ICCOPT 2019
Sixth International Conference on Continuous Optimization
Berlin, Germany, August 5–8, 2019

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Welcome Address

On behalf of the ICCOPT 2019 Organizing Committee, the Weierstrass Institute for Applied Analysis and Stochastics Berlin, the Technische Universität Berlin, and the Mathematical Optimization Society, I welcome you to ICCOPT 2019, the 6th International Conference on Continuous Optimization.

The ICCOPT is a flagship conference of the Mathematical Optimization Society. Organized every three years, it covers all theoretical, computational, and practical aspects of continuous optimization. With about 150 invited and contributed sessions and twelve invited state-of-the-art lectures, totaling about 800 presentations, this is by far the largest ICCOPT so far. Besides that, the ICCOPT 2019 includes a Summer School (August 3–4), a poster session, and an exhibition. The finalists for the Best Paper Prize in Continuous Optimization will present their contributions, and the prize will be awarded at the conference banquet.

More than 900 participants from about 70 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 Continuous Optimization as a scientific discipline and a key technology for future developments in numerous application areas.

World-renowned cultural and research institutions, a thriving creative scene and a rich history make Berlin a popular place to live, work and travel. During a river cruise, participants of the Conference Dinner are invited to enjoy Berlin’s historic city center and main sights while having dinner with colleagues from all over the world. 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 lifestyle, and to explore the many attractions of this wonderful city.

Finally, I would like to express my sincere appreciation to 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 many days, weeks and even months of work.

I wish you all a pleasant and memorable ICCOPT 2019, and a lot of exciting mathematics in the open-minded and international atmosphere of Berlin.

Berlin, August 2019

Michael Hintermüller
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Overview of Events

Registration
The ICCOPT Registration Desk is located in the lobby of the Main Building, see the floor plan on page 7. The opening times are listed on page 8.

Welcome Reception, Sunday, 17:00–20:00
Everyone is invited to join the welcome reception in the Lichthof. Drinks and snacks will be offered, and you can already collect your conference materials at the ICCOPT Registration Desk.

Opening Ceremony, Monday, 09:00
The Opening of the ICCOPT with welcome addresses and an artistic sand show takes place in H 0105 (Audimax).

Best Paper Award in Continuous Optimization
The winner will be determined after the Best Paper Session on Monday, 16:20–18:20 in H 0105 (Audimax), see page 13. The prize will be awarded at the conference dinner, see below.

Plenary and Semi-Plenary Talks
Featured state-of-the-art talks are given by twelve distinguished speakers, see page 12.

Memorial Session, Tuesday, 16:30–17:45
A special session in honor of Andrew R. Conn, who passed away on March 14, 2019 takes place in H 0105 (Audimax), see page 15.

Parallel Sessions
More than 800 talks are given in almost 170 invited and contributed sessions, see the session overview on page 27 and the detailed session description starts on page 39. All alterations in the scientific program will be displayed on a board near the information desk in the lobby of the Main Building.

Poster Session
On Monday, a poster session with snacks and drinks is planned in the Lichthof, see page 21.

Conference Dinner
On Tuesday, the conference dinner will take place on the boat “MS Mark Brandenburg” on the river Spree. The cruise will depart at 19:00 (boarding starts at 18:30) and last four hours. More details can be found on page 8.

Board Meetings
The following board meetings will take place:

  SIOPT Tuesday, August 6, 12:00  H 3005,
  COAP Wednesday, August 7, 13:00  H 3005,
  MOR Wednesday, August 7, 13:00  H 2036.

Snacks and beverages will be served. Please note that those events are not open to the public.
Conference Dinner departure at Gotzkowskybrücke
20 min from TU Main Building, or
12 min with Bus 245 from Ernst-Reuter-Platz to Franklinstr.
General Information

ICCOPT Registration Desk. The ICCOPT Registration Desk is located in the lobby (Foyer, ground floor, left) of the TU Berlin Main Building. The opening times are as follows:

- Sunday, August 4: 17:00–20:00
- Monday, August 5: 07:00–20:00
- Tuesday, August 6: 08:00–18:00
- Wednesday, August 7: 08:00–18:30
- Thursday, August 8: 08:00–17:30

Registration fee. 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, poster session on Monday evening, and two coffee breaks per day.

Badges required for conference sessions. ICCOPT badges must be worn at all sessions and events. Attendees without badges will be asked to go to the ICCOPT Registration Desk to register and pick up their badges. All participants, including speakers and session chairs, must register and pay the registration fee.

Conference dinner tickets. The conference dinner on Tuesday evening is open to attendees and guests who registered and paid in advance for tickets. Tickets are included in your registration envelope. There may be a limited number of tickets available on site. You may go to the ICCOPT Registration Desk to enquire. Tickets are 65 EUR. For further details, see page 26.

Info board. Changes at short notice and other important items will be displayed on an info board next to the ICCOPT Registration Desk.

Rooms for spontaneous meetings. The following rooms are available for spontaneous meetings, phone calls, or other:

- H 2036: Monday–Thursday
- H 3008: Monday, Tuesday, and Thursday

A reservation form will be available outside of each room.

Internet access. If your home institution participates in eduroam and you have an account, you can directly connect to the eduroam Wi-Fi. Otherwise, a guest account, for using the Wi-Fi network at the TU Berlin, is included in your conference materials. If you need help, please visit the Wi-Fi helpdesk, which is located in the lobby of the Main Building.

Cloakroom. Participants are asked to carefully look after their belongings for which the organizers are not liable. You will find a cloakroom next to the ICCOPT Registration Desk.

Snacks and coffee breaks. Coffee, tea, and beverages are served during all breaks at the conference venue. Water and fruits will be available over the whole conference period. Moreover, various cafeterias are located in or close to the Main Building of TU Berlin.

Food. The Mensa of the TU Berlin offers plenty of opportunities for lunch at moderate prices. Payment is only permitted with a “Mensa card”: it will be possible to get one on the conference premises. In the vicinity of the TU Berlin, there is also a variety of restaurants from fast food to gourmet restaurants. For the daily lunch break, please consult the Restaurant Guide for a list of nearby cafeterias and restaurants. You will find this guide in your conference bag and on the ICCOPT USB flash drive.

Getting around by public transport. The conference badge allows you to use all public transport in and around Berlin (zone ABC) during the conference from August 5 to August 8. In order to identify yourself, you need to carry along your passport or national ID card. The “FahrInfo Plus” app for Android and iOS will help you move inside the city. For more information on public transport in Berlin, visit the BVG webpage https://www.bvg.de/en/

Emergency numbers. On the ground floor, next to the lobby and the Audimax, a paramedic station will be manned during the conference. In case of an emergency keep the following important phone numbers in your mind.

- Police: 110
- Ambulance: 112
- Fire brigade: 112

Questions and information. The organizers, staff of the registration desk, and student assistants will be identifiable by colored name tags and green T-shirts. Please contact them if you have any questions. Do not hesitate to enquire about all necessary information concerning the conference, orientation in Berlin, accommodations, restaurants, going out, and cultural events at the information desk which is located in the lobby of the Main Building.

Shopping. Most supermarkets are open from 08:00 to 22:00 in the city. The opening times of cafés, restaurants and small shops varies, but the vast majority should be accessible between 10:00 and 18:00. Note that most shops are closed on Sundays.

Since Berlin is a vibrant city, a variety of different kinds of shops can be found around the TU Berlin. Indeed, the famous shopping center KaDeWe is only two subway stations away from the conference venue. Prices can drastically vary from store to store.
Social Program/City Tours

Tour 1: Monday, August 5, 14:00–16:00

Discover the historic heart of Berlin

Every street in the center of Berlin has its history, much of it no longer visible: On this walk you will meet the ghosts and murmurs of Prussians and Prussian palaces, Nazis and Nazi architecture, Communists and real, existing socialist architecture, as well as visit some sites of the present.

Meeting point: Berliner Abgeordnetenhaus, Niederkirchnerstraße (near Potsdamer Platz)
End: Unter den Linden/ Museumsinsel

Tour 2: Tuesday, August 6, 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.

Meeting point: U-Bhf. Stadtmitte, at the platform of U6 (not U2!)
End: Potsdamer Platz

Tour 3: Wednesday, August 7, 14:00–16:00

Kreuzberg — Immigrant City

From Immigrants to Inhabitants

Huguenots, Viennese Jews, Silesians: Immigration has always characterized the history of Berlin. One of the most vibrant Berlin districts today consists of Turkish, Swabian, Polish and other “Kreuzbergers”. Encounter churches, mosques, synagogues, and a variety of ethnic food. Social tensions become visible here, too. Is Kreuzberg an example of a modern multi-cultural society made up of many (sub-)cultures? Is the district truly a melting pot, or do its inhabitants simply co-exist in parallel worlds?

Meeting point: Kottbusser Tor/ Corner Admiralstraße, before the “is-bank” (U-Bhf. Kottbusser Tor)
End: Oranienplatz

Tour 4: Thursday, August 8, 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.

Meeting point: U-Bhf. Stadtmitte, at the platform of U6 (not U2!)
End: Potsdamer Platz

Tours must be booked online at
https://iccopt2019.berlin/tours.html

All sightseeing tours are held in English and are offered by StattReisen Berlin GmbH. The following holds for all tours:

- Price: 10 EUR
- Payment: cash only, on site to the guide
- Every participant needs to register herself/himself
- Group size: min. 6, max. 25; if a tour has more than 25 bookings, the participants are split into groups.
- Booking deadline: July 28, 2019

The tour operator offers additional tours: you may have a look at their offering at
https://www.stattreisenberlin.de/english/
Speaker and Chair Information

General guidelines

- Date, timeslot, and location of the parallel sessions are listed as an overview on page 27. The detailed description starts on page 39.
- For each session, helpers will be present to help with potential technical issues. Speakers and chairs can approach them for help with conference equipment. For general questions about the conference, consult the conference web page https://iccopt2019.berlin or address the ICCOPT Registration Desk located in the lobby.

Speaker guidelines

- Please bring a USB flash drive with a copy of your presentation with you.
- Please arrive at least 15 minutes before the beginning of the session. This is needed as a reaction time in case of unforeseen complications.
- To guarantee a smooth running of the conference activities, we ask to ensure that the presentation lasts 20 mins, so as to leave 5 mins for questions and change of speakers.
- In justified exceptional cases, it is possible to connect your laptop to the conference equipment. Under these circumstances, make sure to bring a power adapter compatible to the German power grid (230 V, 50 Hz). All session rooms are equipped with a video projector with HDMI and VGA input. If your device does not support that format, please have the required adapter at hand. However, we do recommend the use of a USB flash drive instead.

Chair guidelines

- The chairs introduce the speakers, ensure the compliance of the speaking time limit and guarantee the smooth running of the session. Each presentation is supposed to last 20 minutes, the discussion together with the change of speaker to last 5 minutes.
- Please arrive at least 15 minutes before the beginning of the session. This is needed as a reaction time in case of unforeseen complications.
- We ask the chairs to notify the ICCOPT Registration Desk about short notice changes and cancellations.

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We consider nonconvex optimization problems in which coordinate-wise type optimality conditions are superior to standard optimality conditions such as stationarity. Among the models that we explore are those based on sparsity-inducing terms. We illustrate that the hierarchy between optimality conditions induces a corresponding hierarchy between various optimization algorithms.

We analyze risk models representing distributional characteristics of a functional depending on the decision maker’s choice and on random data. Very frequently, models of risk are nonlinear with respect to the underlying distributions; we represent them as structured compositions.

We discuss the statistical estimation of risk functionals and present several results regarding the properties of empirical and kernel estimators. We compare the performance of the estimators theoretically and numerically. Several popular risk measures will be presented as illustrative examples. Furthermore, we consider sample-based optimization problems which include risk functionals in their objective and in the constraints. We characterize the asymptotic behavior of the optimal value and the optimal solutions of the sample-based optimization problems. While we show that many known coherent measures of risk can be cast in the presented structures, we emphasize that the results are of more general nature with a potentially wider applicability. Applications of the results to hypothesis testing of stochastic orders, portfolio efficiency, and others will be outlined.
Semi-Plenary Talk

Mon 15:30–16:15 H 0104

Amr S. El-Bakry, ExxonMobil Upstream Research Comp
Optimization in Industry: Overview from the Oil and Gas Energy Sector
Chair: Peter Schütz

The oil and gas energy industry is witnessing a renewed interest in optimization technology across the value chain. With applications spanning exploration, development, production, and transportation of extracted material, there is greater awareness of the value optimization technology can provide. The questions of whether this resurgence of optimization in this sector of the economy is sustainable or is a part of the cyclic technology interest remains to be seen.

This talk will provide an overview of some classical optimization models and other newer ones. Examples from the area of production optimization will be presented. Links to machine learning will be emphasized in multiple applications. Opportunities and challenges will be discussed.

Best Paper Session

Mon 16:20–18:20 H 0105

Chair: Andrzej Ruszczyński

Four papers have been selected as finalists of the best paper competition by the best paper committee

- Andrzej Ruszczyński
  Rutgers University, Chair
- Dietmar Hömberg
  Weierstrass Institute/TU Berlin
- Philippe L. Toint
  University of Namur
- Claudia Sagastizábal
  University of Campinas

The finalists will be featured in a dedicated session at ICCOPT 2019, and the prize winner will be determined after the finalist session.

Amal Alphonse, Weierstrass Institute for Applied Analysis and Stochastics (WIAS) (joint work with Michael Hintermüller, Carlos Rautenberg)
Directional differentiability of quasi-variational inequalities and related optimization problems

In this talk, which is based on recent work with Prof. Michael Hintermüller and Dr. Carlos N. Rautenberg, I will discuss the directional differentiability of solution maps associated to elliptic quasi-variational inequalities (QVIs) of obstacle type. QVIs are generalisations of variational inequalities (VIs) where the constraint set associated to the inequality also depends on the solution, adding an extra source of potential nonlinearity and nonsmoothness to the problem. I will show that the map taking the source term into the set of solutions is directionally differentiable in a certain sense and give an outline of the proof, and we will see that the directional derivative can be characterised as the monotone limit of directional derivatives associated to certain VIs. If time allows, the theory will be illustrated with an application of QVIs in thermoforming.

Yuxin Chen, Princeton University (joint work with Emmanuel J. Candes)
Solving Random Quadratic Systems of Equations Is Nearly as Easy as Solving Linear Systems

We consider the fundamental problem of solving quadratic systems of equations in $n$ variables. We propose a novel method, which starting with an initial guess computed by means of a spectral method, proceeds by minimizing a nonconvex functional. There are several key distinguishing features, most notably, a distinct objective functional and novel update rules, which operate in an adaptive fashion and drop terms bearing too much influence on the search direction. These careful selection rules provide a tighter initial guess, better descent directions, and thus enhanced practical performance. On the theoretical side, we prove that for certain unstructured models of quadratic systems, our algorithms return the correct solution in linear time, i.e. in time proportional to reading the data as soon as the ratio between the number of equations and unknowns exceeds a fixed numerical constant. We extend the theory to deal with noisy systems and prove that our algorithms achieve a statistical accuracy, which is nearly un-improvable. We complement our theoretical study with numerical examples showing that solving random quadratic systems is both computationally and statistically not much harder than solving linear systems of the same size. For instance, we demonstrate...
empirically that the computational cost of our algorithm is about four times that of solving a least-squares problem of the same size.

Damek Davis, Cornell University (joint work with Dmitriy Drusvyatskiy, Sham Kakade, Jason D. Lee)

**Stochastic Subgradient Method Converges on Tame Functions**

The stochastic subgradient method forms the algorithmic core of modern statistical and machine learning. We understand much about how it behaves for problems that are smooth or convex, but what guarantees does it have in the absence of smoothness and convexity? We prove that the stochastic subgradient method, on any semialgebraic locally Lipschitz function, produces limit points that are all first-order stationary. More generally, our result applies to any function with a Whitney stratifiable graph. In particular, this work endows the stochastic subgradient method, and its proximal extension, with rigorous convergence guarantees for a wide class of problems arising in data science—including all popular deep learning architectures.

Xudong Li, Fudan University

**Exploiting Second Order Sparsity in Big Data Optimization**

In this talk, we shall demonstrate how second order sparsity (SOS) in important optimization problems can be exploited to design highly efficient algorithms. The SOS property appears naturally when one applies a semismooth Newton (SSN) method to solve the subproblems in an augmented Lagrangian method (ALM) designed for certain classes of structured convex optimization problems. With in-depth analysis of the underlying generalized Jacobians and sophisticated numerical implementation, one can solve the subproblems at surprisingly low costs. For lasso problems with sparse solutions, the cost of solving a single ALM subproblem by our second order method is comparable or even lower than that in a single iteration of many first order methods. Consequently, with the fast convergence of the SSN based ALM, we are able to solve many challenging large scale convex optimization problems in big data applications efficiently and robustly. For the purpose of illustration, we present a highly efficient software called SuiteLasso for solving various well-known Lasso-type problems.

