polynomial time. In the context of column generation, it would be very useful to have good characterizations of this graph class. A graph is \( N_{\infty} \)-perfect if the support graph of every facet defining inequality of its stable set polytope is near-bipartite. It is known that \( N_{\infty} \)-perfect graphs constitute a subclass of \( N_{\infty} \)-perfect graphs. In a previous work, we handled the question whether any \( N_{\infty} \)-perfect graph and proved it is true when restricted to near-perfect graphs. In this work we extend this result to the proper superclass of near-perfect graphs defined by those graphs for which its stable set polytope is described by the clique constraints and at most one full support inequality. We also prove that any graph obtained by applying the clique subdivision operation on an \( N_{\infty} \)-imperfect graph cannot be \( N_{\infty} \)-perfect.

Claudio Smeul, Università di Roma Tor Vergata (with Flavia Bonomo, Giangiolo Oriolo)

Minimum weighted clique cover on strip-composed perfect graphs

On a perfect graph \( G \) where a non-negative weight function on the vertices \( w: V \to R^+ \) is given, the minimum weighted clique cover problem (MWCC), consists on finding a collection of cliques \( C \), each one with a non-negative value \( w(C) \), such that for every vertex \( v \in V \), \( \sum_{C \in C} w(C) \geq w(v) \) and the weight \( \sum_{C \in C} w(C) \) 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 \( G \), can be found in polynomial time, provided that the MWCC problem can be solved on \( G \) in polynomial time. We also design a new, more efficient, combinatorial algorithm for the MWCC problem on strip-composed claw-free perfect graphs.

Pavlo Serafin, 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 insight into the problem structure and sometimes exhibits a computational better performance than the original formulation. It is possible to develop compact formulations for the following problems: Bin packing, Max cut, Stable set, TSP, Minimum routing cost tree, Steiner tree, Cycle packing, Alternate 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 sequences 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, Marika 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 this approach include the train scheduling problem (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).
Complementarity & variational inequalities

Precisely, the feasible sets of semidefinite programming, sometimes called spectrahedra, are affine slices of the cone of positive semidefinite matrices. For a given convex set it might however be quite complicated to decide whether it is such a slice or not. Alternative characterizations of spectrahedra are thus highly desirable. This interesting problem turns out to be related to algebra, algebraic geometry and non-commutative geometry. I will explain some of the recent developments in the area.

Sabine Burgdorf, École Polytechnique Fédérale de Lausanne (with Kristijan Cafuta, Igor Klep, Janez Povh)

Lasserre relaxation for trace-optimization of NC polynomials

Given a polynomial \( f \) in noncommuting (NC) variables, \( f(x_1, \ldots, x_n) \), what is the smallest trace value \( \text{tr}(A) \)? 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 optimization and for eigenvalue optimization respectively.

Raman Sanyal, Freie Universität Berlin (with Aminsa 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.

Matsuzawa Tsuchiya, University of Tsukuba (with Yoshiko Aoki)

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 too long. The result suggests a primal barrier function approach for the DNN optimization problem. However, the experience of 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 \( K \). Each subset 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.

Derivative-free & simulation-based opt.

MINLP and constrained optimization without derivatives

Many derivative-free methods for constrained problems are not ef-
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 (Nonsmooth 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 problems. 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; they may be 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. For local search algorithms normally limited to real variables, this provides a simple framework for supporting integer variables that fits naturally in a parallel context. 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.

Constanta Radulescu, National Institute for Research and Development in Informatics (with Marius Radulescu, Sorin Radulescu)
Portfolio selection models with complementarity constraints

We extend Markowitz's portfolio selection model to include transaction costs in the presence of initial holdings for the investor. Our approach is new. Our aim is to obtain an optimal portfolio which has a minimum risk or a maximum return. Our portfolio selection models include complementarity constraints. This type of constraints increases the difficulty of the problems, which now enter in the category of combinatorial optimization problems. The set feasible solutions for the problems from the above mentioned class is the union of a set of convex sets but it is no longer convex. We give an algorithm for finding solutions of portfolio selection models with complementarity constraints. Several numerical results are discussed.

Marius Radulescu, Institute of Mathematical Statistics and Applied Mathematics (with Constanta Radulescu, Sorin Radulescu)
The efficient frontiers of mean-variance portfolio selection problems

In the paper are defined the notions of efficient frontier set and efficient frontier function of a parametric optimization problem. 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.

Juliane Müller, Tampere University of Technology (with Robert Piché, Christine Shoemaker)

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 (Nonsmooth 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.

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The scheme is effective and efficient. Numerical results show that the proposed algorithm can be looked on as a generalization of the Nash equilibrium problem (NEP), which contains several leaders and followers. On the other hand, in such real-world problems, uncertainty normally exists and sometimes cannot simply be ignored. To handle mathematical programming problems with uncertainty, the robust optimization (RO) technique assumes that the uncertain data belong to some sets, and the objective function is minimized with respect to the worst case scenario. In this paper, we focus on a class of multi-leader-follower games under uncertainty with some special structure. We particularly assume that the follower’s problem only contains equality constraints. By means of the RO technique, we formulate the game as the robust Nash equilibrium problem, and then the generalized variational inequality (GVI) problem. We then establish some results on the existence and uniqueness of a robust leader-follower Nash equilibrium. We also apply the forward-backward splitting method to solve the GVI formulation of the problem and present some numerical examples to illustrate the behavior of robust Nash equilibria.

Silvia Schroeter, University of Hamburg; with Justo Puerto, Anita Schöbel

Equilibria in generalized Nash games with applications to games on polyhedra

In generalized Nash equilibrium (GNE) games, a player’s strategy set depends on the strategy decisions of the competitors. In particular, we consider games on polyhedra, where the feasible strategy space is represented by a polyhedron. We investigate best-reply improvement paths in games on polyhedra and prove the finiteness of such paths for special cases. In particular, under the assumption of a potential game, we prove existence of equilibria for strictly convex payoffs when the parameters are restricted. In addition, we study multidimensional echinoid optimality properties of equilibria for the restricted class of potential games.

Yin Chen, City University of Hong Kong; with Chuangyin Dang

Computing perfect equilibria of finite n-person games in normal form with an interior-point path-following method

For any given sufficiently small positive number $\varepsilon$, we show that the imposition of a minimum probability $\varepsilon$ on each pure strategy in a Nash equilibrium leads to an $\varepsilon$-perfect equilibrium of a finite n-person game in normal form. To compute such an $\varepsilon$-perfect equilibrium, we introduce a homotopy parameter to combine a weighted logarithmic barrier term with each player’s payoff function and devise a new game. When the parameter varies from 0 to 1, the new game deforms from a trivial game with each player’s payoff function and deviates from the original game. With the help of a perturbation term, it is proved that there exists a smooth interior-point path that starts from an unique Nash equilibrium of the trivial game and leads to an $\varepsilon$-perfect equilibrium of the original game at its limit. A predictor-corrector method is presented to follow the path. As an application of this result, we derive a scheme to compute a perfect equilibrium. Numerical results show that the scheme is effective and efficient.

Brendan Lucier, Microsoft Research New England; with Allan Borodin, Mark Braverman, Joel Oren

Strategyproof mechanisms for competitive influence in social networks

Motivated by models of competitive influence spread in networks, we study mechanisms for allocating nodes to self-interested agents with optimization objectives. For example, a social network provider may wish to allow advertisers to provide special offers to influential individuals. The advertisers benefit in that product adoption may spread through the network, but a competing product may adversely impact the rate of adoption.

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.
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, they demonstrate strong convergence properties of optimal values 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 LSMP with decomposable assignment costs.

Advances in global optimization IV
Chair Syuji Yamada, Niigata University
Syuji Yamada, Niigata University (with Tatsuki Tamada, Tetsuo 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 CDCs. Hence, for CDCs, 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. Hence, to calculate an approximate solution of a large scale [CDC], we propose new iterative solution methods. 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 modelling 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 when 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 simplex methods. This talk explores some of the difficulties encountered in connecting the COIN-OR solver suite to a common AML, and the methods we used to overcome them.

John Forrest, FasterCoin
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 guiding the generation of new subproblem’s solutions in the following iteration. 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 strong convergence properties of optimal values of the problem via mixed-integer programming. Some alternative more efficient approximation algorithms will be discussed as well.
A heuristic for competence building with the use of nurse re-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 much 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 heuristic 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%.

Marco Boscetti, University of Bologna (with Turrichella Elisa, Golarielli Matteo, Rizi Stefano, Maniezzo 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 nimbler. 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(s) (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.

Patrick Schittekat, SINTEF ICT (with Tomas Nordlander)

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 (TIBB) formulation of this problem discretizes a planning horizon into periods of unit length. We present a big-budget time-indexed (TIBBB) 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 TIBBB model has fewer periods than the TI model. We show how to adapt facet-defining inequalities for the TI model to the TIBBB model and describe conditions under which they are facet-defining. Computational experiments compare the performance of the TIBBB model to the TI model for both weighted completion time and weighted tardiness instances described in the literature.

Hamish Waterer, University of Newcastle (with Nataliha Boland, Thomas Kalinowski, Zheng Langle)

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 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 problem 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.

Fri.1, MA 376

Model discrimination and experimental design

Christopher A. therapy, Philipps-Universität Marburg

A quadratic approximation of confidence regions

Dealing with the task of identifying unknown quantities from a set of erroneous data, the performance of a sensitivity analysis is inevitable. Without the determination of the statistical accuracy, we are not able to make any quality statements about the estimate. Consequently the result is almost meaningless. Commonly one applies linearization techniques to determine the statistical accuracy of the solution. But particularly in highly nonlinear cases this may cause problems and linear confidence regions may not be adequate. In this talk, we are going to present and analyze a confidence region based on a quadratic approximation. Furthermore, we demonstrate our results using applications from biology. Furthermore, we discuss the impact of the new results to optimum experimental design.