Uday Shanbhag, Penn State University

**Addressing Uncertainty in Equilibrium Problems**

Chair: Jong-Shi Pang

We address two sets of fundamental problems in the context of equilibrium problems: (i) Of these, the first pertains towards the development of existence statements for stochastic variational inequality and complementarity problems. A naive application of traditional deterministic existence theory requires access to closed-form expressions of the expectation-valued map; instead, we develop a framework under which verifiable a.s. requirements on the map allow for making existence claims in a broad set of monotone and non-monotone regimes. Time permitting, we consider how such avenues can allow for building a sensitivity theory for stochastic variational inequality problems. (ii) Our second question considers the development of synchronous, asynchronous, and randomized inexact best-response schemes for stochastic Nash games where an inexact solution is computed by using a stochastic gradient method. Under a suitable spectral property on the proximal best-response map, we show that the sequence of iterates converges to the unique Nash equilibrium at a linear rate. In addition, the overall iteration complexity (in gradient steps) is derived and the impact of delay, asynchronicity, and randomization is quantified. We subsequently extend these avenues to address the distributed computation of Nash equilibria over graphs in stochastic regimes where similar rate statements can be derived under increasing rounds of communication and variance reduction.
Andrew R. Conn passed away on March 14, 2019. He played a pioneering role in nonlinear optimization and remained very active in the field until shortly before his death. At this session, 5 of his friends and colleagues will give 10-minute tributes to his work and his life. These will be followed by 30 minutes where everyone will have the opportunity to contribute a few words in memory of Andy, as he was always known. The five speakers are:

- Philippe L. Toint, University of Namur
- Katya Scheinberg, Lehigh University
- Annick Sartenaer, University of Namur
- Henry Wolkowicz, University of Waterloo
- James Burke, University of Washington

Andrew R. Conn was born in London on Aug. 6, 1946, and died at his home in Westchester County, NY, on Mar. 14, 2019. He played a pioneering role in nonlinear optimization starting in the early 1970s, and he remained very active in the field until shortly before his death. Andy obtained his B.Sc. with honours in Mathematics at Imperial College, London, in 1967, and his Ph.D. from the University of Waterloo in 1971. He was a faculty member at Waterloo for 18 years starting in 1972, and then moved to the IBM T.J. Watson Research Center in Yorktown Heights, NY, where he spent the rest of his career.

Andy’s research interests were extensive but centered on nonlinear optimization. They were typically motivated by algorithms, and included convergence analysis, applications and software. His first published paper, Constrained optimization using a nondifferentiable penalty function, which appeared in SIAM J. Numer. Anal. in 1973, was already quite influential, helping to pave the way for the eventually widespread use of exact penalty functions in nonlinear programming. Later work included an extraordinarily productive collaboration with Nick Gould and Philippe Toint, resulting in more than 20 publications by these three authors alone. One highlight of this collaboration was the definitive treatise Trust Region Methods (2000), the first book in the optimization series published by the Mathematical Programming Society (MPS, later MOS) in collaboration with SIAM. Another highlight was the LANCELOT software for large-scale constrained optimization, for which the authors were awarded the prestigious Beale–Orchard-Hays Prize for Excellence in Computational Mathematical Programming in 1994. A third highlight was the introduction of the influential Constrained and Unconstrained Testing Environment (CUTE). In more recent years, Andy became interested in derivative-free optimization (DFO) and, together with Katya Scheinberg and Luis Nunes Vicente, published several papers on DFO as well as a book, Introduction to Derivative-Free Optimization (MPS-SIAM Series on Optimization, 2009), for which they were awarded the Lagrange Prize in Continuous Optimization by MOS and SIAM in 2015. The citation states that the book “includes a groundbreaking trust region framework for convergence that has made DFO both principled and practical”.

Andy is survived by his wife Barbara, his mother and four siblings in England, his daughter Leah and his son Jeremy, and three grandchildren. He will be greatly missed by his family, the optimization community, and his many friends.
Frauke Liers, Friedrich-Alexander-Universität Erlangen-Nürnberg

Robust Optimization for Energy Applications: Current Challenges and Opportunities

Chair: Wolfram Wiesemann

In this talk, we will give an overview over optimization problems under uncertainty as they appear in energy management, together with global solution approaches. One way of protecting against uncertainties that occur in real-world applications is to apply and to develop methodologies from robust optimization. The latter takes these uncertainties into account already in the mathematical model. The task then is to determine solutions that are feasible for all considered realizations of the uncertain parameters, and among them one with best guaranteed solution value. We will introduce a number of electricity and gas network optimization problems for which robust protection is appropriate. Already for simplified cases, the design of algorithmically tractable robust counterparts and global solution algorithms is challenging. As an example, the stationary case in gas network operations is complex due to non-convex dependencies in the physical state variables pressures and flows. In the robust version, two-stage robust problems with a non-convex second stage are to be solved, and new solution methodologies need to be developed. We will highlight robust optimization approaches and conclude by pointing out some challenges and generalizations in the field.

Radu Boţ, University of Vienna

Proximal Algorithms for Nonsmooth Nonconvex Optimization

Chair: Russell Luke

During the last decade many efforts have been made to translate the powerful proximal algorithms for convex optimization problems to the solving of nonconvex optimization problems. In this talk we will review such iterative schemes which possess provable convergence properties and are designed to solve nonsmooth nonconvex optimization problems with structures which range from simple to complex. We will discuss the pillars of the convergence analysis, like the boundedness of the generated iterates, techniques to prove that cluster points of this sequence are stationary points of the optimization problem under investigation, and elements of nonconvex subdifferential calculus. We will also emphasize the role played by the Kurdyka-Lojasiewicz property when proving global convergence, and when deriving convergence rates in terms of the Lojasiewicz exponent.
The Douglas-Rachford algorithm is a popular method for finding minimizers of sums of nonsmooth convex functions; or, more generally, zeros of sums of maximally monotone operators.

In this talk, I will focus on classical and recent results on this method as well as challenges for the future.

Primal-dual interior-point methods for semidefinite programming, as implemented in widely used solvers, rely on the elegant theory of self-scaled barriers and the property that the dense symmetric positive semidefinite matrices form a symmetric convex cone.

In applications it is very common that the constraints in a semidefinite program are sparse. It is natural to pose such problems as conic optimization problems over cones of sparse positive semidefinite matrices, in order to exploit theory and algorithms from sparse linear algebra. Examples of this approach are the splitting techniques based on decomposition theorems for chordal sparsity patterns, which have been applied successfully in first-order methods and interior-point algorithms. However sparse semidefinite matrix cones are not symmetric, and conic optimization algorithms for these cones lack the extensive theory behind the primal-dual methods for dense semidefinite optimization. The talk will explore new formulations of primal-dual interior-point methods for sparse semidefinite programming. It will mostly focus on the important special case of chordal sparsity patterns that define homogeneous convex cones.

The talk is based on joint work with Levent Tuncel.
One of the most important developments in the design of optimization algorithms came with the advent of quasi-Newton methods in the 1960s. These methods have been used to great effect over the past decades, and their heyday is not yet over. In this talk, we introduce a new advance in quasi-Newton methodology that we refer to as displacement aggregation. We also discuss other new advances for extending quasi-Newton ideas for stochastic and nonconvex, nonsmooth optimization.

The theory of mean field games has been developed in the last decade by economists, engineers, and mathematicians in order to study decision making in very large populations of small interacting agents. The approach by Lasry and Lions leads to a system of nonlinear partial differential equations, the solution of which can be used to approximate the limit of an N-player Nash equilibrium as N tends to infinity. This talk will mainly focus on deterministic models, which are associated with a first order pde system. The main points that will be addressed are the existence and uniqueness of solutions, their regularity in the presence of boundary conditions, and their asymptotic behaviour as time goes to infinity.
Nonsmoothness arises in PDE-constrained optimization in multifaceted ways and is at the core of many recent developments in this field. This talk highlights selected situations where nonsmoothness occurs, either directly or by reformulation, and discusses how it can be handled analytically and numerically.

Projections, proximal maps, and similar techniques provide powerful tools to convert variational inequalities and stationarity conditions into nonsmooth operator equations. These then enable the application of semismooth Newton methods, which belong to the most successful algorithms for inequality constrained problems with PDEs. Nonsmoothness also arises in problems with equilibrium constraints, such as MPECs, or with bilevel structure. This is particularly apparent when reduced problems are generated via solution operators of subsystems. Similarly, nonlinear PDEs, even if looking smooth at first sight, often pose challenges regarding the differentiability of the solution operator with respect to parameters such as control or shape. There are also important applications where nonsmoothness arises naturally in the cost function, for instance in sparse control or when risk measures like the CVaR are used in risk-averse PDE-constrained optimization. Also other approaches for PDE-constrained optimization under uncertainty exhibit nonsmoothness, e.g., (distributionally) robust optimization.

All this shows that PDE-constrained optimization with nonsmooth structures is a broad and highly relevant field. This talk discusses specific examples to highlight the importance of being able to master nonsmoothness in PDE optimization. General patterns are identified and parallels to the finite dimensional case are explored. The infinite dimensional setting of PDEs, however, poses additional challenges and unveils problem characteristics that are still present after discretization but then are much less accessible to a rigorous analysis.
Exhibition

The exhibition is open during the full conference period.

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FBP 2020

The 15th International Conference on Free Boundary Problems: Theory and Applications 2020 (FBP 2020) will take place on the campus of the Humboldt University (HU) of Berlin, September 7–11, 2020. The FBP conference is a flagship event that brings together the free boundary/partial differential equation community and is organized every few years.

The Call For Papers is expected to be sent in Fall 2019. More information on https://fbp2020.de
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Waleed Alhaddad
Uncertainty Quantification in Wind Power Forecasting

Anas Barakat
Convergence of the ADAM algorithm from a Dynamical System Viewpoint

Jo Andrea Brüggemann
Elliptic obstacle-type quasi-variational inequalities (QVIs) with volume constraints motivated by a contact problem in biomedicine

Renzo Caballero
Stochastic Optimal Control of Renewable Energy

Jongchen Chen
Towards Perpetual Learning Using a Snake-Like Robot Controlled by a Self-Organizing Neuromolecular System

Sarah Chenche
A new approach for solving the set covering problem

Maxim Demenkov
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Simon Funke
Algorithmic differentiation for coupled FEniCS and pyTorch models

Carmen Gräßle
Time adaptivity in POD based model predictive control

Seyyed Masoumeh Hosseini Nejad
Accelerated Bregman proximal gradient methods for the absolute value equation

Tomoyuki Iori
A Symbolic-Numeric Penalty Function Method for Parametric Polynomial Optimizations via Limit Operation in a Projective Space

Chesoong Kim
Modeling and Optimization for Wireless Communication Networks using Advanced Queueing Model

Elisabeth Köbis
An Inequality Approach to Set Relations by Means of a Nonlinear Scalarization Functional

Markus Arthur Köbis
A New Set Relation in Set Optimization

Chul-Hee Lee
Optimization and Experimental Validation on the Frame of Resistance Spot Welding Gun

Chiao-Wei Li
Data-driven equilibrium pricing in a multi-leader-one-follower game

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On Comparison of Experiments due to Shannon

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Ketan Rajawat
Nonstationary Nonparametric Optimization: Online Kernel Learning against Dynamic Comparators

Adrian Redder
Learning based optimal control and resource allocation for large-scale cyber-physical systems.

Olaf Schenk
Balanced Graph Partition Refinement in the p-Norm

Johanna Schultes
Bijective Shape Optimization of Ceramic Components using Weighted Sums: Reliability versus Cost

Roya Soltani [canceled]
Robust optimization for the redundancy allocation problem with choice of component type and price discounting

Alexander Spivak
Successive Approximations for Optimal Control in Nonlinear Systems with Small Parameter

Steven-Marian Stengl
On the Convexity of Optimal Control Problems involving Nonlinear PDEs or VIs

Adrian Viorel
An average vector field approach to second-order nonconvex gradient systems

Meihua Wang
Application of quasi-norm regularization into robust portfolio optimization problem

Yue Xie
Resolution of nonconvex optimization via ADMM type of schemes

Peng-Yeng Yin
Simulation Optimization of Co-Sited Wind-Solar Farm under Wind Irradiance and Dust Uncertainties

Jia-Jie Zhu
A Learning Approach to Warm-Start Mixed-Integer Optimization for Controlling Hybrid Systems
Towards Perpetual Learning Using a Snake-Like Robot

A robot that works no matter how well designed, the results of its operation in the actual environment are sometimes quite different from the expected results of its design environment. In this study, we train a snake-type robot Snaky with 8 joints and 4 control rotary motors to learn to complete the specified snake mission through an autonomous learning mechanism. The core learning mechanism is the artificial neuromolecular system (ANM) developed by the research team in the early days. The learning continues until the robot achieves the assigned tasks or stopped by the system developer.

Uncertainty Quantification in Wind Power Forecasting

Reliable wind power generation forecasting is crucial to meet energy demand, to trade and invest. We propose a model to simulate and quantify uncertainties in such forecasts. This model is based on Stochastic Differential Equations whose time-dependent parameters are inferred using continuous optimization of an approximate Likelihood function. The result is a skew stochastic process that simulates uncertainty of wind power forecasts accounting for maximum power production limit and other temporal effects. We apply the model to historical Uruguayan data and forecasts.

Elliptic obstacle-type quasi-variational inequalities (QVIs) with volume constraints motivated by a contact problem in biomedicine

Motivated by a contact model in biomedicine, a compliant obstacle problem arises exemplarily in the situation of two elastic membranes enclosing a region of constant volume, which are subject to external forces. The motivating model enables a reformulation as a obstacle-type quasi-variational inequality (QVI) with volume constraints. We analyse this class of QVIs and present a tailored path-following semismooth Newton method to solve the problem. In view of the numerical performance, adaptive finite elements are used based on a posteriori error estimation.

Stochastic Optimal Control of Renewable Energy

Uruguay has always been a pioneer in the use of renewable sources of energy. Nowadays, it can usually satisfy its total demand from renewable sources, but half of the installed power, due to wind and solar sources, is non-controllable and has high uncertainty and variability. We deal with non-Markovian dynamics through a Lagrangian relaxation, solving then a sequence of open-loop finite horizon problem as a biharmonic equation. In order to find suitable time horizon lengths, we utilize a residual-based time horizon problem is split into a sequence of open-loop finite horizon problem setting due to external influences. In order to find a relevant approximation of the Adam iterates.

Algorithmic differentiation for coupled FEniCS and pyTorch models

This poster presents recent advances in dolfin-adjoint, the algorithmic differentiation tool for the finite element framework FEniCS. We will show dolfin-adjoint can be used to differentiated and optimised PDE models in FEniCS that are coupled to neural network models implemented in pyTorch. Our approach allows to compute derivatives with respect to weights in the neural network, and as PDE coefficients such as initial condition, boundary conditions and even the mesh shape.

Time adaptivity in POD based model predictive control

Within model predictive control (MPC), an infinite time horizon problem is split into a sequence of open-loop finite horizon problems which allows to react to changes in the problem setting due to external influences. In order to find a relevant approximation of the optimal control and cost function. We introduce a monotone scheme to avoid spurious oscillations. Finally, we study the usefulness of extra system storage capacity.

Accelerated Bregman proximal gradient methods for the absolute value equation

The absolute value equation plays a outstanding role in optimization. In this paper, we employ proximal gradient method to present a efficient solution for solving it. We use accelerated
Bregman proximal gradient methods that employ the Bregman distance of the reference function as the proximity measure.

11 Tomoyuki Iori, Kyoto University (joint work with Toshiyuki Ohtsuka)
A Symbolic-Numeric Penalty Function Method for Parametric Polynomial Optimizations via Limit Operation in a Projective Space

We propose a symbolic-numeric method to solve a constrained optimization problem with free parameters where all the functions are polynomials. The proposed method is based on the quadratic penalty function method and symbolically performs the limit operation of a penalty parameter by using projective spaces and tangent cones. As its output, we obtain an implicit function representation of optimizers as a function of the free parameters. Some examples show that the exact limit operation enables us to find solutions that do not satisfy the Karush-Kuhn-Tucker (KKT) conditions.

12 Chesoong Kim, Sangji University
Modeling and Optimization for Wireless Communication Networks using Advanced Queuing Model

We consider an advanced queuing model with energy harvesting and multi-threshold control by the service modes. The account of the possibility of error occurrence is very important in modelling wireless sensor networks. This model generalizes a previously considered in the literature by suggestions that the buffer for customers has an infinite capacity and the accumulated energy can leak from the storage. Under the fixed thresholds defining the control strategy, behavior of the system is described by multi-dimensional Markov chain what allows to formulate and solve optimization problems.

13 Elisabeth Köbis, Martin Luther University Halle-Wittenberg (joint work with Markus Arthur Köbis)
An Inequality Approach to Set Relations by Means of a Nonlinear Scalarization Functional

We show how a nonlinear scalarization functional can be used in order to characterize several well-known set relations and which thus plays a key role in set optimization. By means of this functional, we derive characterizations for minimal elements of set-valued optimization problems using a set approach. Our methods do not rely on any convexity assumptions on the considered sets. Furthermore, we introduce a derivative-free descent method for set optimization problems without convexity assumptions to verify the usefulness of our results.

14 Markus Arthur Köbis, Free University Berlin (joint work with Jia-Wei Chen, Elisabeth Köbis, Jen-Chih Yao)
A New Set Relation in Set Optimization

We show the construction of a novel set relation implementing a compromise between the known concepts “upper set less relation” on the one hand and “lower set less relation” on the other. The basis of the construction lies in the characterization of the relation of two sets by means of a single real value that can be computed using nonlinear separation functionals of Tammer-Weidner-type. The new relation can be used for the definition of flexible robustness concepts and the theoretical study of set optimization problems based on this concepts can be based on properties of the other relations.