Tanja Binder, Philipps-Universität Marburg (with Ekaterina Kostina)

Numerical optimization methods for significance analysis of parameters and subsets of metabolic networks

New numerical methods show a very promising performance: using complex problems from Systems Biology, our approach can be used to guide experimental biologists in their choice which proteins they should measure. Mathematically, the problem results in the question how much improvement in terms of the cost function can be achieved by adding additional terms to the underlying dynamical model, i.e., whether these are to be included or not. The cost function describes the quality of the model response in comparison to process observations. After a parameter estimation for the simplest model, we can decide fast whether additional terms should be included in the model without having to re-optimize the enlarged model. We show the capability, reliability and efficiency of our approach using complex problems from Systems Biology.

Alexandra Herzog, Philipps-Universität Marburg (with Regina Gente, Ekaterina Kostina)

Discrimination of competitive model candidates for reversals in bacterium Myxococcus xanthus

Reversals in the gram-negative bacterium M. xanthus are still poorly understood. In general, the spatial relocation of motility proteins is assumed to determine the dynamic orientation of the cell polarity axis and hence cell reversals. The difficulty is that experimental data from fluorescence microscopy on the simultaneous localisation of the involved proteins is both rare and of a more qualitative nature. Protein dynamics are recorded individually. Correlated data is available as protein interaction networks. In the context of metabolic pathways, our approach can be used to guide experimental biologists in their choice which proteins they should measure. Mathematically, the problem results in the question how much improvement in terms of the cost function can be achieved by adding additional terms to the underlying dynamical model, i.e., whether these are to be included or not. The cost function describes the quality of the model response in comparison to process observations. After a parameter estimation for the simplest model, we can decide fast whether additional terms should be included in the model without having to re-optimize the enlarged model. We show the capability, reliability and efficiency of our approach using complex problems from Systems Biology.

Alexandra Herzog, Philipps-Universität Marburg (with Regina Gente, Ekaterina Kostina)
protein localisation of the supposed predominant proteins MglA and MglB. Qualitative reconstruction of the observed characteristic dynamics and transport times for available proteins is used as discrimination criteria. The extremely sparse experimental data sets mark a special challenge of this application. Current results and limitations of this approach are discussed.

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.

Cornelius Schauer, University of Bayreuth (with Joachim Schauer)

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 a 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.

Logistics, traffic, and transportation

Fri.1.AB D108

Optimizing robot welding cells

Organizers/Chairs Jörg Rambau, Universität Bayreuth; Martin Skutella, TU Berlin - Invited Session

Lucian Lenzen, Department Information Systems (with Natalia Kliewer)

Stochastic optimization models for airline resource schedules under disruptions

In this talk we compare two stochastic models considering the robustness and cost-efficiency of airline resource schedules. The first model deals with the delay absorbing capacity of schedules, the second with the recoverability during operations. These two aspects can be called stability and flexibility. Both models are solved by a branch-and-price & cut-algorithm. The resulting solutions are evaluated by an event-based simulation including a delay propagation model and a rule-based recovery approach. This enables us to identify possible mutual impacts, e.g., if stable schedules still offer the same degree of swap opportunities for operational recovery and vice versa. The presented analysis is a pre-step to an integrated stochastic approach for considering both stability and flexibility aspects at the same time during scheduling.

Logistics, traffic, and transportation

Fri.1.AB B42

Disruption management

Chair: Stephen Maher, University of New South Wales

Stephen Maher, University of New South Wales

Integrated airline recovery problem on a minimal disruption neighbourhood

The airline recovery problem is a very complex process involving a number of stages in the operations control centre. In an effort to reduce the size of the recovery problem a disruption neighbourhood is defined, generally in a preprocessing step, to determine the disruptive resources. While this reduces the problem size and improves tractability, there is a tradeoff with the final solution quality. We propose a model that aims to solve the integrated crew and aircraft recovery problem on a minimal disruption neighbourhood. As a result we attempt to provide a solution to the operations controller that requires the least amount of disruptive aircraft and crew at a minimal cost in the recovery process.
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 MISOP. 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 hang- ers 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.H 1029
Bilevel optimization and risk management
Chair Frank Heyde, University of Graz
Johannes Jahe, University of Erlangen-Nuremberg (with Dietmar Fey, Steffen Limmer)
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 algo- rithm with subdivision technique we describe a possible implementa- tion and we present numerical results for test problems together with the achieved speed ups.

Joerg Fliege, University of Southampton (with Konstantinos Kaporis, 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 func- tion of a particular direction search problem. Preliminary numerical results on bilevel problems occurring in electricity markets show the ef- ficacy of the approach. Further, we consider possible extensions to the multilevel case.

Frank Heyde, University of Graz (with Andreas Hamel, Birgit Rudloff, Benjamin Weissling)
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 mea- sure is “Average (Conditional) Value at Risk (AVaR)”. In the presence of transaction costs it turned out that set-valued risk measures are in gen- eral better suited to cope with multiple markets than real-valued func- tions. A general theory of set valued convex risk measures was devel- oped by Hamel, Heyde and Rudloff (2010) and (Zamel, Heyde, Rudloff 2011). Within this framework we will present a set-valued version of the AVaR. A pri- mal 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.H 0107
Optimality conditions and constraint qualifications
Organizer/Chair: José Mario Martinez, University of Campinas - Invited Session
Maria Maciel, Universidad Nacional del Sur (with Gabriel Carrizo, Pablo Lotito)
A trust region algorithm for the nonconvex unconstrained vector optimization problem
A trust-region-based algorithm for the non convex unconstrained vector optimization problem is considered. It is a generalization of the algorithms proposed by Fliege, Graña Drumond and Svaiter (2009) for the convex problem. Similarly to the scalar case, at each iteration, a trust region subproblem is solved and the step is evaluated. The notions of decrease condition and reduction of predicted reduction are adapted to the vec- tor case. A rule to update the trust region radius is introduced. Under differentiability assumptions, the algorithm converges to a Pareto point satisfying a necessary condition and in the convex case to a Pareto point satisfying necessary and sufficient conditions like the procedure proposed by the cited authors.

Paulo Silva, University of Sis Paulda (with Roberto Andreani, Gabriel Haeser, Maria Schuverdt)
Constant positive generators: A new weak constraint qualification with algorithmic applications
This talk introduces a generalization of the constant rank of the subspace component constraint qualification called the constant posi- tive generator condition (CPG). This new constraint qualification is much weaker: For example, it can hold even in the absence of an error bound for the constraints and it can hold at a feasible point \( x \) while failing ar- bitrarily close to \( x \).

In spite of its generality, it is possible to show that CPG is enough to ensure that almost-KKT points are actually KKT. Hence, this new constraint can be used as a minimal assumption to assert the converge- nce of many algorithms to first order stationary points. As examples, we present extensions of convergence results for algorithms belong- ing to different classes of nonlinear optimization methods: augmented Lagrangians, inexact restoration, SQP, and interior point methods.

Santosh Sivasaran, Jaypee University of Engineering and Technology
Fritz John duality in the presence of equality and inequality constraints
A dual for a nonlinear programming problem in the presence of equality and inequality constraints is formulated which uses Fritz John optimality conditions instead of the Karush-Kuhn-Tucker optimality conditions and thus does not require a constraint qualifications. Vari- ous duality results, namely, weak, strong, strict converse and converse duality theorems are established under suitable generalized convexity assumptions.

Fri,1.H 0112
Complexity issues in optimization
Chair: Jianming Shi, Muroran Institute of Technology (MuIT)
Stefan König, Technische Universität Miinchen (with Christian Knaus, Daniel Werner)
Norm maximization is \( W[1] \)-hard
The problem of maximizing the p-th power over a half-sapce- presented polytope in \( R^n \) 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 dimen- sion 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 analysing how the hardness of problems depends on spe- cific parameters of the input. In this talk, we will briefly discuss the pre- requisites from parametrized complexity and then investigate the complex- ity of norm maximization with the natural choice of \( p \) as parameter.

More precisely, we show that, for \( p = 1 \), the problem is \( fix- ed \) pa- rameter 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 max- imization is \( W[1] \)-hard. The presented reduction also yields that, under standard complexity theoretic assumptions, there is no algorithm with running time \( \alpha(d) \) that answers the problem correctly.

Claudio Santiago, Lawrence Livermore National Laboratory (with Maria Helena Jadim, Nelson Maculan)
An efficient algorithm for the projection of a point on the intersection of two hyperplanes and a box in \( R^n \)
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 \( R^n \). Interior point methods are the most efficient algorithm 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 addi- tion, their efficiency is highly dependent on a series of parameters de- pending on the specific method chosen (especially for nonlinear prob- lems), 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 Lagrangian mul- tipiers of the hyperplanes and seek to find the pair of multipliers that corresponds to the optimal solution. We prove that the algorithm has complexity \( O(n^2 \log n) \).

Jianming Shi, Muroran Institute of Technology (MuIT) (with Shi Jianming)
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 ap- proach and the existing methods, like the interior point method, Simplex method.
Nonsmooth optimization

Topics in nonsmooth nonconvex optimization
Chair Jean-Louis Goffin, McGill University
Wilhelm Freire, Federal University of Juiz de Fora (with Regina Burachik, C. Yalcin Kaya)
Interior epigraph directions method for nonsmooth and nonconvex optimization via generalized augmented Lagrangian duality
We present a new method, called Interior Epigraph Directions Method (IED), for constrained nonsmooth and nonconvex optimization which uses a generalized augmented Lagrangian duality scheme. The IED method takes advantage of the special structure of the epigraph of the dual function. We prove that all the accumulation points of the primal sequence generated by IED are solutions of the original problem. We carry out numerical experiments by using test problems from the literature. In particular, we study several instances of the Kissing Number Problem. Our experiments show that the quality of the solutions obtained by IED is comparable with those obtained by other solvers.

Izhar Ahmad, King Fahd University of Petroleum and Minerals
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.

Jean-Louis Goffin, McGill University (with Abdol Dehgani, Dominiqe Urban)
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, ACCPM_AdapToI and ACCPM_FIXToI on 158 problems of this set. The number of variables on these 158 problems varies from 2 to 20,000. This software presents ACCPM_AdapToI as the best solver on more that 22% of the problems and it can solve approximately 85% of the problems.