15 Chul-Hee Lee, INHA University (joint work with Ji-Su Hong, Gwang-Hee Lee)
Optimization and Experimental Validation on the Frame of Resistance Spot Welding Gun

Resistance spot welding gun is generally used to bond parts in the automotive and home appliance industry. The industrial robot is essential because most of the welding process is automated. The weight of the welding gun should be minimized to increase the efficiency of the robot motion. In this study, welding gun frame optimization is performed using genetic algorithm methods. Several parts of frame thickness are specified as variables and the optimization model is validated through both simulation and experiments. The weight is decreased by up to 14% and cost saving is also achieved.

16 Chiao-Wei Li, National Tsing Hua University (joint work with Yong-Ge Yang, Yu-Ching Lee, Po-An Chen, Wen-Ying Huang)
Data-driven equilibrium pricing in a multi-leader-one-follower game

We consider a periodic-review pricing problem. There are firms i = 1,...,N competing in the market of a commodity in a stationary demand environment. Each firm can modify the price over discretized time. The firm i’s demand at period n consists of the linear model conditional on the selling prices of its own and other firms with an independent and identically distributed random noise. The coefficients of the linear demand model is not known a priori. Each firms’ objective is to sequentially set prices to maximize revenues under demand uncertainty and competition.

17 Sebastian Lämmel, Technische Universität Chemnitz (joint work with Vladimir Shikhman)
On Comparison of Experiments due to Shannon

In order to efficiently design experiments, decision makers have to compare them. The comparison of experiments due to Blackwell is based on the notion of garbling. It is well-known that the Blackwell order can be characterized by agents’ maximal expected utility. We focus on the comparison of experiments due to Shannon by allowing pre-garbling. We show that for any subset of decision makers the comparison of their maximal expected utilities does not capture the Shannon order. For characterizing the Shannon order, we enable decision makers to redistribute noise, and convexify the garbling.

18 Martin Morin, Lund University (joint work with Pontus Giselsson)
Stochastic Variance Adjusted Gradient Descent

We present SVAG, a variance reduced stochastic gradient method with SAG and SAGA as special cases. A parameter interpolates and extrapolates SAG/SAGA such that the variance the gradient approximation can be continuously adjusted, at the cost of introducing bias. The intuition behind this bias/variance trade-off is explored with numerical examples. The algorithm is analyzed under smoothness and convexity assumptions and convergence is established for all choices of the bias/variance trade-off parameter. This is the first result that simultaneously captures SAG and SAGA.

19 Ketan Rajawat, Indian Institute of Technology Kanpur (joint work with Amrit Singh Bedi, Alec Koppel)
Nonstationary Nonparametric Optimization: Online Kernel Learning against Dynamic Comparators

We are interested in solving an online learning problem when the decision variable is a function f which belongs to reproducing kernel Hilbert space. We present the dynamic regret analysis for an optimally compressed online function learning algorithm. The dynamic regret is bounded in terms of the loss function variation. We also present the dynamic regret analysis in terms of the function space path length. We prove that the learned function via the proposed algorithm has a finite memory requirement. The theoretical results are corroborated through simulation on real data sets.
20 Adrian Redder, Automatic Control Group / Paderborn University (joint work with Arunselvan Ramaswamy, Daniel E. Quevedo) 
Learning based optimal control and resource allocation for large-scale cyber-physical systems.

Typical cyber-physical Systems consist of many interconnected heterogeneous entities that share resources such as communication or computation. Here optimal control and resource scheduling go hand in hand. In this work, we consider the problem of simultaneous control and scheduling. Speciﬁcally, we present DIRA, a Deep Reinforcement Learning based Iterative Resource Allocation algorithm, which is scalable and control sensitive. For the controller, we present three compatible designs based on actor-critic reinforcement learning, adaptive linear quadratic regulation and model predictive control.

21 Olaf Schenk, Universität della Svizzera Italiana (joint work with Dimosthenis Pasadakis, Drosos Kourounis) 
Balanced Graph Partition Refinement in the p-Norm

We present a modiﬁed version of spectral partitioning utilizing the graph p-Laplacian, a nonlinear variant of the standard graph Laplacian. The computation of the second eigenvector is achieved with the minimization of the graph p-Laplacian Rayleigh quotient, by means of an accelerated gradient descent approach. A continuation approach reduces the p-norm from a 2-norm towards a 1-norm, thus promoting sparser solution vectors, corresponding to smaller edgecuts. The effectiveness of the method is validated in a variety of complex graphical structures originating from power and social networks.

22 Johanna Schultes, University of Wuppertal (joint work with Kathrin Klamroth, Michael Stingl, Onur Tanil Doganay, Hanno Gottschalk, Camilla Hahn) 
Biobjective Shape Optimization of Ceramic Components using Weighted Sums: Reliability versus Cost

We consider a biobjective PDE constrained shape optimization problem maximizing the reliability of a ceramic component under tensile load and minimizing its material consumption. The numerical implementation is based on a finite element discretization with a B-spline representation of the shapes. Using the B-spline coefficients as control variables we combine it with a single objective gradient descent algorithm for solving the weighted sum scalarization and apply it to 2D test cases. While varying the weights we determine different solutions representing different preferences.

23 [canceled] Roya Soltani, Khatam University (joint work with Reza Soltani, Soheila Soltani) 
Robust optimization for the redundancy allocation problem with choice of component type and price discounting

In this paper, a redundancy allocation problem (RAP) with an active strategy and choice of a component type is considered, in which there are different components with various reliabilities and costs considered as imprecise and varied in an interval uncertainty set. Therefore, a robust model for the RAP is presented to propose a robust design for different realization of uncertain parameters. Finally, uncertainty and price discounting are considered together in a comprehensive model for the RAP and the effects on warranty costs with minimal repair are investigated.

24 Alexander Spivak, HIT - Holon Institute of Technology 
Successive Approximations for Optimal Control in Nonlinear Systems with Small Parameter

Bilinear systems are linear on phase coordinates when the control is ﬁxed, and linear on the control when the coordinates are ﬁxed. They describe the dynamic processes of nuclear reactors, kinetics of neutrons, and heat transfer. Further investigations show that many processes in engineering, biology, ecology and other areas can be described by the bilinear systems. The problem is to ﬁnd optimal control minimizing the quadratic functional for the system driven by white noise with small parameter. Successive approximations are constructed by perturbation theory method.

25 Steven-Marian Stengl, WIAS/HU Berlin 
On the Convexity of Optimal Control Problems involving Nonlinear PDEs or VIs

In recent years, generalized Nash equilibrium problems in function spaces involving control of PDEs have gained increasing interest. One of the central issues arising is the question of existence, which requires the topological characterization of the set of minimizers for each player. In this talk, we propose conditions on the operator and the functional, that guarantee the reduced formulation to be a convex minimization problem. Subsequently, we generalize the results of convex analysis to derive optimality systems also for nonsmooth operators. Our ﬁndings are illustrated with examples.

26 Adrian Viorel, Tehnican University of Cluj-Napoca 
An average vector ﬁeld approach to second-order nonconvex gradient systems

The average vector ﬁeld (AVF) discrete gradient, originally designed by Quispel and McLaren as an energy-preserving numerical integrator for Hamiltonian systems has found a variety of applications, including Optimization. In contrast to the very recent work of Ehrlhardt et. al. which deals with AVF discretizations of gradient ﬂows, the present contribution aims at deriving discrete versions of second-order gradient systems based on AVF discrete gradients. The obtained optimization algorithms are shown to inherit the asymptotic behavior of their continuous counterparts.

27 Meihua Wang, Xidian University (joint work with Caoyuan Ma, Fengmin Xu)
Application of quasi-norm regularization into robust portfolio optimization problem

This paper concerns robust portfolio optimization problem which is a popular topic in ﬁnancial engineering. To reach the investor’s requirement on asset selection, we build a sparse robust portfolio optimization model by adding a nonconvex penalty item into the objective function instead of the cardinality constraint. A series of models based on different uncertainty sets for expected return rates and covariance are present. The Alternating Quadratic Penalty (AQP) method is applied to solve the relative sparse robust portfolio selection models.

28 Yue Xie, University of Wisconsin-Madison (joint work with Uday Shanbhag, Stephen Wright) 
Resolution of nonconvex optimization via ADMM type of schemes

First, we consider a class of nonconvex optimization problems including 10 norm minimization and dictionary learning which can be efﬁciently solved using ADMM and its variants. In particular, the nonconvex problem is decomposed such that each subproblem is either a tractable convex program or endowed with hidden convexity. Competitive performance is demonstrated through preliminary numerics. Second, we show that for a general class of nonconvex optimization problems, proximal ADMM is able to avoid strict saddle points with probability 1 using random initialization.
29 Peng-Yeng Yin, National Chi Nan University (joint work with Chun-Ying Cheng)

Simulation Optimization of Co-Sited Wind-Solar Farm under Wind Irradiance and Dust Uncertainties

This paper considers a hybrid system deploying both wind and solar photovoltaic (PV) farms at the same site. We propose a simulation optimization approach. The simulation of uncertain wind, sky irradiance, and dust deposition is based on a meteorological dataset. The co-siting constraints which degrade the production are handled by calculating wind-turbine’s umbra and penumbra on PVs, planning shortest roads for routing the maintenance vehicles, and minimizing the land usage conflict by an evolutionary algorithm. We propose several models to leverage the production, cost, and uncertainty.

30 Jia-Jie Zhu, Max Planck Institute for Intelligent Systems

A Learning Approach to Warm-Start Mixed-Integer Optimization for Controlling Hybrid Systems

Motivated by practical challenges in controlling hybrid systems (i.e. robot trajectory optimization through contact), we propose a machine learning approach to speed up the mixed-integer optimization (MIO) for numerical optimal control. We learn policies to serve as a form of solution memory by casting the training as learning from suboptimal demonstrations. The resulting policies provide feasible incumbent solutions for the branch-and-bound (-cut) process of MIO. Coupled with other insights developed in this work, the approach speeds up numerical optimal control of hybrid systems.
Conference Dinner: Cruise along the river Spree on the “MS Mark Brandenburg”

The river cruise starts at Gotzkowskybrücke, a bridge in 20 minutes walking distance from the conference venue. You can alternatively take Bus 245 from Ernst-Reuter-Platz to Franklinstr., see maps on page 6, and on the inside-back cover. We will then cruise through the city of Berlin while having dinner from buffet with modern German food.

Important Facts

**Time and Date**  Tuesday, August 6, 19:00–23:00

**Venue**  River Cruise on “MS Mark Brandenburg”, Stern und Kreisschifffahrt GmbH.

**Start**  Gotzkowskybrücke, 10555 Berlin, Stern und Kreisschifffahrt pier

Boarding starts at 18:30, *check-in no later than 19:00*.

**End**  23:00 at the starting point

**Participation fee**  65 EUR

**Tickets**  The Conference Dinner is open to attendees and guests who registered and paid in advance for tickets. Tickets are included in your registration envelope. There may be a limited number of tickets available on site — please enquire at the ICCOPT Registration Desk.

**Menu**  Vegetarian options will be available. Please advise, in advance, of any dietary requirements via email to dinner@iccopt2019.berlin

**Contact**  dinner@iccopt2019.berlin

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Tue.4 H 3013 **Recent Developments in Set Optimization (Part IV)**, Akhtar A. Khan, Elisabeth Kübis, Christiane Tammer, Radu Strugariu, Theodor Chelmus, Diana Maxim

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Tue.4 H 0107 **Optimal Control and Dynamical Systems (Part IV)**, Cristopher Hermosilla, Michele Palladino, Maria Soledad Aronna, Jorge Becerril, Michele Palladino

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Tue.4 H 3012 **Embracing Extra Information in Distributionally Robust Models**, Rui Gao, Zhenzhen Yan, Zhiping Chen

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Optimization in Healthcare (Part I)
Organizers: Felix Jost, Christina Schenk
Chair: Felix Jost
Marta Sauter, University of Heidelberg (joint work with Hans Georg Bock, Kathrin Hatz, Ekaterina Kostina, Katja Mombaur, Johannes P. Schlöder, Sebastian Wolf)
Simultaneous Direct Approaches for Inverse Optimal Control Problems and Their Application to Model-Based Analysis of Cerebral Palsy Gait

Inverse optimal control problems arise in the field of modeling, simulation and optimization of the human gait. For our studies we consider a bilevel optimization problem. The lower optimal control model includes unknown parameters that have to be determined by fitting the model to measurements, which is done in the upper level. We present mathematical and numerical methods using a simultaneous direct approach for inverse optimal control problems and derive optimal control models for the gait of patients with cerebral palsy from real-world motion capture data.

Leonard Wirsching, Heidelberg University (joint work with Hans Georg Bock, Ekaterina Kostina, Johannes P. Schlöder, Andreas Sommer)
Solution and Sensitivity Generation for Differential Equations with State-Dependent Switches – an Application-Oriented Approach

For ODEs with switched or non-smooth dynamics, modelers often provide code containing conditionals like IF, ABS, MIN, and MAX. Standard black-box integrators, in general, show poor performance or may compute wrong dynamics without notice. Transformation into model descriptions suitable for state-of-the-art methods is often cumbersome or infeasible. In this talk, we present a new approach that works on the dynamic model equations as provided by the modeler and allows to treat switched and non-smooth large-scale dynamics efficiently and accurately for both integration and sensitivity generation.

Christina Schenk, Carnegie Mellon University (joint work with Lorenz Biegler, Lu Han, Jason Mustakis)
Kinetic Parameter Estimation Based on Spectroscopic Data and Its Application to Drug Manufacturing Processes

The development of drug manufacturing processes involves dealing with spectroscopic data. In many cases kinetic parameter estimation from spectra has to be performed without knowing the absorbing species in advance, such that they have to be estimated as well. That is why we take a closer look at the development of optimization-based procedures in order to estimate the variances of system and measurement noise and thus determine the concentration and absorbance profiles, and parameters simultaneously. The further investigations related to the application specific challenges are presented.

Optimization for Data Science (Part I)
Organizers: Ying Cui, Jong-Shi Pang
Chair: Jong-Shi Pang
Jong-Shi Pang, University of Southern California (joint work with Ying Cui, Ziyu He)
Multi-composite Nonconvex Optimization for Learning Deep Neural Network

We present in this paper a novel deterministic algorithmic framework that enables the computation of a directional stationary solution of the empirical deep neural network training problem formulated as a multi-composite optimization problem with coupled nonconvexity and nondifferentiability. This is the first time to our knowledge that such a sharp kind of stationary solutions is provably computable for a nonsmooth deep neural network. Numerical results from a matlab implementation demonstrate the effectiveness of the framework for solving reasonably sized networks.

Defeng Sun, The Hong Kong Polytechnic University
A majorized proximal point dual Newton algorithm for nonconvex statistical optimization problems

We consider high-dimensional nonconvex statistical optimization problems such as the regularized square-root Lasso problem, where in the objective the loss terms are possibly nonsmooth or non-Lipschitzian and the regularization terms are the difference of convex functions. We introduce a majorized proximal point dual Newton algorithm (mPPDNA) for solving these large scale problems. We construct proper majorized proximal terms that are conducive to the design of an efficient dual based semismooth Newton method of low computational complexities. Extensive numerical results are provided.

Gesualdo Scutari, Purdue University (joint work with Guang Cheng, Ying Sun, Ye Tian)
Distributed inference over networks: geometrically convergent algorithms and statistical guarantees

We study distributed high-dimensional M-estimation problems over networks, modeled as arbitrary graphs (with no centralized node). We design the first class of distributed algorithms with convergence guarantees for such a class of Empirical Risk Minimization (ERM) problems. We prove that, under mild technical assumptions, the proposed algorithm converges at a linear rate to a solution of the ERM that is statistically optimal. Furthermore, for a fixed network topology, such a linear rate is invariant when the problem dimension scales properly with respect to the sample size.
**Non-Convex Optimization for Neural Networks**  
Organizers: Mingyi Hong, Ruoyu Sun  
Chair: Mingyi Hong

**Ruoyu Sun, UIUC**  
**Landscape of Over-parameterized Networks**

Non-convexity of neural networks may cause bad local minima, but the recent guess is that over-parameterization can smooth the landscape. We prove that for any continuous activation functions, the loss function has no bad strict local minimum, both in the regular sense and in the sense of sets. This result holds for any convex and continuous loss function, and the data samples are only required to be distinct in at least one dimension. Furthermore, we show that bad local minima do exist for a class of activation functions.

**Sijia Liu, MIT-IBM Watson AI Lab, IBM Research (joint work with Mingyi Hong)**

**On the convergence of a class of adam-type algorithms for non-convex optimization**

We study a class of adaptive gradient based momentum algorithms, called “Adam-type” algorithm, that update search directions and learning rate simultaneously using past gradients. The convergence of these algorithms for nonconvex problems remains an open question. We provide a set of mild sufficient conditions that guarantee the convergence of the Adam-type methods. We prove that under our derived conditions, these methods can achieve convergence rate $O(\log(T)/\sqrt{T})$ for nonconvex optimization. We show the conditions are essential in the sense that violating them may cause divergence.

**Alex Schwing, University of Illinois at Urbana-Champaign**

**Optimization for GANs via Sliced Distance**

In the Wasserstein GAN, the Wasserstein distance is commonly transformed to its dual via the Kantorovich-Rubinstein Duality and then optimized. However, the dual problem requires a Lipschitz condition which is hard to impose. One idea is to solve the primal problem directly, but this is computationally expensive and has an exponential sample complexity. We propose to solve the problem using the sliced and max-sliced Wasserstein distance, which enjoy polynomial sample complexity. Analysis shows that this approach is easy to train, requires little tuning, and generates appealing results.

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**Linear Complementarity Problem (Part I)**  
Organizers: Tibor Illés, Janez Povh  
Chair: Janez Povh

**Marianna E.-Nagy, Budapest University of Technology and Economics**

**Constructing and analyzing sufficient matrices**

The sufficient matrix class was defined related to Linear complementarity problems. This is the widest class for which the criss-cross and the interior point algorithms (IPM) for solving LCPs are efficient in some sense. It is an NP-complete problem to decide whether a matrix belongs to this class. Therefore, we build a library of sufficient matrices to provide a test set for algorithms solving such LCPs. We show different techniques to generate such matrices. Furthermore, we present results about the handicap, which matrix parameter is important for the theoretical complexity of the IPM.

**Tibor Illés, Budapest University of Technology and Economics, Budapest, Hungary**

**Interior point algorithms for general linear complementarity problems**

Linear Complementarity Problems (LCP) belong to the class of NP-complete problems. Darvay et al. (2018) showed that predictor-corrector (PC) interior point algorithms (IPA) using algebraic equivalent transformation (AET) solves sufficient LCPs in polynomial time. Our aim is to construct new PC IPAs based on AETs which in polynomial time either give an $\epsilon$-optimal solution of the general LCP or detect the lack of sufficiency property. In the latter case, the algorithms give a polynomial size certificate depending on parameter $\kappa$, the initial interior point and the input size of the (LCP).

**Janez Žerovnik, University of Ljubljana (joint work with Tibor Illés, Janez Povh)**

**On sufficient properties for sufficient matrices**

In this talk we present new necessary and sufficient conditions for testing matrix sufficiency, which is an NP-hard problem. We discuss methods for testing matrix sufficiency based on the new characterizations and propose an algorithm with exponential complexity which in its kernel solves many simple instances of linear programming problems. Numerical results confirm relevance of this algorithm.
Nash Equilibrium Problems and Extensions (Part I)
Organizer: Anna Thünen
Chair: Anna Thünen
Jan Becker, TU Darmstadt (joint work with Alexandra Schwartz)
Linear-quadratic multi-leader-follower games in Hilbert spaces

Multi-leader-follower games (MLFGs) can be seen as an hierarchical extension of Nash equilibrium problems. By now, the analysis of the latter is well-known and well-understood even in infinite dimensions. While the analysis of MLFGs in finite dimensions is restricted to special cases, the analysis in function spaces is still in its infancy. Therefore, the talk focuses on linear-quadratic MLFGs in Hilbert spaces and their corresponding equilibrium problems with complementarity constraints (EPCCs). By considering relaxed equilibrium problems, we derive a novel equilibrium concept for MLFGs.

Giancarlo Bigi, Università di Pisa (joint work with Simone Sagratella)
Algorithms for generalized Nash games in semi-infinite programming

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

Benoît Legat, UCLouvain (joint work with Raphaël Jungers, Paulo Tabuada)
Computing polynomial controlled invariant sets using Sum-of-Squares Programming

We develop a method for computing controlled invariant sets of discrete-time affine systems using Sum-of-Squares programming. We apply our method to the controller design problem for switching affine systems with polytopic safe sets but our work also improves the state of the art for the particular case of LTI systems. The task is reduced to a Sum-of-Squares programming problem by enforcing an invariance relation in the dual space of the geometric problem.

Chris Coey, MIT OR Center (joint work with Lea Kapelevich, Juan Pablo Vielma)
Nonsymmetric conic optimization algorithms and applications

Hypatia is an open-source optimization solver in Julia for primal-dual conic problems involving general convex cones. Hypatia makes it easy to define and model with any closed convex conic set for which an appropriate primal or dual barrier function is known. Using novel nonsymmetric cones, we model control applications with smaller, more natural formulations, and demonstrate Hypatia’s superior performance (relative to other state-of-the-art conic interior point solvers) on several large problems.
Recent Advances in Applications of Conic Programming
Organizers: Mituhiro Fukuda, Masakazu Muramatsu, Makoto Yamashita, Akiko Yoshise
Chair: Makoto Yamashita
Yuzhu Wang, University of Tsukuba (joint work with Akihiro Tanaka, Akiko Yoshise)
Polyhedral Approximations of the Semidefinite Cone and Their Applications
Large and sparse polyhedral approximations of the semidefinite cone have been shown important for solving hard conic optimization problems. We propose new approximations that contain the diagonally dominant cone and are contained in the scaled diagonally dominant cone, by devising a simple expansion of the semidefinite bases. As their applications, we propose 1. methods for identifying elements in certain cones, 2. cutting plane methods for conic optimization and 3. a Lagrangian-DNN method for some quadratic optimization problems. Numerical results showed the efficiency of these methods.

Shinichi Kanoh, University of Tsukuba (joint work with Akiko Yoshise)
A centering ADMM for SDP and its application to QAP
We propose a new method for solving SDP problems based on primal dual interior point method and ADMM, called Centering ADMM (CADMM). CADMM is an ADMM but it has the feature of updating the variables toward the central path. We conduct numerical experiments with SDP relaxation problems of QAP and compare CADMM with ADMM. The results demonstrate that which of two methods is favorable depends on instances.

Sena Safarina, Tokyo Institute of Technology (joint work with Tim J. Mullin, Makoto Yamashita)
A Cone Decomposition Method with Sparse Matrix for Mixed-Integer SOCP problem
Our research is focused on an optimal contribution selection (OCS) problem in equal deployment, which is one of the optimization problems that aims to maximize the total benefit under a genetic diversity constraint. The constraint allows the OCS problem to be modeled as mixed-integer second-order cone programming (MI-SOCP). We proposed a cone decomposition method (CDM) that is based on a geometric cut in combination with a Lagrangian multiplier method. We also utilized the sparsity found in OCS, into a sparse linear approximation, that can strongly enhance the performance of CDM.

Optimization and Quantum Information
Organizers: Hamza Fawzi, James Saunderson
Chair: Hamza Fawzi
Sander Gribling, CWI, Amsterdam (joint work with Monique Laurent, David de Laat)
Quantum graph parameters and noncommutative polynomial optimization
Graph parameters such as the chromatic number can be formulated in several ways. E.g., as polynomial optimization problems or using nonlocal games (in which two separated parties must convince a referee that they have a valid coloring of the graph of a certain size). We show how these formulations lead to quantum analogues of graph parameters, which can be used in quantum information theory to study the power of entanglement. We apply techniques from the theory of noncommutative polynomial optimization to obtain hierarchies of semidefinite programming bounds, unifying existing bounds.

Andreas Bluhm, Technical University of Munich (joint work with Ion Nechita)
Compatibility of quantum measurements and inclusion constants for free spectrahedra
One of the defining properties of quantum mechanics is the existence of incompatible observables such as position and momentum. We will connect the problem of determining whether a given set of measurements is compatible to the inclusion of free spectrahedra, which arise in convex optimization. We show how results from algebraic convexity can be used to quantify the degree of incompatibility of binary quantum measurements. In particular, this new connection allows us to completely characterize the case in which the dimension of the quantum system is exponential in the number of measurements.

Kun Fang, University of Cambridge (joint work with Hamza Fawzi)
Polynomial optimization on the sphere and entanglement testing
We consider the problem of maximizing a homogeneous polynomial over the unit sphere and its Sum-of-Square (SOS) hierarchy relaxations. Exploiting the polynomial kernel technique, we show that the convergence rate of the hierarchy is no worse than $O(d^2/|I|^2)$, where d is the dimension of the sphere and |I| is the level of the hierarchy. Moreover, we explore the duality relation between the SOS polynomials and the quantum extendable states in details, and further explain the connection of our result with the one by Navascues, Owari & Plenio from quantum information perspective.
**Convex-Composite Optimization (Part I)**
Organizer: Tim Hoheisel  
Chair: Tim Hoheisel

Andre Milzarek, The Chinese University of Hong Kong, Shenzhen (joint work with Michael Ulbrich)  
A globalized semismooth Newton method for nonsmooth nonconvex optimization

We propose a globalized semismooth Newton framework for solving convex-composite optimization problems involving smooth nonconvex and nonsmooth convex terms in the objective function. A prox-type fixed point equation representing the stationarity conditions forms the basis of the approach. The proposed algorithm utilizes semismooth Newton steps for the fixed point equation to accelerate an underlying globally convergent descent method. We present both global and local convergence results and provide numerical experiments illustrating the efficiency of the semismooth Newton method.

James Burke, University of Washington (joint work with Abraham Engle)  
Quadratic convergence of SQP-like methods for convex-composite optimization

We discuss the local convergence theory of Newton and quasi-Newton methods for convex-composite optimization: minimize $f(x) = h(c(x))$, where $h$ is an infinite-valued closed proper convex function and $c$ is smooth. The focus is on the case where $h$ is infinite-valued convex piecewise linear-quadratic. The optimality conditions are embedded into a generalized equation, and we show the strong metric subregularity and strong metric regularity of the corresponding set-valued mappings. The classical convergence of Newton-type methods is extended to this class of problems.

Tim Hoheisel, McGill University, Montréal  
On the Fenchel conjugate of convex-composite functions

We study convex conjugacy results of compositions of a convex function $g$ and a nonlinear mapping $F$ (possibly extended-valued in a generalized sense) such that the composition $g \circ F$ is still convex. This composite structure which preserves convexity models a myriad of applications comprising e.g. conic programming, convex additive composite minimization, variational Gram functions or vector optimization. Our methodology is largely based on infimal convolution combined with cone-induced convexity.
**Recent Advances in Derivative-Free Optimization (Part I)**

Organizers: Ana Luisa Custodio, Sébastien Le Digabel, Margherita Porcelli, Francesco Rinaldi, Stefan Wild  
Chair: Francesco Rinaldi

Coralia Cartis, Oxford University (joint work with Adilet Otemissov)  
**Dimensionality reduction techniques for global optimization**

We show that the scalability challenges of Global Optimization (GO) algorithms can be overcome for functions with low effective dimensionality, which are constant along certain subspaces. We propose the use of random subspace embeddings within (any) global optimization algorithm, extending Wang et al (2013). Using tools from random matrix theory and conic integral geometry, we investigate the success rates of our low-dimensional embeddings of the original problem, in both a static and adaptive formulation. We illustrate our algorithmic proposals and theoretical findings numerically.

Jeffrey Larson, Argonne National Laboratory (joint work with Kamil Khan, Matt Menickelly, Stefan Wild)  
**Manifold Sampling for Composite Nonconvex Nonsmooth Optimization**

We present and analyze a manifold sampling method for minimizing $f(x) = h(F(x))$ when $h$ is nonsmooth, nonconvex, and has a known structure and $F$ is smooth, expensive to evaluate, and has a relatively unknown structure. Manifold sampling seeks to take advantage of knowledge of $h$ in order to efficiently use past evaluations of $F$.

Florian Jarre, Heinrich-Heine Universität Düsseldorf (joint work with Felix Lieder)  
**The use of second order cone programs in constrained derivative-free optimization**

We discuss a derivative-free solver for nonlinear programs with nonlinear equality and inequality constraints. The algorithm aims at finding a local minimizer by using finite differences and sequential quadratic programming (SQP). As approximations of the derivatives are expensive compared to the numerical computations that usually dominate the computational effort of NLP solvers a somewhat effortful trust-region SQP-subproblem is solved at each iteration by second order cone programs. The public domain implementation in Matlab or Octave is suitable for small to medium size problems.

**Applications of Multi-Objective Optimization (Part I)**

Organizers: Gabriele Eichfelder, Alexandra Schwartz  
Chair: Alexandra Schwartz

Arun Pankajakshan, University College London (joint work with Federico Galvanin)  
**A multi-objective optimal design of experiments framework for online model identification platforms**

In many real world applications, sequential model-based design of experiments (MBDoE) methods employed in online model-based optimization platforms may involve more than one objective in order to drive the real process towards optimal targets, while guaranteeing the satisfaction of quality, cost and operational constraints. In this work, a flexible multi-objective optimal design of experiments framework suitable for online modelling platforms is proposed. The proposed framework is integrated in an online model identification platform for studying the kinetics of chemical reaction systems.

Bennet Gebken, Paderborn University (joint work with Sebastian Peitz)  
**Inverse multiobjective optimization: Inferring decision criteria from data**

It is a very challenging task to identify the objectives on which a certain decision was based, in particular if several, potentially conflicting criteria are equally important and a continuous set of optimal compromise decisions exists. This task can be understood as the inverse problem of multiobjective optimization, where the goal is to find the objective vector of a given Pareto set. To this end, we present a method to construct the objective vector of a multiobjective optimization problem (MOP) such that the Pareto critical set contains a given set of data points.

Alexandra Schwartz, TU Darmstadt (joint work with Daniel Nowak)  
**A Generalized Nash Game for Computation Offloading**

The number of tasks performed on wireless devices is steadily increasing. Due to limited resources on these devices computation offloading became a relevant concept. In order to minimize their own task completion time, users can offload parts of their computation task to a cloudlet with limited power. We investigate the resulting nonconvex generalized Nash game, where the time restriction from offloading is formulated as a vanishing constraint. We show that a unique Nash exists and that the price of anarchy is one, i.e. the equilibrium coincides with a centralized solution.
Analysis of the BFGS Method with Errors

The classical convergence analysis of quasi-Newton methods assumes that the function and gradients employed at each iteration are exact. Here we consider the case when there are (bounded) errors in both computations and study the complex interaction between the Hessian update and step computation. We establish convergence guarantees for a line search BFGS method.

Fred Roosta, University of Queensland (joint work with Yang Liu, Michael Mahoney, Peng Xu)

Newton-MR: Newton’s Method Without Smoothness or Convexity

Establishing global convergence of the classical Newton’s method has long been limited to making restrictive assumptions on (strong) convexity as well as Lipschitz continuity of the gradient/Hessian. We show that two simple modifications of the classical Newton’s method result in an algorithm, called Newton-MR, which is almost indistinguishable from its classical counterpart but it can readily be applied to invex problems. By introducing a weaker notion of joint regularity of Hessian and gradient, we show that Newton-MR converges even in the absence of the traditional smoothness assumptions.

Frank E. Curtis, Lehigh University
NonOpt: Nonsmooth Optimization Solver

We discuss NonOpt, an open source C++ solver for nonconvex, nonsmooth minimization problems. The code has methods based on both gradient sampling and bundle method approaches, all incorporating self-correcting BFGS inverse Hessian approximations. The code comes equipped with its own specialized QP solver for solving the arising subproblems. It is also extensible, intended to allow users to add their own step computation strategies, line search routines, etc. Numerical experiments show that the software is competitive with other available codes.
**Non**

**Mon.1 H 3006**

**Mixed-Integer Optimal Control and PDE Constrained Optimization (Part I)**  
Organizers: Falk Hante, Christian Kirches, Sven Leyffer  
Chair: Sven Leyffer

Christian Clason, Universität Duisburg-Essen  
**Discrete material optimization for the wave equation**  
This talk is concerned with optimizing the spatially variable wave speed in a scalar wave equation whose values are assumed to be taken pointwise from a known finite set. Such a property can be included in optimal control by a so-called "multibang" penalty that is nonsmooth but convex. Well-posedness as well as the numerical solution of the regularized problem are discussed.

Richard Krug, Friedrich-Alexander-Universität Erlangen-Nürnberg (joint work with Günter Leugering, Alexander Martin, Martin Schmidt)  
**Domain decomposition of systems of hyperbolic equations**  
We develop a decomposition method in space and time for optimal control problems on networks governed by systems of hyperbolic PDEs. The optimality system of the optimal control problem can be iteratively decomposed such that the resulting subsystems are defined on small time intervals and (possibly) single edges of the network graph. Then, virtual control problems are introduced, which have optimality systems that coincide with the decomposed subsystems. Finally, we prove the convergence of this iterative method to the solution of the original control problem.

Falk Hante, FAU Erlangen-Nürnberg (joint work with Simone Göttlich, Andreas Potschka, Lars Schewe)  
**Penalty-approaches for partial minima in mixed-integer optimal control**  
We consider mixed-integer optimal control problems with combinatorial constraints that couple over time such as minimum dwell times. A lifting allows a decomposition into a mixed-integer optimal control problem without combinatorial constraints and a mixed-integer problem for the combinatorial constraints in the control space. The coupling is handled using a penalty-approach. We present an exactness result for the penalty which yields a solution approach that convergences to partial-epsilon-minima. The quality of these dedicated points can be controlled using the penalty parameter.

**Mon.1 H 3012**

**Optimization of Biological Systems (Part I)**  
Organizer: Pedro Gajardo  
Chair: Pedro Gajardo

Anna Desilles, ENSTA ParisTech  
**HJB approach to optimal control problems with free initial conditions**  
This talk will focus on some recent results about HJB approach to solve optimal control problems of Mayer’s type with free initial state. First, we show that such problems can be solved by using the associated value function as function of the initial state. Then, some sensitivity relations can be established to link the subdifferential of the value function and the adjoint state of the problem, coming from the Pontryagin's maximum principle. These theoretical results will be illustrated by practical examples from optimal control of bio-processes.

Victor Riquelme, Universidad Tecnica Federico Santa Maria  
**Optimal control of diseases in jailed populations**  
We study the control of a communicable disease in a prison. Its time evolution is modeled by a SIS model, typically used for illnesses that do not confer immunity after recovery. To control the disease, we consider an strategy that consists on performing a screening to a proportion (control variable) of the new prisoners, followed by a treatment. We determine the optimal strategies that minimize a tradeoff between the treatment cost and the number of infective prisoners, in a predetermined time horizon, and characterize qualitatively different behaviors depending on the model parameters.