Optimization in energy systems

Power flow modelling and mechanism design
Chair Deepak Bagchi, Infosys Ltd.
Steaphan Lenkens, RWTH Aachen University (with Aric Koster)
Structural properties of power grid design
The problem of designing a cost minimal power grid is often formulated as a mixed integer linear program using the well known DC power flow linearization. We consider its projection on the integral space, as every feasible integral point can be considered as a possible power grid design. We define the DC power grid design polytope as the convex hull of these integral points. At first, we will consider the case in which the power flow on each line is not restricted by any means. We will show, that in that setting the convex hull is described by the connected subgraph polytope of the topology graph. In addition, we will discuss the structural properties under the influence of bounded power flows, as every real world scenario requires bounded flows. Further, we will study the effects on the convex hull under the assumption of a metric topology. Finally, we will discuss the impact on the stated results in the case where we use AC linear power flows instead of the DC power flow linearization.
Wagquas Bukhsh, University of Edinburgh (with Andreas Griehay, Ken McKinon, Paul Trodden)
Local solutions of optimal power flow problem
Optimal power flow (OPF) is a well studied optimization problem in electricity systems. 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. Often 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.

Optimization in energy systems

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

Optimal control of PDEs with advection terms
Chair Mohamed Al-Lawatia, Sultan Qaboos University
Aris Younes, Research Unit: Optimization, Modeling and Decision Support (with Mohamed Bouchiba, Abdenacer Jarray)
The Navier-Stokes problem in velocity-pressure formulation: Convergence and optimal control
We study the nonlinear Navier-Stokes problem in velocity-pressure formulation. We construct a sequence of a Newton-linearized problems and we show that the sequence of weak solutions converges towards the solution of the nonlinear one in a quadratic way. A control problem on the homogenous problem is considered.
Sebastian Pfaff, Technische Universität Darmstadt (with Stefan Ulbrich)
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 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.

Daniela Koller, Technische Universität Darmstadt (with Stefan Ulbrich)

Reduced order model based 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 necessary 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.

Jane Ghiglieri, 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 finite element based simulation for the considered problem. Finally, we present our cancellation results with this MPC approach in a numerical simulation.

Daniela Koller, 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 metals with bifurcated cross section. These sheet metal products are examined within the Collaborative Research Centre (CRC) 668. 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 holder force. Since the resulting 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 computational complexity as well. In this talk, we propose strategies that indicate that such advances can indeed be made; we provide a novel analysis that establishes general bounds, and note that performing the greedy step efficiently weakens the dependency on the size of the problem. Our 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 like L1 (Iterative Thresholding with Hard Thresholding Pursuit), the other end of the spectrum leads to a novel algorithm that we call Orthogonal Matching Pursuit with Replacement (OMPR). OMPR, like the classic greedy algorithm OMP, adds exactly one coordinate to the support at each iteration. We provide brief introduction to the OMP, and their relation with 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 known guarantees for sparse recovery in terms of the Restricted Isometry Property (a condition on the measurement matrix).

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 computational efficiency. In particular, a key effort for the Progressive Hedging (PH) algorithm is the decomposition of the scenario set. Although the idea was floated (Wets89, Wets91) 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 this algorithm. Although the idea was floated (Wets89, Wets91) 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 this algorithm.

Jia Kang, Texas A&M University (with Carl Laird, Jean-Paul Watson, David Woodruff, Daniel Wood)
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 inverse 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 reduce computational complexity. In particular, we investigate the greedy coordinate descent algorithm with IPOPT (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 (independently); increases. To mitigate 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.
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. In real networks different links may share physical structures and therefore may be affected by the same physical fault. We address this problem by proposing a multi-layer network design model that takes into account the possibility of two predefined links failing. We formulate this as an integer program, which we then solve using a hybrid heuristic approach. We also provide computational results showing the effectiveness of our approach.

Cell load coupling in planning and optimization of LTE networks

This presentation considers a system model that characterizes the coupling relation among cell load levels in Orthogonal frequency division multiple access (OFDMA) wireless networks. The model takes into account non-uniform traffic demand and the load-dependent interference. Solving the system model enables a network-wide performance evaluation in terms of resource efficiency. We provide a summary of the key computationally properties of the model. The properties allow for designing powerful means for performance assessment in network planning and optimization. The theoretical insights are accompanied by an illustration of applying the model in load balancing of heterogeneous LTE networks via range optimization of pico-cells.

A second-order dual variational approach for second-order dual variational problems

A second-order dual variational approach. This dual uses the Fritz John type necessity 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

Models for p-cycle networks design without cycle enumeration

A major issue for telecommunication networks is to be cost efficient with a high level of quality of service. A network is said survivable if it is operational even if certain component fails, that is, if it is still able to provide communication between sites it connects. Mesh restoration schemes were widely used in the 1970s and early 1980s. Ring based topologies were introduced in the late 80s based on self-healing rings (SHR) networks technology. Around ten years later appeared the p-cycle networking concept. A single unit capacity p-cycle is a cycle composed of one spare channel on each span it crosses. So a p-cycle provides one protection path for a failed span and it also protects spans that have both end nodes on the cycle but are not themselves on the cycle. The problem we deal with may be seen as the problem of covering with p-cycles all the demands on a 2-connected graph minimizing the total cost. We propose four new compact ILP and MIP models for this problem. They were tested in standard benchmark cases and on a set of networks representing real USA telecommunications networks. Results were competitive with those of previous work and in several cases improved them.

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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 non-smooth 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

Dietmar Pallaschke, Karlsruhe Institute of Technology (KIT) (with Ryszard Urbanski)

Quasidifferentiable calculus and minimal pairs of compact convex sets

The quasidifferential calculus developed by V.F. Demyanov and A.M. Rubinov provides a complete analogon to the classical calculus of differentiation for a wide class of non-smooth functions. Although this looks at the first glance as 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 Karmitsa, Nargiz 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 Evora (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 duality 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 dynamics rotundity (equivalently, smoothness of the dual set) or differential properties of the target. In both cases the [Fréchet] differentiability of the value function is extremely relevant. Some counter-examples are presented.

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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 duality 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 dynamics rotundity (equivalently, smoothness of the dual set) or differential properties of the target. In both cases the [Fréchet] differentiability of the value function is extremely relevant. Some counter-examples are presented.

Adil Bagirov, University of Ballarat (with Ali A. Nuamah, Napsu Karmitsa, Nargiz 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.

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Finally, we study the identifying code polyhedron of cycles. In particular we identify their {0,1,2} facet defining inequalities.

Peter Valicov, LaBRI, University of Bordeaux (with Florent Foucaud, Sylvain Gravel, Rena Nesseran, Aline Parrau)

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 $N[v]$ be the closed neighbourhood of a vertex $v$. Then $v \in N[v] \cap C \neq \emptyset$ and $u \in E, N[u] \cap C \neq N[v] \cap C$. 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 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 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 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 NP-complete.

Frank Baumann, TU Dortmund (with Sebastian Berckey, Christoph Buchheim)

Exact algorithms for combinatorial optimization problems with submodular objective functions
Many combinatorial optimization problems have natural formulations as submodular minimization problems over well-studied combinatorial structures. A standard approach to these problems is to linearize the objective function by introducing new variables and constraints, yielding an extended formulation. We propose two new approaches for constrained submodular minimization problems. The first is a linearization approach that requires only a small number of additional variables. We exploit a tight polyhedral description of this new model and an efficient separation algorithm. The second approach uses Lagrangean decomposition to create two subproblems which are solved with polynomial combinatorial algorithms; the first subproblem corresponds to the objective function while the second consists of the constraints. The bounds obtained from both approaches are then used in a branch-and-bound-algorithm. We apply our general results to problems from wireless network design and mean-risk optimization. Our experimental results show that both approaches compare favorably to the standard techniques.

Rafael Martelli, Pontifícia Universidade Católica 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 these problems by considering all possible routes and selecting a subset of them 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 OVVRP and CVPR. We report for the first time experiments with ng-set sizes up to sixty-four obtaining several new best lower bounds.

Marcos Poggi and Diego Pecin

Improved LP-rounding approximation algorithm for k-level uncapacitated facility location
We study the k-level uncapacitated 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 $O_T$, where $O_T$ is an increasing function of $k$, with $l_{k-1} \to k_{\infty} = 3$.

We improve the approximation ratio for $k$-UFL for all $k \geq 3$, in particular we obtain the ratio equal to $2.02, 2.14$, and $2.24$ for $k = 3, 4,$ and $5$.

Marcos Poggi and Diego Pecin

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 $(c_i)$, a set $D$ of clients, a lower-bound $M$, and connection costs $(e_{ij})$ specifying the cost of assigning a client $i$ to a facility $j$. 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 Svitkina] to $83$. Our improvement comes from a variety of ideas in algorithm design and analysis. Our chief algorithmic novelty is to reduce a more-structured LBFL instance to a problem we introduce, called
Complementarity & variational inequalities

Fri.2.MA 313
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 work, we consider two methods of approximation. 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 monotonic 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 popular example is the characteristics model as a quadratic program with nonlinear complementarity. We present numerical results to demonstrate the effectiveness of our approach.

Huifu Xu, University of Southampton (with Yongsian 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 results are based on an application of the cut-value theorem and an application to 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.

Jordan Klein, Laboratory Jean Kuntzmann (with Roland Hildebrand)

Abstract cones of positive polynomials and sums of squares

In [Recent Advances in Optimization and its Applications in Engineering, pp. 41–50, Springer, 2010] we presented a new approach to the construction of sums of squares relaxations, that of abstract cones of positive polynomials. In this framework, a fixed cone of positive polynomials is considered as a subset in an abstract coefficient space and corresponds to an infinite, partially ordered set of concrete cones of positive polynomials of different degrees and in a different number of variables. To each such concrete cone corresponds its own SOS cone, leading to a hierarchy of increasingly tighter SOS relaxations for the abstract cone. In the present contribution, we consider further theoretical properties and test the practical performance of this approach. In particular, we propose an alternative method for the construction of SOS relaxations to general polynomially constrained optimization problems and apply it to some classical combinatorial optimization problems which can be cast in a polynomially constrained form.