Pedro Gajardo, Universidad Tecnica Federico Santa Maria  
**Links between sustainability standards, maximin, and viability: methods and applications**  
The maximin criterion, as the highest performance that can be sustained over time, promotes intergenerational equity, a pivotal issue for sustainability. The viable control approach, by investigating trajectories and actions complying over time with various standards and constraints, provides major insights into strong sustainability. In this presentation we address the links between maximin and viability approaches in a multi-criteria context, showing practical methods for computing sustainability standards based in dynamic programming principle and level-set approach.
**Bilevel Optimization in Image Processing (Part I)**

Organizers: Michael Hintermüller, Kostas Papafitsoros  
Chair: Kostas Papafitsoros

Juan Carlos De los Reyes, Escuela Politécnica Nacional

**Bilevel Optimal Parameters Selection in Nonlocal Image Denoising**

We propose a bilevel learning approach for the determination of optimal weights in nonlocal image denoising. We consider both spatial weights in front of the nonlocal regularizer, as well as weights within the kernel of the nonlocal operator. In both cases, we investigate the differentiability of the solution operator in function spaces and derive a first-order optimality system that characterizes local minima. For the numerical solution of the problems, we propose a second-order optimization algorithm in combination with a suitable finite element discretization of the nonlocal denoising models.

Michael Hintermüller, Weierstrass Institute for Applied Analysis and Stochastics

**Several Applications of Bilevel Programming in Image Processing**

Opportunities and challenges of bilevel optimization for applications in image processing are addressed. On the mathematical side, analytical and algorithmic difficulties as well as solution concepts are highlighted. Concerning imaging applications, statistics-based automated regularization function choice rules, and blind deconvolution problems are in the focus.

Kostas Papafitsoros, Weierstrass Institute for Applied Analysis and Stochastics

**Generating structure non-smooth priors for image reconstruction**

We will bind together and extend some recent developments regarding data-driven non-smooth regularization techniques in image processing through the means of bilevel minimization schemes. The schemes, considered in function space, take advantage of dualization frameworks and are designed to produce spatially varying regularization parameters adapted to the data for well-known regularizers, e.g., Total Variation and Total Generalized Variation, leading to automated (monolithic), image reconstruction workflows.

**Infinite-Dimensional Optimization of Nonlinear Systems (Part I)**

Organizers: Fredi Tröltzsch, Irwin Yousept  
Chair: Irwin Yousept

Fredi Tröltzsch, Technische Universität Berlin (joint work with Eduardo Casas Rentería)

**Sparse optimal control for a nonlinear parabolic equation with mixed control-state constraints**

A problem of sparse optimal control for a semilinear parabolic equation is considered, where pointwise bounds on the control and mixed pointwise control-state constraints are given. A quadratic objective functional is to be minimized that includes a Tikhonov regularization term and the $L^1$-norm of the control that accounts for sparsity. Special emphasis is laid on existence and regularity of Lagrange multipliers associated with the mixed control-state constraints. Since the interior of the underlying non-negative cone is empty, the duality theory for linear programming problems in Hilbert spaces is applied in a special way to prove the existence of Lagrange multipliers. First-order necessary optimality conditions are established and discussed up to the sparsity of optimal controls.

Yifeng Xu, Shanghai Normal University (joint work with Irwin Yousept, Jun Zou)

**AFEM for quasilinear magnetostatic phenomena**

In this talk, I introduce an adaptive edge element method for a quasilinear $H$(curl)-elliptic problem in magnetostatics, based on a residual-type a posteriori error estimator and general marking strategies. The error estimator is shown to be reliable and efficient, and its resulting sequence of adaptively generated solutions converges strongly to the exact solution of the original quasilinear system. Numerical experiments are provided to verify the validity of the theoretical results.

Irwin Yousept, University of Duisburg-Essen

**Hyperbolic Maxwell variational inequalities of the second kind**

Physical phenomena in electromagnetism can lead to hyperbolic variational inequalities with a Maxwell structure. They include electromagnetic processes arising in polarizable media, nonlinear Ohm’s law, and high-temperature superconductivity (HTS). In this talk, we present well-posedness and regularity results for a class of hyperbolic Maxwell variational inequalities of the second kind, under different assumptions.
**Mon.1 H 1058**

**Advances in Robust Optimization (Part I)**
Organizer: Shimrit Shtern
Chair: Shimrit Shtern

**Krzysztof Postek**, Erasmus University Rotterdam (joint work with Shimrit Shtern)

**First-order methods for solving robust optimization problems**

We show how robust optimization problems where each constraint is convex in the decision variables and concave in the uncertain parameters, can be solved using a first-order saddle-point algorithm. Importantly, the computations of proximal operators involving the uncertain parameters (“pessimization”) are parallelizable over the problem’s constraints. The scheme has an $O(1/T)$ convergence rate with known both optimality and feasibility guarantees.

**Dick den Hertog**, Tilburg University, The Netherlands

**Solving hard non-robust optimization problems by Robust Optimization**

We discuss several hard classes of optimization problems that contain no uncertainty, and that can be reformulated to (adaptive) robust optimization (RO) problems. We start with several geometrical problems that can be modeled as RO problems. Then, we show that disjoint bilinear and concave minimization problems with linear constraints can be efficiently solved by reformulating these problems as adaptive linear RO problems. This talk summarizes several (recent) papers and is joint work with many other researchers. We expect that more hard classes of problems can be treated in this way.

**Shimrit Shtern**, Technion-Israel Institute of Technology (joint work with Dimitris Bertsimas, Bradley Sturt)

**Data-Driven Two-Stage Linear Optimization: Feasibility and Approximation Guarantees**

In this talk, we focus on two-stage linear optimization problems wherein the information about uncertainty is given by historical data. We present a method that employs a simple robustification of the data combined with a multi-policy approximation in order to solve this problem, and prove that combines (i) strong out-of-sample finite-sample guarantees and (ii) asymptotic optimality. A key contribution of this work is the development of novel geometric insights, which we use to show our approximation is asymptotically optimal.

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**Mon.1 H 3025**

**Advances in Optimization Under Uncertainty**
Organizer: Fatma Kilinc-Karzan
Chair: Fatma Kilinc-Karzan

**Paul Grigas**, University of California, Berkeley

**New Results for Contextual Stochastic Optimization**

We consider a class of stochastic optimization problems where the distribution defining the objective function can be estimated based on a contextual feature vector. We propose an estimation framework that leverages the structure of the underlying optimization problem that will be solved given an observed feature vector. We provide theoretical, algorithmic, and computational results to demonstrate the validity and practicality of our framework.

**Anirudh Subramanyam**, Argonne National Laboratory (joint work with Kibaek Kim)

**Wasserstein distributionally robust two-stage convex optimization with discrete uncertainty**

We study two-stage distributionally robust convex programs over Wasserstein balls centered at the empirical distribution. Under this setting, recent works have studied single-stage convex programs and two-stage linear programs with continuous parameters. We study two-stage convex conic programs where the uncertain parameters are supported on mixed-integer programming representable sets. We show that these problems also admit equivalent reformulations as finite convex programs and propose an exact algorithm for their solution that is scalable with respect to the size of the training dataset.

**Prateek R Srivastava**, University of Texas at Austin (joint work with Grani A. Hanasusanto, Purnamrita Sarkar)

**A Semidefinite Programming Based Kernel Clustering Algorithm for Gaussian Mixture Models with Outliers**

We consider the problem of clustering data points generated from a mixture of Gaussians in the presence of outliers. We propose a semidefinite programming based algorithm that takes the original data as input in the form of a Gaussian kernel matrix, uses the SDP formulation to denoise the data and applies spectral clustering to recover the true cluster labels. We show that under a reasonable separation condition our algorithm is weakly consistent. We compare the performance of our algorithm with existing algorithms like k-means, vanilla spectral clustering and other SDP-based formulations.
Recent Advances in First-Order Methods
Organizer: Shoham Sabach
Chair: Shoham Sabach
Russell Luke, Georg-August-University of Göttingen
Inconsistent Nonconvex Feasibility: algorithms and quantitative convergence results

Feasibility models can be found everywhere in optimization and involve finding a point in the intersection of a collection (possibly infinite) of sets. The focus of most of the theory for feasibility models is on the case where the intersection is nonempty. But in applications, one encounters infeasible problems more often than might be expected. We examine a few high-profile instances of inconsistent feasibility and demonstrate the application of a recently established theoretical framework for proving convergence, with rates, of some elementary algorithms for inconsistent feasibility.

Yakov Vaisbourd, Tel Aviv University (joint work with Marc Teboulle)
Novel Proximal Gradient Methods for Sparsity Constrained Nonnegative Matrix Factorization

In this talk we consider the nonnegative matrix factorization (NMF) problem with a particular focus on its sparsity constrained variant (SNMF). Of the wide variety of methods proposed for NMF, only few are applicable for SNMF and guarantee global convergence to a stationary point. We propose several additional, globally convergent methods, which are applicable to SNMF. Some are extensions of existing state of the art methods, while others are genuine proximal methods that tackle non standard decompositions of NMF, leading to subproblems lacking a Lipschitz continuous gradient objective.

Shoham Sabach, Technion-Israel Institute of Technology
Recent Advances in Proximal Methods for Composite Minimization

Proximal based methods are nowadays starring in optimization algorithms, and are effectively used in a wide spectrum of applications. This talk will present some recent work on the impact of the proximal framework for composite minimization, with a particular focus on convergence analysis and applications.
Mon.2 13:45–15:00

**Optimization in Healthcare (Part II)**
Organizers: Felix Jost, Christina Schenk
Chair: Christina Schenk

Corinna Maier, University of Potsdam (joint work with Niklas Hartung, Wilhelm Huisingsa, Charlotte Kloft, Jana de Wiljes)

**Reinforcement Learning for Individualized Dosing Policies in Oncology**

For cytotoxic anticancer drugs, the combination of a narrow therapeutic window and a high variability between patients complicates dosing policies, as strict adherence to standard protocols may expose some patients to life-threatening toxicity and others to ineffective treatment. Therefore, individualisation is required for safe and effective treatments. We present a reinforcement learning framework for individualised dosing policies that not only takes into account prior knowledge from clinical studies, but also enables continued learning during ongoing treatment.

Patrick-Marcel Lilienthal, Otto-von-Guericke-Universität Magdeburg (joint work with Sebastian Sager, Manuel Tetschke)

**Mathematical Modeling of Erythropoiesis and Treatment Optimization in the Context of Polycythemia Vera**

The disease Polycythemia Vera (PV) leads to patients, which suffer from an uncontrolled production of red blood cells (RBC). If untreated, this might be fatal. Initial treatment is done by phlebotomy in certain regular intervals. Until now it is not known, how to find an individual optimal timing of the treatment schedule, w.r.t. side effects. We extend our published model of RBC dynamics to PV and verify it using simulations. Different approaches for the computation of optimal treatment schedules are formulated and discussed. We illustrate our conclusions with numerical results.

Felix Jost, Otto-von-Guericke University Magdeburg (joint work with Hartmut Döhner, Thomas Fischer, Sebastian Sager, Enrico Schalk, Daniela Weber)

**Optimal Treatment Schedules for Acute Myeloid Leukemia Patients During Consolidation Therapy**

In this talk we present a pharmacokinetic-pharmacodynamic model describing the dynamics of healthy white blood cells (WBCs) and leukemic cells during chemotherapy for acute myeloid leukemia patients. Despite the primary treatment goal of killing cancer cells, a further clinically relevant event is the cytoreduction of WBCs increasing the risk of infections and delayed or stopped therapy. We present optimal treatment schedules derived by optimization problems considering terms for disease progression, healthiness and therapy costs.

Benjamin Recht, University of California, Berkeley
Training on the Test Set and Other Heresies

Conventional wisdom in machine learning taboos training on the test set, interpolating the training data, and optimizing to high precision. This talk will present evidence demonstrating that this conventional wisdom is wrong. I will additionally highlight commonly overlooked phenomena imperil the reliability of current learning systems: surprising sensitivity to how data is generated and significant diminishing returns in model accuracies given increased compute resources. New best practices to mitigate these effects are critical for truly robust and reliable machine learning.

Suriya Gunasekar, Toyota Technological Institute at Chicago
Characterizing optimization bias in terms of optimization geometry [canceled]

In the modern practice of machine learning, especially deep learning, many successful models have far more trainable parameters compared to the number of training examples. Consequently, the optimization objective for such models have multiple minimizers that perfectly fit the training data, but most such minimizers will simply overfit or memorize the training data and will perform poorly on new examples. When minimizing the training objective for such ill posed problems, the implicit inductive bias from optimization algorithms like (S)GD plays a crucial role in learning. In this talk, I will specifically focus on how the characterization of this optimization bias depends on the update geometry of two families of local search algorithms – mirror descent w.r.t. strongly convex potentials and steepest descent w.r.t general norms.

Tengyuan Liang, University of Chicago
New Thoughts on Adaptivity, Generalization and Interpolation

In the absence of explicit regularization, Neural Networks (NN) and Kernel Ridgeless Regression (KRR) have the potential to fit the training data perfectly. It has been observed empirically, however, that such interpolated solutions can still generalize well on test data. We show training NN with gradient flow learns an adaptive RKHS representation, and performs the global least squares projection onto the adaptive RKHS, simultaneously. We then isolate a phenomenon of implicit regularization for minimum-norm interpolated solutions for KRR which could generalize well in the high dim setting.
**Mon.2 H 3004**

**Optimization Methods for Machine Learning and Data Science**  
Organizer: Shuzhong Zhang  
Chair: Shuzhong Zhang  

Yin Zhang, The Chinese University of Hong Kong, Shenzhen  

**Data clustering: a subspace-matching point of view and $K$-scalable algorithms**

Data clustering is a fundamental unsupervised learning strategy. The most popular clustering method is arguably the $K$-means algorithm ($K$ being the number of clusters), albeit it is usually applied not directly to a dataset given, but to its image in a processed “feature space” (such as the case in spectral clustering). The $K$-means algorithm, however, has been observed to have a deteriorating performance as $K$ increases. In this talk, we will examine some clustering models from a subspace-matching viewpoint and promote a so-called $K$-indicators model. We apply a partial convex-relaxation scheme to this model and construct an “essentially deterministic” algorithm requiring no randomized initialization. We will present theoretical results to justify the proposed algorithm and give extensive numerical results to show its superior scalability over $K$-means as the number of clusters grows.

Shuzhong Zhang, University of Minnesota, joint appointment with Institute of Data and Decision Analytics, The Chinese University of Hong Kong, Shenzhen (joint work with Bo Jiang, Tianyi Lin)

**Optimization Methods for Learning Models: Adaptation, Acceleration, and Subsampling**

In this talk we present a suite of algorithms for solving optimization models arising from applications in machine learning and statistics. Popular optimization methods for solving such problems include the high-order tensor approximation approach, which requires the knowledge on some problem parameters. To make such methods practical, one will need to find ways of implementation without such knowledge. We discuss methods that exhibit an accelerated iteration bound while maintaining the traits of being adaptive.

Bo Jiang, Shanghai University of Finance and Economics (joint work with Haoyue Wang, Shuzhong Zhang)

**An Optimal High-Order Tensor Method for Convex Optimization**

Optimization algorithms using up to the $d$-th order derivative information of the iterative solutions are called high-order tensor methods. In this talk, we propose a new high-order tensor algorithm for the general composite case, with the iteration complexity of $O(1/k^{(3d+1)/2})$, which matches the lower bound for the $d$-th order tensor methods, hence is optimal. Our approach is based on the so-called Accelerated Hybrid Proximal Extragradient (A-HPE) framework.

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**Mon.2 H 3002**

**Linear Complementarity Problem (Part II)**  
Organizers: Tibor Illés, Janez Povh  
Chair: Tibor Illés  

Zsolt Darvay, Babes-Bolyai University (joint work with Tibor Illés, Janez Povh, Petra Renáta Rigó)  

**Predictor-corrector interior-point algorithm for sufficient linear complementarity problems based on a new search direction**

We introduce a new predictor-corrector (PC) interior-point algorithm (IPA), which is suitable for solving linear complementarity problem (LCP) with $P^*(K)$-matrices. We use the method of algebraically equivalent transformation (AET) of the nonlinear equation of the system which defines the central path. We show the complexity of this algorithm and implement it in C++ programming language. We demonstrate its performance on two families of LCPs: LCP with matrices, which have positive handicap and on instances of LCP related to the copositivity test.

Janez Povh, University of Ljubljana  

**Multi-type symmetric non-negative matrix factorization**

Multi-type symmetric non-negative matrix factorization problem is a strong model to approach data fusion e.g. in bioinformatics. It can be formulated as a non-convex optimization problem with the objective function being polynomial of degree 6 and the feasible set being defined by sign and complementarity constraints. In the talk we will present how to obtain good solutions, often local extreme points, by the fixed point method, the projected gradient method, the Alternating Direction Method of Multipliers and ADAM. We also demonstrate the application of this approach in cancer research.
Nash Equilibrium Problems and Extensions (Part II)
Organizer: Anna Thünen
Chair: Anna Thünen
Mathias Staudigl, Maastricht University (joint work with Panayotis Mertikopoulos)
Stochastic Dual Averaging in Games and Variational Inequalities

We examine the convergence of a broad class of distributed learning dynamics for games with continuous action sets. The dynamics comprise a multi-agent generalization of Nesterov’s dual averaging method, a primal-dual mirror descent method that has seen a major resurgence in large-scale optimization and machine learning. To account for settings with high temporal variability we adopt a continuous-time formulation of dual averaging and we investigate the dynamics’ behavior when players have noiseless or noisy information. Asymptotic and non-asymptotic convergence results are presented.