André Uschmajew, TUB Berlin

Convergence of algorithms on quotient manifolds of Lie groups

When it comes to analyzing the local convergence properties of algorithms for optimization with respect to certain tensor formats of fixed low rank, such as PARAFAC-ALS or TUCKER-ALS, one is confronted with the non-uniqueness of the low-rank representations, which causes naive contraction arguments to fail. This non-uniqueness is (at least partially) caused by a Lie group action on the parameters of the tensor format (scaling indeterminacy). On the other hand, for instance in the case of ALS, the algorithm has an invariance property (with respect to the Lie group), namely to map equivalent representations to equivalent ones. In this talk we show how these ingredients lead to natural convergence results for the equivalence classes (orbits) of the Lie group, which are the true objects of interest. For subspace tensor formats, such as the Tucker format, the quotient manifold is diffeomorphic to the variety of fixed-rank. For the CP format one has to make additional assumptions. The results are presented in a generality which does not restrict them to the low-rank tensor approximation only.

Fri.2.H 2308

Algebraic geometry and conic programming

Organizers: Chairs Cordian Riener, University of Konstanz; Lek-Heng Lim, University of Chicago - Invited Session

Jiewang Nie, University of California, San Diego

Certifying convergence of Lasserre’s hierarchy via flat truncation

Consider the optimization problem of minimizing a polynomial function subject to polynomial constraints. A typical approach for solving it globally is applying Lasserre’s hierarchy of semidefinite relaxations, based on either Putinar’s or Schmüdgen’s Positivstellensatz. A practical question in applications is: how to certify its convergence and get minimizers? In this paper, we propose flat truncation as a certificate for this purpose. Assume the set of global minimizers is nonempty and finite. Our main results are: (i) Putinar type Lasserre’s hierarchy has finite convergence if and only if flat truncation holds, under some generic assumptions; the same conclusion holds for the Schmüdgen type one under weaker assumptions. (ii) Flat truncation is asymptotically satisfied for Putinar type Lasserre’s hierarchy if the Archimedean condition holds; the same conclusion holds for the Schmüdgen type one if the feasible set is compact. (iii) We show that flat truncation can be used as a certificate to check exactness of standard SOS relaxations and Jacobian SDP relaxations.

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Fri.2.H 2308

Warmstarting interior point methods

Organizer/Chair: Jacek Gondzio, University of Edinburgh - Invited Session

Anders Skajaa, Technical University of Denmark (with Erling Andersen, Tin Yiu 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 worst cases 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 as 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 we propose a new warm-start technique in the context of a primal–dual generation method applied to solve a particular class of combinatorial optimization problems. The technique relies on calculating an initial point and on solving auxiliary linear optimization problems to determine the step direction needed to restore primal and dual feasibility 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.

FrI, 3027
Generalized Nash equilibrium problems
Organizer/Chair Kenneth Judd, Hoover Institution - Invited Session
Phütt Pommer, Universität Zürich (with Efthieros Couzoudis)

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. The key idea is to use Putinar's Positivstellensatz, a representation result for positive polynomials. We obtain a system of polynomial equations and inequalities. The solutions to this are all within epsilon to be optimal. In many situations epsilon is zero.

Fri, 2
FrI, 3021
Risk management under probability model misspecification
Organizers/Chairs Apostolos Fertis, ETH Zürich; Victor Demiguel, London Business School - Invited Session
David Wabola, 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 returns. 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 returns. 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 strategies based on the VAR model: conditional mean-variance, conditional mean-value, and conditional mean-beta. We show that, subject to a suitable norm constraint, all three investment strategies substantially outperform the traditional (unconditional) portfolios, even in the presence of transaction costs of up to 10 basis points.

Luis Nunes Vicente, University of Coimbra (with Rui Pedro Brito)
Efficient cardinality/mean-variance portfolios

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 sets. The key idea is to use Putinar's Positivstellensatz, a representation result for positive polynomials. We obtain a system of polynomial equations and inequalities. The solutions to this are all within epsilon to be optimal. In many situations epsilon is zero.

Ana Lucia Custódio, Universidade Nova de Lisboa (with Jose Aguiar Madureira, 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-differentiability, 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 stationary form off the Pareto front. Extensive computational experience has shown, however, that DMS has an impressive capability of generating the whole Pareto front.
Finally, we give an exact polynomial time algorithm for finding the Acriat index.

Eleftherios Cazavinas, Universität Zurich

Finding all 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 family 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.

Nicolas Stier-Moses, Columbia University (with Yoni Gur)

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 traffic 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 under 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 Yoni Gur)

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 adversaries acting 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 converge. In particular we prove that in the non zero-sum case this standard decomposition method can get stuck on a sub-optimal solution.

Fernando Ordonez, Universidad de Chile (with Tomas Spencer)
detection of infeasibility, without solving expensive subproblems with unreliable precision.

Luís Felipe Bueno, University of São Paulo (with Ernesto Birgin, Natanael Krejčí, José María Martínez)

Low order-value approach for solving VaR-constrained optimization problems

In low order-value optimization (LOVO) problems the sum of the smallest values of a finite sequence of function values 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 São 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 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.

Giancarlo Bigi, Università di Pisa (with Antonio Frangioni, Qinhua 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 (CDP), 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 with 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 a PSRP. In principle, this is true also for CAC, as most nonconvex programs have a DC representation, but the formulation as a DC problem in matrix completion. 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 (QS) problems of the form: 

\[ \min \{ \frac{1}{2} \langle A(x), x \rangle + \langle c(x), x \rangle \mid A(x) = b, x \succeq 0 \}. \]

The subproblem 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.

Amitabh Basu, University of California, Davis (with Robert Hildebrand, Matthias Koeppe, Marco Molinaro)

\( \alpha (\beta - 1) \)-slope theorem for the \( \alpha \)-dimensional infinite group relaxation

We prove that any minimal valid function for the \( \alpha \)-dimensional infinite group relaxation is piecewise linear with at most \( \alpha + 1 \) 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 Cornudjols and Molinaro for \( k = 2 \).

Siyuan Shen, University of Michigan

Bilevel intension 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 intension 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 convex relaxations holds matter to the follower’s CCP, and interpret the risk tolerance variable as SO51 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 SO51 binary variables, and solve it via decomposition and modified Benders 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.

Fri.2.H 2022

Integer points in polytopes I

Organizers/Chairs Michael Joswig, TU Darmstadt; Günter M. Ziegler, FU Berlin - Invited Session

Jesse De Loera, University of California, Davis (with V. Baldoni, N. Berline, M. Knepe, and M. Vergne)

Top Ehrhart coefficients of knapsack polytope

For a given sequence \( a = (a_1, a_2, \ldots, a_N, a_{N+1}) \) of \( N + 1 \) positive integers, we consider the parametric knapsack problem \( a_1 x_1 + a_2 x_2 + \cdots + a_N x_N + a_{N+1} x_{N+1} = f \), where right-hand-side \( t \) is a varying non-negative integer. It is well-known that the number \( E_\alpha(t) \) of solutions in non-negative integers \( x_i \) is given by a quasi-polynomial function of \( t \) of degree \( N \). For a fixed number \( k \), we give a new polynomial time algorithm to compute the highest \( k + 1 \) coefficients of the quasi-polynomial \( E_\alpha(t) \) represented as step polynomials of \( t \).

Joseph Gubeladze, San Francisco State University

Continuous evolution of lattice polytopes

The sets of lattice points in normal polytopes, a.k.a. the homogeneous 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, originated 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 is a model for continuous evolution of lattice polytopes.

Fri.2.H 2023

Integer & mixed-integer programming

Organizers/Chair Jeff Linderoth, University of Wisconsin-Madison - Invited Session

Alberto Del Pia, ETH Zurich

On the rank of disjunctive cuts

Let \( L \) be a family of lattice-free polyhedra containing the splits. Given a polyhedron \( P \), we characterize when a valid inequality for the mixed integer hull of \( P \) can be obtained with a finite number of disjunctive cuts corresponding to the polyhedra in \( L \). We also characterize the lattice-free polyhedra \( M \) such that all the disjunctive cuts corresponding to \( M \) can be obtained with a finite number of disjunctive cuts corresponding to the polyhedra in \( L \), for every polyhedron \( P \). Our results imply interesting consequences, related to split rank and to integral lattice-free polyhedra, that extend recent research findings.

Ensa Buyuktasgin, Wichita State University (with Joseph Hartman, Cole Smith)

Partial objective function inequalities for the multi-item capacitated lot-sizing problem

We study a mixed integer programming model of the multi-item capacitated lot-sizing problem (MCLSP), which incorporates shared capacity on the production of items for each period throughout a planning horizon. We derive valid bounds on the partial objective function of the MCLSP formulation by solving the first \( t \)-periods of the problem over a subset of all items, using dynamic programming and integer programming techniques. We then develop algorithms for strengthening these valid inequalities by lifting and back-lifting binary and continuous variables. These inequalities can be utilized in a cutting-plane strategy, in which we perturb the partial objective function coefficients to identify violated inequalities to the MCLSP polytope. We test the effectiveness of the proposed valid inequalities on randomly generated instances.

Robertilde Widdauw, 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.

Fri.2.A 274

Cell biology

Organizers/Chair Stefan Cancer, Johns Hopkins University - Invited Session

Xin Gao, King Abdullah University of Science and Technology (KAUST)

Towards automatic NMR protein structure determination

Protein three-dimensional structure determination is the key towards the understanding of protein functions. Nuclear magnetic resonance (NMR) is one of the two main methods for protein structure determination. Current processes are time consuming and heavily depend on expert knowledge. If we could fully automate this process, this would significantly speedup the structural biology research. In this talk, we will identify the key obstacles in this process and propose solutions by computational methods. We developed peak picking methods based on signal processing techniques, a resonance assignment method based on optimization techniques, and a structure calculation method based on machine learning techniques. Each of these methods subtly handles the noise and imperfection of the others and significantly outperforms the state-of-the-art approaches. Our final system has succeeded in determining high resolution protein structures from a small set of NMR spectra, in a day.