Matt Barker, Imperial College London
A Comparison of Stationary Solutions to Mean Field Games and the Best Reply Strategy

In this talk I will briefly discuss the Best Reply Strategy (BRS) – an instantaneous response to a cost function – and how it can be related to a Mean Field Game (MFG) through a short-time rescaling. I will then focus on stationary solutions to linear-quadratic MFGs and the BRS, describing a proof for existence and uniqueness of such MFGs and comparing existence between the two models. I will highlight some specific examples of MFGs and BRS that show typical differences between the two models. Finally, I will explain the importance of these differences and their modelling consequences.

Anna Thünen, Institut für Geometrie und Praktische Mathematik (IGPM), RWTH Aachen University (joint work with Michael Herty, Sonja Steffensen)
Multi-Level Mean Field Games

We discuss an application motivated two level game with a large amount of players. To overcome the challenge of high dimensionality due to the number of players, we derive the mean field limit of infinitely many players. We discuss the relation between optimization and mean field limit for different settings and establish conditions for consistency.
**Recent Advances and Applications of Conic Optimization**

**Organizer:** Anthony Man-Cho So  
**Chair:** Anthony Man-Cho So

Hamza Fawzi, University of Cambridge  
**On polyhedral approximations of the positive semidefinite cone**

Let $D$ be the set of density matrices, i.e., the set of positive definite matrices of unit trace. We show that any polytope $P$ that is sandwiched between $(1 - \epsilon)D$ and $D$ (where the origin is taken to be the scaled identity matrix) must have linear programming extension complexity at least $\exp(c\sqrt{n})$ where $c > 0$ is a constant that depends only on $\epsilon$. The main ingredient of our proof is hypercontractivity of the noise operator on the hypercube.

Huikang Liu, The Chinese University of Hong Kong (joint work with Rujun Jiang, Anthony Man-Cho So, Peng Wang)  
**Fast First-Order Methods for Quadratically Constrained Quadratic Optimization Problems in Signal Processing**

Large-scale quadratically constrained quadratic programming (QCQP) finds many applications in signal processing. Traditional methods, like semidefinite relaxation (SDR) and successive convex approximation (SCA), become inefficient because they are sensitive to the problem dimension. Thus, we are motivated to design a fast first-order method, called linear programming-assisted subgradient decent (LPA-SD), to tackle it. For LPA-SD, we only solve a dimension-free linear programming in each iterate. Numerical results demonstrate its potential in both computational efficiency and solution quality.

Anthony Man-Cho So, The Chinese University of Hong Kong (joint work with K-F Cheung, Sherry Ni)  
**Mixed-Integer Conic Relaxation for TOA-Based Multiple Source Localization**

Source localization is among the most fundamental and studied problems in signal processing. In this talk, we consider the problem of localizing multiple sources based on noisy distance measurements between the sources and the sensors, in which the source-measurement association is unknown. We develop a mixed-integer conic relaxation of the problem and propose a second-order cone-based outer approximation algorithm for solving it. We show that the proposed algorithm enjoys finite convergence and present numerical results to demonstrate its viability.

**Convex-Composite Optimization (Part II)**

**Organizer:** Tim Hoheisel  
**Chair:** Tim Hoheisel

Dmitry Kamzolov, Moscow Institute of Physics and Technology, MIPT (joint work with Pavel Dvurechensky, Alexander Gasnikov)  
**Composite High-Order Method for Convex Optimization**

In this paper, we propose a new class of convex optimization problem with the objective function formed as a sum of $m + 1$ functions with the different order of smoothness: non-smooth but simple with known structure, with Lipschitz-continuous gradient, with Lipschitz-continuous second-order derivative, ..., with Lipschitz-continuous m-order derivative. To solve this problem, we propose a high-order optimization method, that takes into account information about all functions. We prove the convergence rate of this method. We obtain faster convergence rates than the ones known in the literature.

Pedro Merino, Escuela Politécnica Nacional (joint work with Juan Carlos De los Reyes)  
**A Second-order method with enriched hessian information for composite sparse optimization problems**

In this talk we present a second order method for solving composite sparse optimization problems, which consist in minimizing the sum of a differentiable, possibly nonconvex function and a nondifferentiable convex term. The composite nondifferentiable convex penalization is given by $\ell_1$-norm of a matrix times the coefficient vector. Our proposed method generalizes the previous OESOM algorithm in its three main ingredients to the case of the generalized composite optimization: outward directions, the projection step and, in particular, the full second-order information.
Mon.2 H 1029

Recent Advances in First-Order Methods for Constrained Optimization and Related Problems (Part II)
Organizers: Shiqian Ma, Ion Necoara, Quoc Tran-Dinh, Yangyang Xu
Chair: Ion Necoara

Nam Ho-Nguyen, (joint work with Fatma Kilinc-Karzan)
A dynamic primal-dual first-order framework for convex optimization under uncertainty

Many optimization problems in practice must be solved under uncertainty, i.e., only with noisy estimates of input parameters. We present a unified primal-dual framework for deriving first-order algorithms for two paradigms of optimization under uncertainty: robust optimization (RO) where constraint parameters are uncertain, and joint estimation-optimization (JEO) where objective parameters are uncertain. The key step is to study a related ‘dynamic saddle point’ problem, and we show how RO and JEO are covered by our framework through choosing the dynamic parameters in a particular manner.

Guanghui Lan, Georgia Institute of Technology (joint work with Digvijay Boob, Qi Deng)
Proximal point methods for constrained nonconvex optimization

We present novel proximal-point methods for solving a class of nonconvex optimization problems with nonconvex constraints and establish its computational complexity for both deterministic and stochastic problems. We will also illustrate the effectiveness of this algorithm when solving some application problems in machine learning.

Quoc Tran-Dinh, University of North Carolina at Chapel Hill
Adaptive Primal-Dual Methods for Convex Optimization with Faster Rates

We discuss a new class of primal-dual methods for solving nonsmooth convex optimization problem ranging from unconstrained to constrained settings. The proposed methods achieve optimal convergence rates and faster rates in the last iterates instead of taking averaging sequence, and essentially maintain the same per-iteration complexity as in existing methods. Our approach relies on two different frameworks: quadratic penalty and augmented Lagrangian functions. In addition, it combines with other techniques such as alternating, linearizing, accelerated, and adaptive strategies in one

Mon.2 H 2038

Challenging Applications in Derivative-Free Optimization (Part I)
Organizers: Ana Luisa Custodio, Sébastien Le Digabel, Margherita Porcelli, Francesco Rinaldi, Stefan Wild
Chair: Margherita Porcelli

Yves Lucet, University of British Columbia (joint work with Mahdi Aziz, Warren Hare, Majid Jaberipour)
Multi-fidelity derivative-free algorithms for road design

We model the road design problem as a bilevel problem. The top level calculates the road path from a satellite’s viewpoint while the lower level is a mixed-integer linear problem (solving the vertical alignment i.e. where to cut and fill the ground to design the road and the earthwork i.e. what material to move to minimize costs) for which we build a variable-fidelity surrogate using quantile regression. We compare two variable-fidelity algorithms from the literature (a generalized pattern search with adaptive precision vs. a trust-region with controlled error) and report significant speedups.

Miguel Diago, Polytechnique Montréal (joint work with Peter R. Armstrong, Nicolas Calvet)
Net power maximization in a beam-down solar concentrator

The reflectors of a beam-down solar concentrator are adjusted to maximize the net power collected at the receiver. The performance of the solar plant is predicted with a Monte Carlo ray-tracing model as a function of a feasible reflector geometry. Optimization is carried out with NOMAD, an instance of the mesh-adaptive direct search (MADS) blackbox algorithm. Challenges include reducing the number of optimization variables, dealing with the stochastic aspect of the blackbox, and the selection of effective MADS optimization parameters.

Sébastien Le Digabel, Polytechnique Montréal (joint work with Dounia Lakhmiri, Christophe Tribes)
HYPERNOMAD: Hyper-parameter optimization of deep neural networks using mesh adaptive direct search

The performance of deep neural networks is highly sensitive to the choice of the hyper-parameters that define the structure of the network and the learning process. Tuning a deep neural network is a tedious and time consuming process that is often described as a “dark art”. This work introduces the HYPERNOMAD package based on the MADS derivative-free algorithm to solve this hyper-parameter optimization problem including the handling of categorical variables. This approach is tested on the MNIST and CIFAR-10 datasets and achieves results comparable to the current state of the art.
Applications of Multi-Objective Optimization (Part II)
Organizers: Gabriele Eichfelder, Alexandra Schwartz
Chair: Alberto De Marchi

Floriane Mefo Kue, University of Siegen (joint work with Thorsten Raasch)
Semismooth Newton methods in discrete TV and TGV regularization

We consider the numerical minimization of Tikhonov-type functionals with discrete total generalized variation (TGV) penalties. The minimization of the Tikhonov functional can be interpreted as a bilevel optimization problem. The upper level problem is unconstrained, and the lower level problem is a mixed $\ell_1$-TV separation problem. By exploiting the structure of the lower level problem, we can reformulate the first-order optimality conditions as an equivalent piecewise smooth system of equations which can then be treated by semismooth Newton methods.

Zahra Forouzandeh, Faculdade de Engenharia da Universidade do Porto (joint work with Mostafa Shamsi, Maria do Rosário de Pinho)
Multi-objective optimal control problems: A new method based on the Pascoletti-Serafini scalarization method

A common approach to determine efficient solutions of a Multi-Objective Optimization Problems is to reformulate it as a parameter dependent Single-Objective Optimization: this is the scalarization method. Here, we consider the well-known Pascoletti-Serafini Scalarization approach to solve the nonconvex Multi-Objective Optimal Control Problems (MOOCPs). We show that by restricting the parameter sets of the Pascoletti-Serafini Scalarization method, we overcome some of the difficulties. We illustrate the efficiency of the method for two MOOCPs comprising both two and three different costs.

Alberto De Marchi, Bundeswehr University Munich (joint work with Matthias Gerdts)
Mixed-Integer Linear-Quadratic Optimal Control with Switching Costs

We discuss the linear-quadratic optimal control of continuous-time dynamical systems via continuous and discrete-valued control variables, also considering state-independent switching costs. This is interpreted as a bilevel problem, involving switching times optimization, for a given mode sequence, and continuous optimal control. Switching costs are formulated in terms of cardinality, via the $L^0$ “norm”. An efficient routine for the simplex-constrained $L^0$ proximal operator is devised and adopted to solve some numerical examples through an accelerated proximal gradient method.

Nonlinear and Stochastic Optimization (Part II)
Organizers: Albert Berahas, Geovani Grapiglia
Chair: Albert Berahas

Alejandra Peña-Ordieres, Northwestern University, Evanston (joint work with James Luedtke, Andreas Wächter)
A Nonlinear Programming Reformulation of Chance Constraints

In this talk, we introduce a method for solving nonlinear continuous optimization problems with chance constraints. Our method is based on a reformulation of the probabilistic constraint as a smooth sample-based quantile function. We provide theoretical statistical guarantees of the approximation. Furthermore, we propose an S1QP-type trust-region method to solve instances with joint chance constraints. We show that the method scales well in the number of samples and that the smoothing can be used to counteract the bias in the chance constraint approximation induced by the sample.

Stefan Wild, Argonne National Laboratory (joint work with Matt Menickelly)
Manifold Sampling for Robust Calibration

We adapt a manifold sampling algorithm for the composite nonsmooth, nonconvex optimization formulations of model calibration that arise when imposing robustness to outliers present in training data. We demonstrate the approach on objectives based on trimmed loss and highlight the challenges resulting from the nonsmooth, nonconvex paradigm needed for robust learning. Initial results demonstrate that the method has favorable scaling properties. Savings in time on large-scale problems arise at the expense of not certifying global optimality in empirical studies, but the method also extends to cases where the loss is determined by a black-box oracle.

Nikita Doikov, UCLouvain
Complexity of cubically regularized Newton method for minimizing uniformly convex functions

In this talk we discuss iteration complexity of cubically regularized proximal Newton method for solving composite minimization problems with uniformly convex objective. We introduce the notion of second-order condition number of a certain degree and present the linear rate of convergence in a nondegenerate case. The algorithm automatically achieves the best possible global complexity bound among different problem classes of functions with Holder continuous Hessian of the smooth part. This research was supported by ERC Advanced Grant 788368.
Smooth Optimization (Part II)
Organizers: Dominique Orban, Michael Saunders
Chair: Michael Saunders
Dominique Orban, GERAD & Polytechnique (joint work with Ron Estrin, Michael Friedlander, Michael Saunders)
Implementing a smooth exact penalty function for constrained nonlinear optimization

We develop a general constrained optimization algorithm based on a smooth penalty function proposed by Fletcher. The main computational kernel is solving structured linear systems. We show how to solve these systems efficiently by storing a single factorization per iteration when the matrices are available explicitly. We also give a factorization-free implementation. The penalty function shows particular promise when such linear systems can be solved efficiently, e.g., for PDE-constrained optimization problems where efficient preconditioners exist.

Marie-Ange Dahito, PSA Group / École Polytechnique (joint work with Dominique Orban)
The Conjugate Residual Method in Linesearch and Trust-Region Methods

Like the conjugate gradient method (CG), the conjugate residual method (CR), proposed by Hestenes and Stiefel, has properties that are desirable in both linesearch and trust-region contexts for optimization, but is only defined for symmetric positive-definite operators. We investigate modifications that make CR suitable, even in the presence of negative curvature, and perform comparisons on convex and nonconvex problems with CG. We give an extension suitable for nonlinear least-squares problems. CR performs as well as or better than CG, and yields savings in operator-vector products.

Douglas Gonçalves, UFSC Federal University of Santa Catarina (joint work with Fermin Bazan, Juliano Francisco, Lila Paredes)
Nonmonotone inexact restoration method for minimization with orthogonality constraints

We consider the problem of minimizing a differentiable functional restricted to the set of \( n \times p \) matrices with orthonormal columns. We present a nonmonotone line search variant of the inexact restoration method along with implementation details. The restoration phase employs the Cayley transform, which leads to an SVD-free scheme. By exploiting the Sherman-Morrison-Woodbury formula this strategy proved to be quite efficient when \( p \) is much smaller than \( n \). Numerical experiments validate the reliability of our approach on a wide class of problems against a well established algorithm.

Variational Inequalities, Minimax Problems and GANs (Part I)
Organizer: Konstantin Mishchenko
Chair: Konstantin Mishchenko
Simon Lacoste-Julien, University of Montreal & Mila & SAIL Montreal
Negative Momentum for Improved Game Dynamics

Games generalize the single-objective optimization paradigm by introducing different objective functions for different players. Differentiable games often proceed by simultaneous or alternating gradient updates. In machine learning, games are gaining new importance through formulations like generative adversarial networks (GANs) and actor-critic systems. However, compared to single-objective optimization, game dynamics is more complex and less understood. In this work, we analyze gradient-based methods with negative momentum on simple games and show stability of alternating updates.

Dmitry Kovalev, King Abdullah University of Science and Technology (KAUST)
Revisiting Stochastic Extragradient Method.

We revisit stochastic extragradient methods for variational inequalities. We propose a new scheme which uses the same stochastic realization of the operator to perform an extragradient step. We prove convergence under the assumption that variance is bounded only at the optimal point and generalize method to proximal setting. We improve state-of-the-art results for bilinear problems and analyze convergence of the method for non-convex minimization.

Gauthier Gidel, Université de Montréal
New Optimization Perspectives on Generative Adversarial Networks

Generative adversarial networks (GANs) form a generative modeling approach known for producing appealing samples, but they are notably difficult to train. One common way to tackle this issue has been to propose new formulations of the GAN objective. Yet, surprisingly few studies have looked at optimization methods designed for this adversarial training. In this work, we cast GAN optimization problems in the general variational inequality framework and investigate the effect of the noise in this context.
Mixed-Integer Optimal Control and PDE Constrained Optimization (Part II)
Organizers: Falk Hante, Christian Kirches, Sven Leyffer
Chair: Falk Hante
Sebastian Peitz, Paderborn University (joint work with Stefan Klus)

Feedback control of nonlinear PDEs using Koopman-Operator-based switched systems

We present a framework for feedback control of PDEs using Koopman operator-based reduced order models (K-ROMs). The Koopman operator is a linear but infinite-dimensional operator describing the dynamics of observables. By introducing a finite number of constant controls, a dynamic control system is transformed into a set of autonomous systems and the corresponding optimal control problem into a switching time optimization problem, which can be solved efficiently when replacing the PDE constraint of the autonomous systems by K-ROMs. The approach is applied to examples of varying complexity.

Mirko Hahn, Otto-von-Guericke University Magdeburg (joint work with Sven Leyffer, Sebastian Sager)

Set-based Approaches for Mixed-Integer PDE Constrained Optimization

We present a gradient descent method for optimal control problems with ordinary or partial differential equations and integer-valued distributed controls. Our method is based on a derivative concept similar to topological gradients. We formulate first-order necessary optimality conditions, briefly sketch a proof of approximate stationarity, and address issues with second derivatives and sufficient optimality conditions. We give numerical results for two test problems based on the Lotka-Volterra equations and the Laplace equation, respectively.