Julian Mestre, University of Sydney (with Stefan Cancer, Khaled Elbassioni, Somnath Kous)

Tree-constrained matching

We study a generalization of maximum weight bipartite matching, where we are given in addition trees over each side of the bipartition and we add the additional requirement that the matched vertices on each side are not comparable under the ancestor-descendant relation. The
problem arises in the interpretation of live cell video data. We give approximations 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 Andretti, FU Berlin (with Gottar Kliau, 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 scorings schemes. In the graph theoretical formulation the problem corresponds to the longest antisymmetric path 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 Lagrangean 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 performs at the same speed like existing de novo sequencing tools. Further 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. Arnoud den Boer, Centrum Wiskunde & Informatica (with Bert Zwart)

Assortment optimization under general choice
We consider the problem of static assortment optimization, where the goal is to find the assortment of size at most C that maximizes revenues. This is a fundamental decision problem in the area of Operations Management. It has been shown that this problem is provably hard for most of the important families of parametric of choice models, except the multinomial logit (MNL) model. In addition, most of the approximations schemes proposed in the literature are tailored to a specific parametric structure. We deviate from this and propose a general algorithm to find the optimal assortment assuming access to only a subroutine that gives revenue predictions; this means that the algorithm can be applied to any such model. We prove that when the underlying choice model is the MNL model, our algorithm can find the optimal assortment efficiently. We also perform an extensive numerical studies to establish the accuracy of the algorithm under more complex choice models like the mixture of MNL models.

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, Huseyin 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.

Srikanth Jagabathula, NYU Stern School of Business (with Vivek Farias, Devavrat Shah)

Applications of MINLP II
Organizer/Chair Rüdiger Schultz, University of Duisburg-Essen - Invited Session

Optimization in logistics
Markus Feygenschuch, Zuse Institute Berlin (with Georgem Artingues, Rainer Kolsch)

Column generation for planning the outbound baggage handling at airports
At airports, incoming bags are directed via the baggage handling system to handling facilities, where ground handlers load incoming bags into containers. We present a mixed-integer program scheduling flights’ handling period and assigning them to handling facilities. The objective is to minimize the maximal workload of all handling facilities. As the problem exhibits great symmetry, leading to high computation times for branch-and-bound algorithms, the problem is decomposed in several subproblems, reducing symmetry effects. The problem is solved by means of column generation. To further reduce the solution space, dominance criteria are applied.

Julia Foshe, Inform GmbH

A mixed integer program for a variant of the truck and trailer routing problem with time windows
The formal problem we consider comes from a logistic yard background. Containers are located in a yard and have to be moved at certain times, e.g., from a storage area to a production line and then later back to a pick-up area or to an external site. For these operations a pool of truck units and special trailers is available. The tasks should be fulfilled within certain time windows at the least possible cost. Our approach is to define this problem as a mixed integer program and solve it with the MIP-solver SCIP. We define two networks one for truck flows and one for trailer flows. We couple the shared decisions so that the optimization model persists of one 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 factorable MINLPs.

Concerning nonconvexities and integrality constraints as well as the size of the network 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, and a mixed-integer non-linear programming (MINLP) model would be more appropriate. Thanks to recent algorithmic advances and software implementations, the integration of MINLP models into industrial applications has become more viable, yet some challenges remain.

In this talk, we give a few examples of industrial applications where MINLPs can be employed, and demonstrate some challenges and requirements to gain an operator’s acceptance.

Portfolio selection

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 with multiple spectral risk constraints. Since the conditional value at risk (CVaR) is a special case of the spectral risk function, our algorithm solves portfolio selection problems 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.

Stephan Bühler, Institute of Data Analysis and Process Design, Zurich University of Applied Sciences

Stability and solution methods

Organizer: Diethard Klatte, University of Zurich, Invited Session.

Diehard Klatte, University of Zurich (with Bernd Kummer)

Metric regularity versus strong regularity for critical points of nonlinear programs

In this talk, we study perturbed nonlinear optimization problems in a setting which includes standard nonlinear programs as well as cone constrained programs. We discuss conditions for metric regularity of the critical point system, or, equivalently, for the Aubin property of the critical point map. Our focus is on conditions under which the critical point map has the Aubin property if and only if it is locally single-valued and Lipschitz, or, equivalently, metric regularity and strong regularity coincide. In particular, we show that constraint nondegeneracy and hence uniqueness of the multiplier is necessary for the Aubin property of the critical point map.

Stephan Bühler, Institute of Data Analysis and Process Design, Zurich University of Applied Sciences (with Diethard Klatte)

Influence of inexact solutions in a lower level problem on the convergence behavior of a nonsmooth Newton method

In recent works of the authors a nonsmooth Newton method was developed in an abstract framework and applied to certain finite dimensional optimization problems with $C^{1,1}$ data. The $C^{1,1}$ structure stems from the presence of an optimal value function of a lower level problem in the objective or the constraints. Such problems arise, for example, in semi-infinite programs under a reduction approach without strict complementarity and in generalized Nash equilibrium models. Using results from parametric optimization and variational analysis, the authors worked out in detail the concrete Newton schemes for these applications and discussed wide numerical results for (generalized) semi-infinite problems. This Newton scheme requests the exact computation of stationary points of a lower level problem, which is problematic from a numerical point of view. In this talk we discuss the influence of inexact stationary points on the feasibility and the convergence properties of the Newton scheme. We will make use of a perturbed Newton scheme and give concrete estimates of the convergence radius resp. rate for the perturbed scheme.

Bernd Kummer, HK Berlin

Newton schemes for functions and multifunctions

To solve an inclusion $0 \in H(x)$ we consider iterations of the type $0$ in $F(x_{i-1}, x_i)$ in Euclidean spaces. To ensure convergence, the approximations between $H$ and $F$ play the crucial role and will be discussed. We present situations where the auxiliary problems require to study eps-subdifferentials or proximal point steps. Additionally, we consider the case when $H$ is a continuous or only locally Lipschitz function $F$, and $F$ represents inclusions $0 \in f(x_i) + G(x_i)(x_{i+1} - x_i)$ with some generalized derivative $G$. Then the iterations describe certain standard and non-standard nonsmooth Newton methods with more or less strong convergence conditions.

Kalpana Shukla, Banaras Hindu University, Varanasi, India (with Shashi Mishra)

Global parametric sufficient optimality conditions for semi-infinite discrete minimax fractional programming involving generalized $V$-$\tau$-invex functions

In this paper, we have considered semi-infinite discrete minimax fractional programming problems

\begin{align*}
\text{Minimize } \max_{s \in S} & \quad \frac{f_i(x)}{r_i(x)} \\
\text{Subject to } & \quad G_j(x, t) \leq 0, \quad \forall t \in T_j, \quad j \in \mathcal{J}, \quad H_k(x, s) = 0, \quad \forall s \in S_k, \quad k \in \mathcal{K}, \quad x \in X,
\end{align*}

where $p,q$, and $r$ are positive integers, $X$ is an open convex subset of $R^m$ ($m$-dimensional, Euclidean space), for each $j \in \mathcal{J}$, $q_j \in \mathbb{N}$ and $k \in \mathcal{K}$, $T_j$ and $S_k$ are compact subsets of complete metric spaces, for each $t \in T_j$, and $g_i$ are real-valued functions defined on $X$, for each $j \in \mathcal{J}$, $z \rightarrow G_j(x, t)$ is a real-valued function defined on $X$ for all $t \in T_j$, for each $k \in \mathcal{K}$, $z \rightarrow H_k(x, s)$ is a real-valued function defined on $X$ for all $s \in S_k$ for each $x$.

Andrei Dmitruk, Russian Academy of Sciences (with Nikolai Osmolovskii)

Conditions for a weak minimality in optimal control problems with integral equations of Volterra type

On a time interval $[0, T]$ consider the problem:

\begin{align*}
x(t) &= x(0) + \int_0^t f(t, s, x(s), u(s)) ds, \\
q_j(p) &= 0, \quad j = 1, \ldots, m, \quad p \in \mathbb{R}^n, \quad \forall t = 1, \ldots, \nu, \quad f = \psi(p) \rightarrow \min,
\end{align*}

where $p = (x(0), x(T)), x \in \mathbb{R}^n, u \in \mathbb{R}^m$.

Theorem 1 (First order necessary conditions). Let a process $\hat{u} = (\hat{x}(t), \hat{u}(t))$ provide a weak minimum. Then $\exists (a_0, \ldots, a_n) \geq$
0, \( (\beta_1, \ldots, \beta_n) \) not all zero, and \( n \)–vector function \( \psi(t) \) satisfying the conditions:

\[
\psi(s) = \int s(t) \left( \mathbf{f}(t, s, \hat{s}(s), \mathbf{a}(s)) \right) dt - \psi(T) f_a(T, s, \hat{s}, \mathbf{a}) = 0,
\]

where

\[
\psi(0) = l_n, \quad \psi(T) = l_T,
\]

where $l_n$ is the unit ball, and where the final precision $e$ depends on the error precision $e$ of function and subgradient values. In the realm of convex bundling 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.

Fri.2.MA 567

Congestion management and pricing

Organizer/Chair Mette Bjørndal, NHH Norwegian School of Economics - Invited Session
Endre Bjørndal, NHH (with Mette Bjørndal, Victoria Grishkovskaja)

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 redispatching 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 Rul, NHH Norwegian School of Economics (with Mette Bjørndal, Endre Bjørndal)

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 redispatching 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 Smears, Université Catholique de Louvain (with Danny Ralph)

Stochastic equilibrium in investment models: Capacity expansion in the power

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 much more difficult since the incomplete market is no longer amenable to a stochastic programming approach.
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 distributional information set. Our model is static in the sense that the routing decision is made prior to the realization 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.

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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 queueing 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.

Cristobal Guzman, Georgia Institute of Technology (with Roberto Cominetti)

Optimization in infinite dimensional spaces

Joel Bost, 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 differential inequality, x_{t+1} \leq f(x_t, u_t), where the order is defined by 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.

Tasako Donchev, University of Architecture and Civil Engineering (with Robert Bao, Qamar Din)

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^3). 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)

Variational analysis

Variational analysis

Fri.2 3902

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 costs

The existence of collusion 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 model where multiple wireless services, different types of users and the presence of a market regulator. The models used is non-linear market equilibrium in the subgame perfect equilibrium among firms (MPEC). Strategic behavior of firms contemplates Nash equilibria 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.

Optimizing 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.

Jonatan Krolkowski, Zuse Institute Berlin (ZIB) (with Anastasios Giovannidis, Tobias Ratsch)

Game theoretic model for the downlink in cellular mobile networks: Nash equilibria and algorithmic computations

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 BS is served by which BS, and how much power it consumes. The aim is to provide sufficient Signal-to-Interference-Noise-Ratios (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.

Fri.2 3903

Markovian and randomized techniques for network optimization

Chair Olivier Fercoq, INRIA Saclay and CMAP École Polytechnique

Olivier Fercoq, INRIA Saclay and CMAP École Polytechnique (with Marianne Akan, Mustapha Bouzoua, Stéphane Gaudel)

Polyhedral 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 website. 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 size datasets.

Arthur Gómez, University of Vale do Rio dos Sinos (with Carola Weisseheimer, Junier)

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 enable find a good solution that can be simulated by the network simulator 3 (NS3).

Cristobal Guzman, Georgia Institute of Technology (with Roberto Cominetti)

Game theoretic concepts in telecommunications

Chair Fabian Medel, Universidad de Chile

Fri.2 3923

Telematic networks & services

Discrete-time Pontryagin principles and ordered Banach spaces

Joel Bost, 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 differential inequality, x_{t+1} \leq f(x_t, u_t), where the order is defined by 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.

Tasako Donchev, University of Architecture and Civil Engineering (with Robert Bao, Qamar Din)

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^3). 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)

Variational analysis

Variational analysis

Fri.2 3925

Optimization in infinite dimensional spaces

Organizer/Chair Alexander Žaltzman, The Technion - Israel Institute of Technology - Invited Session

Discrete-time Pontryagin principles and ordered Banach spaces

We provide new Pontryagin principles in infinite horizon and discrete time for systems governed by a differential inequality, x_{t+1} \leq f(x_t, u_t), where the order is defined by 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.

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Elena Resmerita, Alpen-Adria University (with Klaus Frick, Dirk Lorenz)

Variational analysis

Variational analysis

Fri.2 3922

Duality in convex optimization

Organizer/Chair Radu Ioan Bot, Chemnitz University of Technology - Invited Session

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 Radu I. Bot, Gert Wanka)

The support vector machines approach via Fenchel-type duality

Supervised learning methods are powerful techniques to learn a
function from a given set of labeled data, the so-called training data. In this talk the support vector machines approach for classification and regression is investigated under a theoretical point of view that makes use of convex analysis and Fenchel duality. Starting with the corresponding Tikhonov regularization problem, reformulated as a convex optimization problem, we introduce a conjugate dual problem to it and prove that, whenever strong duality holds, the function to be learned can be expressed via the optimal solutions of the dual problem. Corresponding dual problems are then derived for different loss functions for the classification task as well as for the regression task. The theoretical results are applied by numerically solving an image classification task originating from a quality control problem a supplier of the automotive industry was faced with. The accuracy of the resulting classifiers demonstrate the excellent performance of support vector classification based on this high dimensional real-world data.

Sorin-Mihai Grad, Chemnitz University of Technology (with Radu Ioan Bot, Gert Wanka)

Classical linear vector optimization duality revisited

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 Böj 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.

Vincenzo Bonifaci, IASI-CNR, Italy (with Varma Girish, Kurt Mehlhorn)

Routing and shortest paths

There are some very intriguing open problems in online optimization and the dynamic search tree conjecture (dynamic optimality conjecture). Both problems are in the class of metrical service systems (online shortest path problems). It is widely believed that dynamic search trees are constant competitive. We show some strong techniques for proving constant competitiveness of metrical service systems and develop a universal theory of competitive analysis of metrical service systems. In particular, we apply this to the generalized 2-server problem and show that the generalized work function algorithm is constant competitive in any metric space, as was conjectured by Koutsoupias and Tayl (2004).

Organizer/Chair Christoph Buchheim, TU Dortmund. Invited Session

Nonlinear combinatorial optimization problems II

Franklin Dejoumou Fomou, Lancaster University (with Adam Letchford)

A dynamic programming heuristic for the quadratic knapsack problem

It is well known that the standard (linear) knapsack problem can be solved exactly by dynamic programming in pseudo-polynomial time. The quadratic knapsack problem, by contrast, is NP-hard in the strong sense, which makes it unlikely that it can be solved in pseudo-polynomial time. It is possible, however, to convert the dynamic programming approach to the linear knapsack problem into a heuristic for...
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 strength 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.

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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 Benczúr 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 $uv$ 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 Benczúr 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, Aleksandar Madry, Gary Miller, Richard Peng, Daniel Spielman, Shanghua Teng)

Electrical flows, linear systems, and faster approximations of maximum flows, minimum $s$-$t$ cuts, and multimmodity 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 multimmodity 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 $m$ vertices and $n$ edges, I’ll show how to compute $\epsilon$-approximately maximum flows in time $O(m^{1/3}poly(1/\epsilon))$, and $\epsilon$-approximately minimum $s$-$t$ cuts in time $O(m + n^{1/3}poly(1/\epsilon))$. 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 multimmodity setting requires more general classes of linear systems and iterative methods. Using these, we find $\epsilon$-approximate solutions to the maximum concurrent flow problem with $k$ commodities in time $O(m^{1/3}poly(k, \epsilon^{-1}))$.

Christophe Weibel, Google Inc. (with Amit Chakrabarti, Lisa Fleischer)

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 projection. We examine these problems at the interface of statistics and convex optimization from the perspective of convex algebraic geometry.

Thorsten Theobald, Goethe University Frankfurt am Main (with Kai Kellner, Christian Trabandt)

Conic programming

Spectrahedra are the feasible regions of semidefinite programs. In this talk we study the computational question(s) whether a given polytope or spectrahedron $S_x$ (as given by a linear matrix pencil $A(x)$) is contained in another one $S_y$. 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 containment (whose study was initiated by Ben-Tal, Nemirovski and Helton, Klep, McCullough).

Algebraic geometry and conic programming III

Caroline Uhler, IST Austria

Invited Session
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, Erdös 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 complete graphs, it is NP-hard to compute 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.

Marianna Eisenberg-Nagy, CW Amsterdam (with Etienne de Klerk, Renata Sotirov, Ivan Tratertch) 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 programming 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.

Dino Giwijt, TU Delft

Symmetric semidefinite programs based on tuples

The independent 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 [Delsarte 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.

John Schoenmakers, Weierstrass Institute Berlin (with Denis Belomestny, Marcel Ladkau) Multilevel primal and dual approaches for pricing American options

In this talk we propose two novel simulation based approaches for pricing American options. (I) The first one is in fact a multi level version of the nested Monte Carlo dual algorithm of Andersen and Broadie (2004), whereas the second one (II) is a multi level version of simulation based policy iteration (cf. Kolodko Sch. 2006), hence a primal approach. The multilevel concept is applied to the number of sub-simulations needed for constructing a dual martingale in (I) and for iterating to a new policy in (II). In both cases the overall complexity turns out to be significantly reduced.

Ari-Pekka Perkkiö, Aalto University (with Teruho Penmanen) Stochastic programs without duality gaps

This talk is on dynamic stochastic optimization problems parameterized by a random variable. Such problems arise in many applications in operations research and mathematical finance. We give sufficient conditions for the existence of solutions and the absence of a duality gap. Our proof uses extended dynamic programming equations, whose validity is established under new relaxed conditions that generalize certain no-arbitrage conditions from mathematical finance.

Dirk Becherer, Humboldt Universität zu Berlin Optimal sparse portfolios in continuous time

We discuss sparse portfolio optimization in continuous time. Optimization objective is to maximize the classical expected utility, that is the maximization of a concave functional of portfolio gains. Sparse optimization aims to find asset allocations that contain only few assets or that deviate only in few coordinated from a reference benchmark allocation. Results show that optimal sparse portfolios are less sensitive to estimation errors and performance is superior to optimal portfolio without sparsity constraints, when estimation of model parameters is taken into account.

Marta Villamil, Universidade do vale do Rio dos Sinos (with Láz Paulo de Oliveira, Bruno Larenz) Modelling and simulation of social segmentation with individual and competitive parameters

Social influence is the process by which individuals develop real

Derivative-free & simulation-based optimization

Novel applications of derivative-free and simulation-based optimization

Organizers/Chairs Luis Nunes Vicente, University of Coimbra; Stefan Wild, Argonne National Laboratory

- Invited Session

Juan Meza, 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 the 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 Duyma, Lior Horesh, Eduardo Jimenez, Gijs van den 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 representativeness 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.

Annick Sartenaer, University of Namur (FUNDP) (with Serge Gratton, Patrick Laloyaux) 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.

Finance & economics

Optimization in financial markets

Organizer/Chair Teruo Penmanen, King’s College London - Invited Session

John Schoenmakers, Weierstrass Institute Berlin (with Denis Belomestny, Marcel Ladkau) Multilevel primal and dual approaches for pricing American options

Decision making

Chair Deepak Kumar, Indian School of Business

Marta Villamil, Universidade do vale do Rio dos Sinos (with Láz Paulo de Oliveira, Bruno Larenz) Modelling and simulation of social segmentation with individual and competitive parameters

Social influence is the process by which individuals develop real
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 a stochastic component, becoming the linear stability analysis nonexistent.

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) maximizing 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 Ramírez, 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.