Paul Manns, TU Braunschweig (joint work with Christian Kirches)

A continuous perspective on Mixed-Integer Optimal Control

PDE-constrained control problems with distributed integer controls can be relaxed by means of partial outer convexification. Algorithms exist that allow to approximate optimal relaxed controls with feasible integer controls. These algorithms approximate relaxed controls in the weak* topology of $L^\infty$ and can be interpreted as a constructive transfer of the Lyapunov convexity theorem to mixed-integer optimal control, which yields state vector approximation in norm for compact solution operators of the underlying process. The chain of arguments is demonstrated numerically.

Optimization of Biological Systems (Part II)
Organizer: Pedro Gajardo
Chair: Pedro Gajardo

Kenza Boumaza, INRA (joint work with Nesrine Kalboussi, Alain Rapaport, Roux Sébastien)

About optimal crop irrigation planning under water scarcity

We study theoretically on a simple crop model the problem of optimizing the crop biomass at harvesting date, choosing the temporal distribution of water under the constraint of a total water volume available for the season. We show with the tools of the optimal control theory that the optimal solution may present a singular arc, under a lower water availability, which leads to a bang-singular-bang solution. This differs from the usual irrigation policies under water scarcity, which are bang-bang.

Ilya Dikariev, University BTU Cottbus-Senftenberg (joint work with Ingrid M. Cholo, Gerard Olivar Tost)

Optimal public and private investments in a model of sustainable development

In this paper, we analyze the existence of an optimal resource control problem with an infinite time horizon of a system of differential equations with nonlinear dynamics and linear control. Our system of differential equations corresponds to a model of sustainable development. The variables in the state space are related to economics, ecosystems and social dimensions. We deal with the problem of non-convexity, and we prove the existence of optimal solutions, which are interpreted in the sustainable and economic environment.
Bilevel Optimization in Image Processing (Part II)
Organizers: Michael Hintermüller, Kostas Papafitsoros
Chair: Michael Hintermüller
Elisa Davoli, University of Vienna (joint work with Irene Fonseca, Pan Liu)
Adaptive image processing: first order PDE constraint regularizers and a bilevel training scheme

In this talk we will introduce a novel class of regularizers, providing a unified approach to standard regularizers such as TV and $\text{TGV}^2$. By means of a bilevel training scheme we will simultaneously identify optimal parameters and regularizers for any given class of training imaging data. Existence of solutions to the training scheme will be shown via Gamma-convergence. Finally, we will provide some explicit examples and numerical results. This is joint work with Irene Fonseca (Carnegie Mellon University) and Pan Liu (University of Cambridge).

Gernot Holler, University of Graz (joint work with Karl Kunisch)
Learning regularization operators using bilevel optimization

We address a learning approach for choosing regularization operators from given families of operators for the regularization of ill-posed inverse problems. Assuming that some ground truth data is given, the basic idea is to learn regularization operators by solving a bilevel optimization problem. Thereby, the lower level problem, which is dependent on the regularization operators, is a Tikhonov-type regularized problem. As concrete examples we consider families of operators arising in multi-penalty Tikhonov regularization and a family of operators inspired by nonlocal energy semi-norms.

Jyrki Jauhiainen, University of Eastern Finland (joint work with Petri Kuusela, Aku Seppänen, Tuomo Valkonen)
An inexact relaxed Gauss–Newton applied to electrical impedance tomography

Partial differential equations (PDE)-based inverse problems—such as image reconstruction in electrical impedance tomography (EIT)—often lead to non-convex optimization problems. These problems are also non-smooth when total variation (TV) type regularization is employed. To improve upon current optimization methods, such as (semi-smooth) Newton’s method and non-linear primal dual proximal splitting (NL-PDPS), we propose a new alternative: an inexact relaxed Gauss-Newton method. We investigate its convergence both theoretically and numerically with experimental EIT studies.

De-Han Chen, Central China Normal University
Variational source condition for the reconstruction of distributed fluxes

This talk is devoted to the inverse problem of recovering the unknown distributed flux on an inaccessible part of boundary using measurement data on the accessible part. We establish and verify a variational source condition for this inverse problem, leading to a logarithmic-type convergence rate for the corresponding Tikhonov regularization method under a low Sobolev regularity assumption on the distributed flux. Our proof is based on the conditional stability and Carleman estimates together with the complex interpolation theory on a proper Gelfand triplet.

Malte Winckler, University of Duisburg-Essen
Shape optimization subject to $H(\text{curl})$-elliptic variational inequalities in superconductivity

We discuss a shape optimization problem subject to an elliptic curl-curl VI of the second kind. By employing a Moreau-Yosida-type regularization to its dual formulation, we obtain the sufficient differentiability property to apply the averaged adjoint method. By means of this, we compute the shape derivative of the regularized problem. After presenting a stability estimate for the shape derivative w.r.t. the regularization parameter, we prove the strong convergence of the optimal shapes and the solutions. Finally, we apply the numerical algorithm to a problem from the (HTS) superconductivity.
This talk is concerned with the optimal control of two immiscible fluids. For the mathematical formulation we use a coupled Cahn–Hilliard/Navier–Stokes system which involves a variational inequality of 4th order. We discuss the differentiability properties of the control-to-state operator and the corresponding stationarity concepts for the control problem. We present strong stationarity conditions and provide a numerical solution algorithm based on a bundle-free implicit programming approach which terminates at an at least C-stationary point which, in the best case, is even strongly stationary.

Masoumeh Mohammadi, TU Darmstadt (joint work with Winfried Wollner)

A priori error estimates for optimal control of a phase-field fracture model

An optimal control problem for a time-discrete fracture propagation process is considered. The nonlinear fracture model is treated once as a linearized one, while the original nonlinear model is dealt with afterwards. The discretization of the problem in both cases is done using a conforming finite element method. Regarding the linearized case, a priori error estimates for the control, state, and adjoint variables will be derived. The discretized nonlinear fracture model will be analyzed as well, which leads to a quantitative error estimate, while we avoid unrealistic regularity assumptions.

Henning Bonart, Technische Universität Berlin (joint work with Christian Kahle, Jens-Uwe Repke)

Controlling Sliding Droplets with Optimal Contact Angle Distributions

In lab-on-a-chip devices liquid drops move over solid surfaces. A specific contact angle distribution can be utilized to influence both speed and path of each drop. In previous works, we improved and implemented a phase field model for energy-consistent simulations of moving contact lines. Building on this, we present first results for the optimal control of droplets on solid surfaces. The static contact angle distribution acts as the control variable and the phase field model is used to calculate the drop dynamics. As optimization problems, desired drop shapes and positions are considered.

Han Yu, University of Southern California (joint work withAngelos Georgiou, Phebe Vayanos)

Robust Optimization with Decision-Dependent Information Discovery

We consider two-stage robust optimization problems in which the first stage variables decide on the uncertain parameters that will be observed between the first and the second decision stages. The information available in the second stage is thus decision-dependent and can be discovered by making strategic exploratory investments in the first stage. We propose a novel min-max-min-max formulation of the problem. We prove the correctness of this formulation and leverage this new model to provide a solution method inspired from the K-adaptability approximation approach.

Viet Anh Nguyen, EPFL (joint work with Daniel Kuhn, Peyman Mohajerin Esfahani)

Distributionally Robust Inverse Covariance Estimation: The Wasserstein Shrinkage Estimator

We introduce a distributionally robust maximum likelihood estimation model with a Wasserstein ambiguity set to infer the inverse covariance matrix of a \( p \)-dimensional Gaussian random vector from \( n \) independent samples. We show that the estimation problem has an analytical solution that is interpreted as a nonlinear shrinkage estimator. Besides being invertible and well-conditioned, the new shrinkage estimator is rotation-equivariant and preserves the order of the eigenvalues of the sample covariance matrix.

Angelos Georgiou, McGill University, Montréal (joint work with Angelos Tsoukalas, Wolfram Wiesemann)

A Primal-Dual Lifting Scheme for Two-Stage Robust Optimization

In this talk, we discuss convergent hierarchies of primal (conservative) and dual (progressive) bounds for two-stage robust optimization problems that trade off the competing goals of tractability and optimality: While the coarsest bounds recover a tractable but suboptimal affine decision rule of the two-stage robust optimization problem, the refined bounds lift extreme points of the uncertainty set until an exact but intractable extreme point reformulation of the problem is obtained.
Advances in Robust Optimization (Part II)
Organizer: Krzysztof Postek
Chair: Krzysztof Postek
Ahmadreza Marandi, Eindhoven University of Technology (joint work with Geert-Jan van Houtum)
Robust location-transportation problems for integer low-demand items
We analyze robust location-transportation problems with uncertain integer demand. The goal is to select locations of the warehouses and determine their stock levels while considering the optimal policy to satisfy the demand of customers. In this presentation, we consider the integer transshipments between customers and local warehouses. We provide theoretical and numerical results on how to solve or approximate a multi-stage robust location-transportation problem. The numerical experiments will show the efficiency of our methods.

Ernst Roos, Tilburg University (joint work with Ruud Brekelmans, Dick den Hertog)
Uncertainty Quantification for Mean-MAD Ambiguity
The Chebyshev inequality and its variants provide upper bounds on the tail probability of a random variable. While it is tight, it has been criticized for only being attained by pathological distributions that abuse the unboundedness of the support. We provide an alternative tight lower and upper bound on the tail probability given a bounded support, mean and mean absolute deviation. This fundamental result allows us to find convex reformulations of single and joint ambiguous chance constraints with right-hand side uncertainty and left-hand side uncertainty with specific structural properties.

Stefan ten Eikelder, Tilburg University, The Netherlands (joint work with Ali Ajdari, Thomas Bortfeld, Dick den Hertog)
Adjustable robust treatment-length optimization in radiation therapy
Technological advancements in radiation therapy (RT) allow for the collection of biomarker data on individual patient response during treatment, and subsequent RT plan adaptations. We present a mathematical framework that optimally adapts the treatment-length of an RT plan, focusing on the inexactness of acquired biomarker data. We formulate the adaptive treatment-length optimization problem as a 2-stage problem in terms of Biological Effective Dose (BED). Using Adjustable Robust Optimization (ARO) techniques we derive explicit stage-2 decision rules and solve the optimization problem.

Nonlinear Optimization Algorithms and Applications in Data Analysis (Part I)
Organizers: Xin Liu, Cong Sun
Chair: Xin Liu
Yaxiang Yuan, State Key Laboratory of Scientific/Engineering Computing, Institute of Computational Mathematics and Scientific/Engineering Computing, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (joint work with Xin Liu, Zaiwen Wen)
Efficient Optimization Algorithms For Large-scale Data Analysis
This talk first reviews two efficient Newton type methods based on problem structures: 1) semi-smooth Newton methods for composite convex programs and its application to large-scale semi-definite program problems and machine learning; 2) an adaptive regularized Newton method for Riemannian Optimization. Next, a few parallel optimization approaches are discussed: 1) parallel subspace correction method for a class of composite convex program; 2) parallelizable approach for linear eigenvalue problems; 3) parallelizable approach for optimization problems with orthogonality constraint.

Liping Wang, Nanjing University of Aeronautics and Astronautics
Robust ordinal regression induced by $l_p$-centroid
We propose a novel type of class centroid derived from the $l_p$-norm (coined as $l_p$-centroid) to overcome the drawbacks above, and provide an optimization algorithm and corresponding convergence analysis for computing the $l_p$-centroid. To evaluate the effectiveness of $l_p$-centroid in Ordinal regression (OR) context against noises, we then combine the $l_p$-centroid with two representative class-center-induced ORs. Finally, extensive OR experiments on synthetic and real-world datasets demonstrate the effectiveness and superiority of the proposed methods to related existing methods.

Cong Sun, Beijing University of Posts and Telecommunications (joint work with Jinpeng Liu, Yaxiang Yuan)
New gradient method with adaptive stepsize update strategy
In this work, a new stepsize update strategy for the gradient method are proposed. On one hand, the stepsizes are updated in a cyclic way, where the Cauchy steps are combined with fixed step lengths; on the other hand, the iteration number in one cycle is adjusted adaptively according to the gradient residue. Theoretically, the new method terminates in 7 iterations for 3 dimensional convex quadratic function minimization problem; for general high dimensional problems, it converges R-linearly. Numerical results show the superior performance of the proposed method over the states of the art.
Stochastic Approximation and Reinforcement Learning
(Part II)
Organizer: Alec Koppel
Chair: Alec Koppel

Stephen Tu, UC Berkeley (joint work with Benjamin Recht)
The Gap Between Model-Based and Model-Free Methods on the Linear Quadratic Regulator: An Asymptotic Viewpoint

We study the sample complexity of popular model-based and model-free algorithms on the Linear Quadratic Regulator (LQR). For policy evaluation, we show that a simple model-based plugin method requires asymptotically less samples than least-squares temporal difference (LSTD) to reach similar performance; the sample complexity gap between the two methods is at least a factor of state dimension. For simple problem instances, nominal (certainty equivalence principle) control requires several factors of state and input dimension fewer samples than policy gradient method for similar performance.

Hoi-To Wai, CUHK (joint work with Belhal Karimi, Blažej Miasojedow, Eric Moulines)
Non-asymptotic Rate for Biased Stochastic Approximation Scheme

In this talk, we analyze a general stochastic approximation scheme to minimize a non-convex, smooth objective function. We consider an update procedure whose drift term depends on a state-dependent Markov chain and the mean field is not necessarily of gradient type, therefore it is a biased SA scheme. Importantly, we provide the first non-asymptotic convergence rate under such dynamical setting. We illustrate these settings with the policy-gradient method for average reward maximization, highlighting its tradeoff in performance between the bias and variance.
APP

Applications in Energy (Part I)
Chair: Bartosz Filipecki
Sauleh Siddiqui, Johns Hopkins University
Solving Problems with Equilibrium Constraints Applied to Energy Markets
We provide a method to obtain stationary points for mathematical and equilibrium problems with equilibrium constraints (MPECs and EPECs). The MPECs and EPECs considered have linear complementarity constraints at the lower level. Our approach is to express the MPEC and EPEC as a complementarity problem by decomposing the dual variables associated with the bilinear constraints, and using a nonlinear optimization over a polytope to find stationary points. We apply this method to the generic setting of energy markets that have operational and infrastructure decisions among many players.

Paolo Pisciella, NTNU-The Norwegian University of Science and Technology
A CGE model for analyzing the economic impacts of the Norwegian energy transition
We introduce a multi-regional dynamic Computable General Equilibrium model representing the Norwegian Economy with a particular focus on the energy system. The model is used to study the effects of macroeconomic policies aimed at decarbonizing the Norwegian economy, such as the reduction of the size of the oil industry, the introduction of carbon capture and storage in the gas industry as well as the introduction of a hydrogen industry and the transition of the transport sector to the usage of hydrogen and electricity to substitute conventional fossil fuels.

Bartosz Filipecki, TU Chemnitz (joint work with Christoph Helmberg)
Semidefinite programming approach to Optimal Power Flow with FACTS devices
Producing accurate and secure solutions to the Optimal Power Flow problem (OPF) becomes increasingly important due to rising demand and share of renewable energy sources. To this end, we consider an OPF model with additional decision variables associated with FACTS devices, such as phase-shifting transformers (PSTs) or thyristor-controlled series capacitors (TCSCs). We show, how a Lasserre hierarchy can be applied to this model. Finally, we provide results of numerical experiments on the resulting semidefinite programming (SDP) relaxation.

BIG

The Interface of Generalization and Optimization in Machine Learning (Part II)
Organizers: Benjamin Recht, Mahdi Soltanolkotabi
Chair: Benjamin Recht
Lorenzo Rosasco, Universita’ di Genova and MIT
Optimization for machine learning: from training to test error
The focus on optimization is a major trend in modern machine learning. In turn, a number of optimization solutions have been recently developed and motivated by machine learning applications. However, most optimization guarantees focus on the training error, ignoring the performance at test time which is the real goal in machine learning. In this talk, take steps to fill this gap in the context of least squares learning. We analyze the learning (test) performance of accelerated and stochastic gradient methods. In particular, we discuss the influence of different learning assumptions.

Mahdi Soltanolkotabi, University of Southern California
Towards demystifying over-parameterization in deep learning
Many neural nets are trained in a regime where the parameters of the model exceed the size of the training dataset. Due to their over-parameterized nature these models have the capacity to (over)fit any set of labels including pure noise. Despite this high fitting capacity, somewhat paradoxically, models trained via first-order methods continue to predict well on yet unseen test data. In this talk I will discuss some results aimed at demystifying such phenomena by demonstrating that gradient methods achieve (1) global optima, (2) are robust to corruption, and (3) generalize to new test data.

Mikhail Belkin, Ohio State University
Interpolation and its implications
Classical statistics teaches the dangers of overfitting. Yet, in modern practice, deep networks that interpolate the data (have near zero training loss) show excellent test performance. In this talk I will show how classical and modern models can be reconciled within a single “double descent” risk curve, which extends the usual U-shaped bias-variance trade-off curve beyond the point of interpolation. This understanding of model performance delineates the limits of classical analyses and opens new lines of inquiry into generalization and optimization properties of models.
Optimization Methods for Graph Analytics
Organizers: Kimon Fountoulakis, Di Wang
Chair: Kimon Fountoulakis

Nate Veldt, Cornell University
Metric-Constrained Linear Program Solvers for Graph Clustering Relaxations
We present a new approach for solving a class of convex relaxations for graph clustering objectives which involve triangle-inequality constraints. Many approximation algorithms for graph clustering rely on solving these metric-constrained optimization problems, but these are rarely implemented in practice due to extremely high memory requirements. We present a memory-efficient approach for solving these problems based on iterative projections methods. In practice we use our approach to address relaxations involving up to 2.9 trillion metric constraints.