Game theory

Fri.3 MA 605
Learning and computation for game-theoretic problems
Organizer/Chair Vinayak Shanbhag, University of Illinois at Urbana-Champaign - Invited Session

W. Ross Morrow, Iowa State University (with Joshua Miniroff, Kate Whitefoot)

Computing equilibria in regulated differentiated product market models

Game theoretic models are applied to study markets for differentiated product such as personal vehicles, consumer electronics, and various food products and services. One of the most important applications concerns the impact of regulatory policy on market behavior: Practical insights from such models rests on the ability to compute equilibria, which in turn requires solving potentially large Mixed Complementarity Problems (MCPs). This seminar discusses several advances in the formulation of such models and the subsequent computation of equilibrium when firms face regulations with non-smooth regulatory costs. Equilibrium prices are modeled with MCPs, while product design decisions are modeled with a Stackelberg-type two-stage game that results in an MPEC/EPEC. One unique feature of these applications is a lack of regularity as prices increase without bound, a consequence of the type of demand model used. We solve this issue by identifying appropriately coercive problem formulations. Computational results obtained with state-of-the-art NLP software [PATH, KNITRO, SNOPIT] are provided for fuel economy regulations in the U.S.

Angelia Nedich, UIUC (with Joyash Kshatri, Udaya Shanbhag)

A gossip algorithm for aggregative games on graphs

We consider a class of games, termed as aggregative games, being played over a distributed multi-agent networked system. In an aggregative 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 aggregative games.

Game theory

Fri.3 MA 643
Analysis of equilibria in noncooperative games
Organizer/Chair Marc Uetz, University of Twente - Invited Session

Martin Hoefer, RWTH Aachen University (with Eliot Artholetsch)

Contribution games in networks

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.

Tobias Harks, Maastricht University (with Max Klimm)

Congestion games with variable demands

We initiate the study of congestion games with variable demands where the (variable) demand has to be assigned to exactly one subset of resources. The players’ incentives to use higher demands are stimulated by non-decreasing and concave utility functions. The payoff for a player is defined as the difference between the utility of the demand and the associated cost on the used resources. Although this class of non-cooperative games captures many elements of real-world applications, it has not been studied in this generality to our knowledge, in the past. We study the fundamental problem of the existence of pure Nash equilibria. As our main result we give a complete characterization of cost functions that ensure the existence of at least one pure Nash equilibrium.

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 wi, processing requirement pi, and deadline di, 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 ϵ-approximation locally, any Nash equilibrium still yields an (ε + 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 . Some of our results also extend to online models with corresponding competitive ratios.

Jasper de Jong, University of Twente
Global optimization
Organizer/Chair: Oliver Stein, Karlsruhe Institute of Technology - Invited Session

Tomas Björk, Karlstads University
Minimization of nonconvex quadratic functions on special feasible sets

We are interested in global minimization of general quadratic functions on a feasible set. It is well-known that depending on the specific feasible set the problem is possibly tractable or hard. We are especially interested in the minimization on the unit simplex. This problem is just the feasibility problem for copositive programming. The latter recently attracted much attention as it appeared that many hard integer programming 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.

Dominik Dorsch, RWTH Aachen University (with Hubertus Th. Jünger, 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 bilevel optimization, general semi-infinite programming and Nash optimization.

Global optimization
Organizer/Chair: Jeff Linderoth, University of Wisconsin-Madison - Invited Session

Katsuki Fujisawa, Chuo University (with Toshiro Endo, 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 purpose 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 super computer 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 super computer utilizing up to 7,168 cores to solve a single difficult MILP. It has also been tested on a Fujitsu PRIMERGY RX200S5 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 in context of the PICO (Parallel Integer and Combinatorial Optimizer) 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.

Integer & mixed-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 model 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 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 MIPLIB 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 Ostoiewski, University of Tennessee (with Jianhu 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 Ehrhart 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 defining inequalities.

Alexander Kasprzyk, Imperial College London (with Sator Hegedus)

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, G. Volyshnev conjectured, and the authors recently proved, that any smooth polytope of dimension at most five are so-called Riemannian polytopes; this is, the roots of $E_P$ all satisfy $\Re(z) = -1/2$.

I shall discuss some recent results on Riemannian polytopes, with particular emphasis on reflexive polytopes. In particular, I will discuss the distribution of the roots in the case of a reflexive polytope $P$, and a characterization of when $P$ is Riemannian.
processes to a particular model. Using simulated gene trees from a known species tree, we compare our non-parametric method to established parametric methods.

Giovanni Felici, Consiglio Nazionale delle Ricerche (with Emanuel Weitschek)

Logic data mining in the presence of noisy data

In this work we consider a method for the extraction of knowledge from data. The knowledge is represented as disjunctive normal form (DNF) logic formulas that identify high precision subsets of the training data. The method is mainly designed for classification purposes, but can be profitably deployed for information compression and data analysis in general. It is based on three main steps: discretization, feature selection and formula extraction. For each step, a mathematical optimization problem is formulated and solved with ad hoc algorithmic strategies. The method is designed to perform exact separation of training data, and can thus be exposed to overfitting when a significant amount of noise is present in the available information. We analyze the main problems that arise when this method deals with noisy data and propose extensions to the discretization, feature selection and formula extraction steps; we motivate these extensions from a theoretical standpoint, and show with experimental evidence how they operate to remove the effect of noise on the mining process.

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 bounding result implying that the fill rate of a long chain increases with the number of products, but this increase converges to zero exponentially fast.
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 Riguzzi, 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 the sample points. For a hyper-rectangular domain \( U \subseteq \mathbb{R}^d \), partitioned into hyper-rectangular subdomains through a grid defined by \( n_i \) points on the \( i \)-axis \( (i = 1, \ldots, L) \), the number of potential simplices is \( \mathcal{L} = \prod_{i=1}^L (n_i - 1) \), 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 \( \sum_{i=1}^L (n_i - 1) \). 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.

**Multi-objective optimization**

Fri.3.1027

Optimality conditions in multiobjective optimization

Organizer/Chair Akhtar Khan, Rochester Institute of Technology - Invited Session

Qunghong Zhang, Northern Michigan University [with G. J. Zalmai]

Efficiency conditions for semi-infinite multiobjective optimization problems

In this study, we present a theorem of the alternative concerning an infinite system of equalities and inequalities, and then, utilizing this result and the concepts of Dini and Hadamard directional derivatives and differentials, we establish a set of Karush-Kuhn-Tucker-type necessary efficiency conditions under the generalized Abadie and Guignard constraint qualifications for a semi-infinite multiobjective optimization problem. Furthermore, we briefly discuss the relevance and applicability of the necessary efficiency results to some semi-infinite multiobjective optimization problems, including a nonclassical problem in the calculus of variations with an infinite number of isoperimetric-type equality and inequality constraints, and problems involving support functions, arbitrary norms, and positive semidefinite quadratic forms.

Akhtar Khan, Rochester Institute of Technology

Second-order optimality conditions and sensitivity analysis in set-valued optimization

This talk will focus on new second-order optimality conditions and sensitivity analysis in set-valued optimization problems. Second-order contingent derivatives and second-order asymptotic derivatives will be used to give optimality conditions and sensitivity analysis. Our second-order results recover a number of known first order optimality conditions and results from sensitivity analysis as special cases. Numerous examples will be presented to explain the main ideas.

Baanamuren Jakab, Rochester Institute of Technology [with Fabio Raciti]

Regularization of stochastic variational inequalities and comparison of an \( l_1 \) and a sample-path approach for network problems

The talk will focus on some recent results on stochastic variational inequalities by using regularization techniques. We will also present a comparison between our approach to stochastic variational inequalities an another approach used extensively in the literature. Two small scale network equilibrium problems will be discussed in detail to better illustrate the conceptual difference between the two approaches as well as the computational methods.

**Decomposition and relaxation methods**

Chair Oleg Burdakov, Linköping University

Quantin Louveaux, University of Liège [with Bernard Boigelot, Damien Ernst, Raphaël Fonteneau]

Relaxation schemes for the evaluation of a policy in batch mode reinforcement learning

We study the min max optimization problem introduced for computing policies for batch mode reinforcement learning in a deterministic setting. First, we show that this problem is NP-hard. In the two-stage case, we provide two relaxation schemes. The first relaxation scheme works by dropping some constraints in order to obtain a problem that is solvable in polynomial time. The second relaxation scheme, based on a Lagrangian relaxation where all constraints are dualized, leads to a conic quadratic programming problem. We also theoretically prove and empirically illustrate that both relaxation schemes provide better results than those given previously for the same problem.

Oleg Burdakov, Linköping University [with John Dunn, Mike Kalish]

An approach to solving decomposable optimization problems with coupling constraints

We consider a problem of minimizing \( f_1(x) + f_2(y) \) over \( x \in \mathbb{X} \subseteq \mathbb{R}^n \) and \( y \in \mathbb{Y} \subseteq \mathbb{R}^m \) subject to a number of extra coupling constraints of the form \( g_i(x)g_j(y) \geq 0 \). Due to these constraints, the problem may have a large number of local minima. For any feasible combination of signs of \( g_i(x) \) and \( g_j(y) \), the coupled problem is decomposable, and the resulting two problems are assumed to be easily solved. An approach to solving the coupled problem is presented. We apply it to solving coupled monotonic regression problems arising in experimental psychology.

**Nonlinear programming**

Fr.3.8.0112

Optimality conditions II

Chair Alexander Strekalovskiy, Institute for System Dynamics & Control Theory, Siberian Branch of Russian Academy of Sciences

Mourad Naftiti, ESSTI Tunisia [with Adrarahman Boukrich, Mabrouk Dallalou]

On the second order optimality conditions for optimization problems with inequality constraints

A nonlinear optimization problem \( P \) with inequality constraints can be converted into a new optimization problem \( P(E) \) with equality constraints only. This is a Valentine method for finite dimensional optimization. We review second order optimality conditions for \( P(E) \) in connection with those of \( P \) and we give some new results.

Alexander Strekalovskiy, Institute for System Dynamics & Control Theory, Siberian Branch of Russian Academy of Sciences

New mathematical tools for new optimization problems

Following new paradigms of J.-S. Pang [Math. Program., Ser.B (2010) 125: 297–323] in mathematical optimization – competition, hierarchy and dynamics – we consider complementarity problems, bimatrices, bilevel optimization problems etc., which turn out to be optimization problems with hidden nonconvexities. However, classical optimization theory and method do not provide tools to escape stationary (critical) KKT points produced by local search algorithms. As well-known, the conspicuous limitation of (classical) convex optimization methods applied to nonconvex problems is their ability of being trapped at a local extremum or even a critical point depending on a starting point. So, the nonconvexity, hidden or explicit, claims new mathematical tools allowing to reach a global solution through, say, a number of critical points.

In such a situation we advanced another approach the core of which is composed by global optimality conditions (GOC) for principal classes of d.c. programming problems. Furthermore, several special local search methods (SLSM) have been developed. Such an approach shows itself really efficient and allows to apply suitable package as X-Press, CPLEX etc.

Fr.3.8.0107

Decomposition and relaxation methods

Chair Oleg Burdakov, Linköping University

Ya-Feng Liu, Chinese Academy of Sciences [with Yu-Hong Dai, Zhi-Quan Luo]

Max-min fairness linear transceiver design for a multi-user MIMO interference channel

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

William Rager, University of Florida (with Hongchao Zhang)

A primal-dual active set algorithm for non-linear optimization with polyhedral constraints

A primal-dual active set algorithm is developed for non-linear 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 non-degenerate 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 COUPLING 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 step-sizes are exactly equal to one; (b) the unit step-size is the unique minimizer of each line search function. Hence the example also applies to the global line-search and the Arjimo line search; (b) The objective function is strongly convex along each search direction although it is not in itself. The unit step-size is the unique minimizer of each line search function. Hence the example also applies to the global line-search and the Arjimo 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.

Optimization in energy systems

Fri.3 MA 549

Stochastic equilibria in energy markets II

Organizer/Chair Daniel Ralph, University of Cambridge - Invited Session

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 modeled 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.

Dzgo Ozturkci, ECN (with Guu Gurkan, Yves Smers)

Generation capacity investments in electricity markets: Perfect competition

We focus on perfectly competitive electricity markets with alternative resource adequacy mechanisms: with VOLL pricing, additional capacity market, and operating-reserve pricing. We model each firm’s problem as a two-stage problem where generation capacities are installed in the first stage and generation takes place in future spot market at the second stage. When future spot market conditions are not known in advance (i.e., uncertain demand), we have a stochastic equilibrium model. We assess the extent to which these stochastic equilibrium models can be cast into a two-stage stochastic program. In case of all the market mechanisms except operating-reserve pricing, the equilibrium point can be found by solving a two-stage stochastic program. This provides the prevalence of stochastic programming for solving stochastic equilibrium models. For operating-reserve pricing, while the formulation of an equivalent stochastic optimization problem is possible when operating reserves are based on observed demand, this simplicity is lost when operating-reserves are based on installed capacities. We illustrate how all these models can be numerically tackled by using the framework of sample path methods.

Daniel Ralph, University of Cambridge (with Yves Smers)

Risk averse long term capacity equilibria: An optimization formulation extending MARKAL

Linear Programming (LP) and other optimization models are standard and useful for long term capacity equilibria, eg. MARKAL for energy capacity equilibria. Such models:
– assume Perfect competition
– can handle uncertainty via risk neutral valuation, ie, 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.

Optimization in energy systems

Fri.3 MA 550

MPEC problems and market coupling

Chair Daniel Hoppmann, DIW Berlin

Bertrand Cornélusse, n-Side (with Yves Langer, Gilles Meyer, Gilles Scouvat, Mathieu Van Vyve)

Coupling European day-ahead electricity markets with COSMOS

Market coupling allows matching orders submitted by participants of several electricity markets while satisfying network constraints. It maximizes the economic welfare and allows the usage of market interconnection capacity. Several types of orders are available, including “block orders” that must either be accepted in full or rejected. This problem translates into a MIGP with complicating constraints. Maximal economic welfare subject to matching and supply equals demand and network constraints yields acceptance decisions for submitted orders. However some market rules are constraints relating acceptance decisions and market prices, and all integer solutions are consequently not acceptable. We present COSMOS, a dedicated branch-and-cut algorithm to solve this difficult problem. COSMOS runs every day for coupling day-ahead markets of Belgium, France, Germany and the Netherlands. Recent developments integrate specific requirements for the Iberian peninsula, the Italian market and the Nord Pool System. The authors would like to thank the owners of COSMOS, who are currently BelPex, APX-ENDEX and EPEX Spot, for allowing them to communicate on this work.

Johannes Müller, FAU Erlangen-Nürnberg (with Alexander Martin, Sebastian Pokutta)

Linear clearing prices in non-convergent European day-ahead electricity markets

The European power grid can be divided into several market areas where the price of electricity is determined in a day-ahead auction. Market participants can provide continuous and combinatorial orders with associated quantities given the prices. The goal of our auction is to maximize the economic surplus of all participants subject to transmission constraints and the existence of linear prices. In general, linear prices do not exist in the presence of non-convex constraints. Therefore we enforce the existence of linear prices such that no one incurs a loss and only combinatorial orders might see a not realized gain. The resulting model is an MPEC that can not be solved efficiently by standard solvers. We present an exact algorithm and a fast heuristic for this type of problem. Both algorithms decompose the MPEC into a master MIP and subproblems (LPs). The modelling technique and the algorithms are applicable to all MIP based combinatorial auctions.

Daniel Hoppmann, DIW Berlin (with Jan Abrell, Wulf-Peter Schill)

Approximating unit commitment using mathematical programming under equilibrium constraints

Modeling the electricity market and computing optimal dispatch is difficult due to many specific features of the power sector, such as unit commitment (i.e., binary decision variables), non-linear cost functions due to the varying efficiency of a power plant contingent on capacity utilization, and other engineering constraints. Models that capture these aspects grow quickly in complexity and are usually tractable in large-scale applications. Hence, researchers frequently resort to linear models. The present work aims to describe a highly non-linear interrelation as accurately as possible. We propose a mathematical program under equilibrium constraints (MPEC) to solve this problem; it minimizes the “distance” between a complex unit commitment model (mixed integer non-linear
Robust iterative solvers for a class of PDE-constrained optimization problems

In this talk we discuss the construction and analysis of robust solution techniques for saddle point problems with a natural block 2-by-2 structure where the left upper and the right lower block are different mass matrices. For these systems, solvers are discussed. Saddle point systems of this structure are, e.g., optimality systems of optimal control problems where the observation domain differs from the control domain or the linearized systems result after applying a semi-smooth Newton method to the nonlinear optimality systems of optimal control problems with inequality constraints on the control or the state. As examples we discuss the distributed elliptic optimal control problem and the distributed optimal control problem for the Stokes equations. Numerical examples are given which illustrate the theoretical results.

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 apply 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.

Ekkehard Sachs, University of Trier (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 add some interesting features. Numerical results on nonlinear test problems are presented.

Hanne Tøsteland, Jacobs University & Frauenhofer M2DS (with Robert Kirby, Tobias Preusser, Dongbin Xiu)

Stochastic collocation for optimal control problems with stochastic PDE constraints

The use of stochastic collocation schemes for the solution of optimal control problems, constrained by stochastic partial differential equations (SPDE), is presented. The SPDE depends on random data and accordingly, the randomness will propagate to the states of the system, whereas the control is assumed to be deterministic. There exist different efficient numerical schemes for the solution of SPDEs, one of them is the stochastic collocation method, which is based on the generalized polynomial chaos. For the minimization of the constrained optimization problems we combine the stochastic collocation method with a gradient descent method as well as a sequential quadratic program (SQP). In the presented work, different optimization problems are considered, i.e., we define different objective functions of tracking type to show different application possibilities. The functions involve several higher order moments of the random states as well as classical regularization of the control. The developed methods are compared to the widely used Monte Carlo method. Numerical results illustrate the performance of the new optimization approach with stochastic collocation.

Claudia Schillings, University Trier (with Volker Schulz)

One influence of robustness measures on shape optimization with stochastic uncertainties

The unavoidable presence of uncertainties poses several difficulties to the numerical treatment of optimization tasks. In this talk, we discuss a general framework attacking the additional computational complexity of treating uncertainty within optimization problems. Appropriate measure of robustness and a proper treatment of constraints to reformulate the underlying deterministic problem are investigated. In order to solve the resulting robust optimization problems, we propose efficient discretization techniques of the probability space as well as algorithmic approaches based on multiple-setpoint ideas in combination with one-shot methods. Finally, numerical results considering optimal aerodynamic design under shape uncertainties will be presented.

Matthias Heinemehl, Rice University

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 theoretical and numerical results using 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.
that can be used by an optimization algorithm to solve the problem. Although the original input process is modeled with an periodic autoregressive 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

Rüdiger Schultz, University of Duisburg-Essen (with Sergio Conti, Harald Held, Martin Paci, 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 set ups, both risk neutral and risk averse, are discussed. Outlines of solution procedures and some computational experiments complete the talk.

Benedict Geihe, Bonn University

A two-scale approach for risk averse shape optimization

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 macroscopic geometries with underlying periodic lattices of fine scale structures. These details are supposed 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 finite elements on the macroscale.

Terry Hacchits, 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. The well-known Network Loading (NL) problem. Given a graph with a demand to be transported through that network, the objective is to find a path that minimizes the total cost of transport, which can be approximated by a discretized distribution with a large number of points. The problem is then solved by 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.

PDE constrained stochastic optimization

Organizers/Chair Rüdiger Schultz, University of Duisburg-Essen - Invited Session

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Shape optimization with linearized elasticity and stochastic loading is put into the framework of two-stage stochastic programming. Principal model set ups, both risk neutral and risk averse, are discussed. Outlines of solution procedures and some computational experiments complete the talk.

Benedict Geihe, Bonn University

A two-scale approach for risk averse shape optimization

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. The well-known Network Loading (NL) problem. Given a graph with a demand to be transported through that network, the objective is to find a path that minimizes the total cost of transport, which can be approximated by a discretized distribution with a large number of points. The problem is then solved by 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.

Terry Hacchits, 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. The well-known Network Loading (NL) problem. Given a graph with a demand to be transported through that network, the objective is to find a path that minimizes the total cost of transport, which can be approximated by a discretized distribution with a large number of points. The problem is then solved by 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.
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