Rasmus Kyng, ETH Zürich
Linear equations and optimization on graphs
Optimization on graphs is a powerful tool for understanding networks, for example we can use it to plan flows of good or data, or to understand network clusters. Second order methods are a powerful tool in optimization, but they require solving linear equations, making them slow. However, second order methods for graph optimization lead to structured linear equations, and we can use this structure to solve the linear equations much faster. We will see how to solve such linear equations, known as Laplacians, quickly both in theory and in practice.

Kimon Fountoulakis, University of Waterloo
Local Graph Clustering
Large-scale graphs consist of interesting small or medium-scale clusters. Existing approaches require touching the whole graph to find large clusters and they often fail to locate small and medium-scale clusters. In this talk we will analyze the performance of a local graph clustering approach, i.e., the \( \ell_1 \)-regularized PageRank model, on large-scale graphs with many small or medium-scale clusters. We will demonstrate average-case results for the \( \ell_1 \)-regularized PageRank model and we will show that proximal gradient descent finds the optimal number of non-zeros without touching the whole graph.

Hyperbolicity Cones and Spectrahedra (Part I)
Organizer: Markus Schweighofer
Chair: Markus Schweighofer

Daniel Plaumann, TU Dortmund University
Hyperbolicity cones and spectrahedra: Introduction
Spectrahedra are the domains of semidefinite programs, contained in the a priori larger class of hyperbolicity regions and hyperbolic programs. In recent years, a lot of research in optimization and real algebraic geometry has been devoted to understanding the relation between these concepts. We will give an overview, focussing on algebraic techniques and on duality.

Simone Naldi, Université de Limoges (joint work with Mario Kummer, Daniel Plaumann)
Spectrahedral representations of plane hyperbolic curves
We describe a new method for constructing a spectrahedral representation of the hyperbolicity region of a hyperbolic curve in the real projective plane. As a consequence, we show that if the curve is smooth and defined over the rational numbers, then there is a spectrahedral representation with rational matrices. This generalizes a classical construction for determinantal representations of plane curves due to Dixon and relies on the special properties of real hyperbolic curves that interlace the given curve.

Mario Kummer, TU Berlin (joint work with Rainer Sinn)
When is the conic hull of a curve a hyperbolicity cone?
Let \( C \) be a semi-algebraic curve in \( n \)-dimensional space. We will present obstructions and constructions for the conic hull of \( C \) to be a hyperbolicity cone. The tools we use are methods from complex and real algebraic geometry.
**Methods for Sparse Polynomial Optimization**  
Organizers: Venkat Chandrasekaran, Riley Murray  
Chair: Riley Murray  
Henning Seidler, TU Berlin (joint work with Helena Müller, Timo de Wolff)  
**Improved Lower Bounds for Global Polynomial Optimization**  
In this article, we describe a new way to obtain a candidate for the global minimum of a multivariate polynomial, based on its SONC decomposition. Furthermore, we present a branch-and-bound algorithm to improve the lower bounds obtained by SONC/SAGE. Applying this approach to thousands of test cases, we mostly obtain small duality gaps. In particular, we optimally solve the global minimization problem in about 75% of the investigated cases.

Venkat Chandrasekaran, California Institute of Technology (Caltech)  
**Generalized SAGE Certificates for Constrained Polynomial Optimization**  
We describe a generalization of the SAGE polynomial cone for obtaining bounds on constrained polynomial optimization problems. Our approach leverages the fact that the SAGE signomial cone conveniently and transparently blends with convex duality. This result is extended to polynomials by the notion of a “signomial representative.” Key properties of the original SAGE polynomial cone (e.g. sparsity preservation) are retained by this more general approach. We illustrate the utility of this methodology with a range of examples from the global polynomial optimization literature.

Jie Wang, Peking University (joint work with Haokun Li, Bican Xia)  
**Exploiting Term Sparsity in SOS Programming and Sparse Polynomial Optimization**  
We consider a new pattern of sparsity for SOS programming named cross sparsity patterns. A new sparse SOS algorithm is proposed by exploiting cross sparsity patterns, and is applied to unconstrained polynomial optimization problems. It is proved that the SOS decomposition obtained by the new algorithm is always a refinement of the block-diagonalization obtained by the sign-symmetry method. Various experiments show that the new algorithm dramatically saves the computational cost compared with existing tools and can handle some really huge polynomials.
Recent Advances of Nonsmooth Optimization  
Organizer: Guoyin Li  
Chair: Guoyin Li  
Boris Mordukhovich, Department of Mathematics, Wayne State University (joint work with Ebrahim Sarabi)  
Superlinear Convergence of SQP Methods in Conic Programming  
In this talk we present applications of second-order variational analysis and generalized differentiation to establish the superlinear convergence of SQP methods for general problems of conic programming. For the basic SQP method, the primal-dual superlinear convergence is derived under an appropriate second-order condition and some stability/calmness property, which automatically holds for nonlinear programs. For the quasi-Newton SQP methods, the primal superlinear convergence is obtained under the Dennis-More condition for constrained optimization.

Jingwei Liang, University of Cambridge (joint work with Clarice Poon)  
Geometry Based Acceleration for Non-smooth Optimization  
In this talk, we will present a geometry based adaptive acceleration framework for speeding up first-order methods when applied to non-smooth optimisation. Such a framework can render algorithms which are able to automatically adjust themselves to the underlying geometry of the optimisation problems and the structure of the first-order methods. State-of-the-art performances are obtained on various non-smooth optimisation problems and first-order methods, particularly the non-descent type methods.

Guoyin Li, University of New South Wales, Australia  
Splitting methods for convex and nonconvex feasibility problems  
Splitting methods is a class of important and widely used approach for solving feasibility problems. The behaviour of these methods has been reasonably understood in the convex setting. They have been further successfully applied to various nonconvex instances recently; while the theoretical justification in this latter setting is far from complete. We will examine global convergence of several popular splitting methods (including Douglas-Rachford and Peaceman Rachford splitting method) for general nonconvex nonsmooth optimization problems.

Recent Advances in First-Order Methods for Constrained Optimization and Related Problems (Part III)  
Organizers: Ion Necoara, Quoc Tran-Dinh  
Chair: Quoc Tran-Dinh  
Masaru Ito, Nihon University (joint work with Mituhiro Fukuda)  
Nearly optimal first-order method under Hölderian error bound: An adaptive proximal point approach  
We develop a first-order method for convex composite optimization problem under the Hölderian Error Bound (HEB) condition which is closely related to the Kurdyka-Lojasiewicz inequality and arises in many applications. The proposed method does not require the prior knowledge on the HEB condition, due to an adaptive proximal point approach. We prove the near optimality of the proposed method in view of the iteration complexity with respect to two kinds of approximation error: the objective function value and the norm of the (generalized) gradient.

Vien Van Mai, KTH Royal Institute of Technology (joint work with Mikael Johansson)  
Anderson Acceleration for Constrained Convex Optimization  
This paper introduces a novel technique for nonlinear acceleration of 1st-order methods for constrained convex optimization. Previous studies of nonlinear acceleration have only been able to provide convergence guarantees for unconstrained problems. We focus on Anderson acceleration of the projected gradient descent method, but our techniques can easily be extended to more sophisticated algorithms, such as mirror descent. We show that the convergence results for Anderson acceleration of smooth fixed-point iterations can be extended to the non-smooth case under certain technical conditions.

Tuomo Valkonen, Escuela Politécnica Nacional (joint work with Christian Clason, Stanislav Mazurenko)  
Primal-dual proximal splitting and generalized conjugation in non-smooth non-convex optimization  
We demonstrate that difficult non-convex non-smooth optimization problems, including Nash equilibrium problems and Potts segmentation, can be written using generalized conjugates of convex functionals. We then show through detailed convergence analysis that a conceptually straightforward extension of the primal-dual method of Chambolle and Pock is applicable to such problems. Under sufficient growth conditions we even demonstrate local linear convergence of the method. We illustrate these theoretical results numerically on the aforementioned example problems. (arXiv:1901.02746)
Derivative-Free Optimization Under Uncertainty (Part I)

Organizers: Ana Luisa Custodio, Sébastien Le Digabel, Margherita Porcelli, Francesco Rinaldi, Stefan Wild
Chair: Stefan Wild

Matt Menickelly, Argonne National Laboratory (joint work with Stefan Wild)

Formulations and Methods for Derivative-Free Optimization Under Uncertainty

In this talk, we will discuss progress made in the incorporation of derivative-free techniques into various paradigms of optimization under uncertainty. In particular, we will consider a novel outer approximations method for derivative-free robust optimization with particular application to so-called implementation error problems. We will also investigate the application of a particular derivative-free method for nonsmooth optimization (manifold sampling) to robust data-fitting of least trimmed estimators, as well to a feasibility restoration procedure for chance-constrained optimization.

Zaikun Zhang, Hong Kong Polytechnic University (joint work with Serge Gratton, Luis Nunes Vicente)

Trust region methods based on inexact gradient information

We discuss the behavior of trust-region method assuming the objective function is smooth yet the gradient information available is inaccurate. We show trust-region method is quite robust with respect to gradient inaccuracy. It converges even if the gradient is evaluated with only one correct significant digit and encounters random failures with a positive probability. The worst case complexity of the method is essentially the same as when the gradient evaluation is accurate.

Morteza Kimiaei, University of Vienna (joint work with Arnold Neumaier)

Efficient black box optimization with complexity guarantees

I’ll report on recent joint work with Morteza Kimiaei on derivative-free unconstrained optimization algorithms that both have high quality complexity guarantees for finding a local minimizer and perform highly competitive with state-of-the-art derivative-free solvers.

Recent Developments in Set Optimization (Part I)

Organizers: Akhtar A. Khan, Elisabeth Köbis, Christiane Tammer
Chair: Akhtar A. Khan

Niklas Hebestreit, Martin-Luther-University Halle-Wittenberg (joint work with Akhtar A. Khan, Elisabeth Köbis, Christiane Tammer)

Existence Theorems and Regularization Methods for Non-coercive Vector Variational and Vector Quasi-Variational Inequalities

In this talk, we present a novel existence result for vector variational inequalities. Since these problems are ill-posed in general, we propose a regularization technique for non-coercive problems which allows to derive existence statements even when the common coercivity conditions in the literature do not hold. For this purpose, we replace our original problem by a family of well-behaving problems and study their relationships. Moreover, we apply our results to generalized vector variational inequalities, multi-objective optimization problems and vector quasi-variational inequalities.

Baasansuren Jadamba, Rochester Institute of Technology

Optimization Based Approaches for the Inverse Problem of Identifying Tumors

This talk focuses on the inverse problem of parameter identification in an incompressible linear elasticity system. Optimization formulations for the inverse problem, a stable identification process using regularization, as well as optimality conditions, will be presented. Results of numerical simulations using synthetic data will be shown.

Ernest Quintana, Martin Luther University Halle-Wittenberg (joint work with Gemayqzel Bouza, Christiane Tammer, Anh Tuan Vu)

Fermat’s Rule for Set Optimization with Set Relations

In this talk, we consider Set Optimization problems with respect to the set approach. Specifically, we deal with the lower less and the upper less relations. Under convexity and Lipschitz properties of the set valued objective map, we derive corresponding properties for suitable scalarizing functionals. We then obtain upper estimates for Clarke’s subdifferential of these functionals. As a consequence of the scalarization approach, we show a Fermat’s rule for this class of problems. Ideas for a descent method are also discussed.
Accelerated Methods for Problems with Group Sparsity

Theoretical convergence results and numerical tests on various learning problems will be presented.

Comparison guarantees for practical second-order algorithms

We discuss methods for smooth unconstrained optimization that converge to approximate second-order necessary points with guaranteed complexity. These methods perform line searches along two different types of directions, approximate Newton directions and negative curvature directions for the Hessian. They require evaluations of functions, gradients, and second derivatives. We compare our method to the state-of-the-art approaches such as logistic regression.

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Katya Scheinberg, Cornell University
New effective nonconvex approximations to expected risk minimization

In this talk, we present novel approach to empirical risk minimization. We will show that in the case of linear predictors, the expected error and the expected ranking loss can be effectively approximated by smooth functions whose closed form expressions and those of their first (and second) order derivatives depend on the first and second moments of the data distribution, which can be precomputed. This results in a surprisingly effective approach to linear classification. We compare our method to the state-of-the-art approaches such as logistic regression.

Daniel Robinson, Lehigh University
Accelerated Methods for Problems with Group Sparsity

I discuss an optimization framework for solving problems with sparsity inducing regularization. Such regularizers include Lasso ($L^1$), group Lasso, and latent group Lasso. The framework computes iterates by optimizing over small dimensional subspaces, thus keeping the cost per iteration relatively low. Theoretical convergence results and numerical tests on various learning problems will be presented.

Clément Royer, University of Wisconsin-Madison (joint work with Michael O’Neill, Stephen Wright)
Complexity guarantees for practical second-order algorithms

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NON

Advances in Nonlinear Optimization With Applications (Part I)
Organizers: Yu-Hong Dai, Deren Han
Chair: Yu-Hong Dai
Zhi-Long Dong, Xi’an Jiaotong University (joint work with Yu-Hong Dai, Fengmin Xu)

Fast algorithms for large scale portfolio selection considering industries and investment styles

In this talk, we consider a large scale portfolio selection problem with and without a sparsity constraint. Neutral constraints on industries are included as well as investment styles. To develop fast algorithms for the use in the real financial market, we shall expose the special structure of the problem, whose Hessian is the summation of a diagonal matrix and a low rank modification. Complexity of the algorithms are analyzed. Extensive numerical experiments are conducted, which demonstrate the efficiency of the proposed algorithms compared with some state-of-the-art solvers.

Xinxin Li, Jilin University (joint work with Ting Kei Pong, Hao Sun, Henry Wolkowicz)

A Strictly Contractive Peaceman-Rachford Splitting Method for the Doubly Nonnegative Relaxation of the Minimum Cut Problem

The minimum cut problem, MC, consists in partitioning the set of nodes of a graph G into k subsets of given sizes in order to minimize the number of edges cut after removing the k-th set. Previous work on this topic uses eigenvalue, semidefinite programming, SDP, and doubly non-negative bounds, DNN, with the latter giving very good, but expensive, bounds. We propose a method based on the strictly contractive Peaceman-Rachford splitting method, which can obtain the DNN bound efficiently when used in combination with regularization from facial reduction, FR. The FR allows for a natural splitting of variables in order to apply inexpensive constraints and include redundant constraints. Numerical results on random data sets and vertex separator problems show efficiency and robustness of the proposed method.

Yu-Hong Dai, Chinese Academy of Sciences

Training GANs with Centripetal Acceleration

The training of generative adversarial networks suffers from cyclic behaviours. In this paper, from the simple intuition that the direction of centripetal acceleration of an object moving in uniform circular motion is toward the center of the circle, we present simultaneous and alternating centripetal acceleration methods to alleviate the cyclic behaviours. We conduct numerical simulations to test the effectiveness and efficiency compared with several other methods.
Eddie Wadbro, Umeå University (joint work with Bin Niu)
Multi-scale design of coated structures with periodic infill

We apply a multi-scale topology optimization method to design an infill structure, which has a solid outer shell, or coating, and a periodic infill pattern. Harmonic-mean based non-linear filters realize length scale control on both the overall macrostructure and the infill design on the microscale. The design optimization of the infill lattice is performed simultaneously with the optimization of the macrostructure, which also includes the coating.

Johannes Haubner, (joint work with Michael Ulbrich)
Numerical realization of shape optimization for unsteady fluid-structure interaction

We consider shape optimization for unsteady fluid-structure interaction problems that couple the Navier–Stokes equations with non-linear elasticity equations. We focus on the monolithic approach in the ALE framework. Shape optimization by the method of mappings approach yields an optimal control setting and therefore can be used to drive an optimization algorithm with adjoint based gradient computation. The continuous formulation of the problem and the numerical realization are discussed. Numerical results for our implementation, which builds on FEniCS, dolfin-adjoint and IPOPT are presented.

Kevin Sturm, TU Wien, Institut für Analysis and Scientific Computing (joint work with Peter Gangl)
Shape and Topology Optimization subject to 3D Nonlinear Magnetostatics – Part I: Sensitivity Analysis

We present shape and topological sensitivities for a 3D nonlinear magnetostatic model of an electric motor. In order to derive the sensitivities, we use a Lagrangian approach, which allows us to simplify the derivation under realistic physical assumptions. The topological derivative for this quasilinear problem involves the solution of two transmission problems on the unbounded domain for each point of evaluation.
Infinite-Dimensional Optimization of Nonlinear Systems (Part III)

Organizers: Fredi Tröltzsch, Irwin Yousept
Chair: Irwin Yousept

Matthias Heinckenschloss, Rice University
ADMM based preconditioners for time-dependent optimization problems

The Alternating Direction Method of Multipliers (ADMM) can be applied to time-decomposition formulations of optimal control problems to exploit parallelism. However, ADMM alone converges slowly and the subproblem solves, while done in parallel, are relatively expensive. Instead ADMM is used as a preconditioner. This approach inherits parallelism, but reduces the number of iterations and allows coarser subproblems solves.

Approach, theoretical and numerical results will be presented.

Moritz Ebeling-Rump, Weierstrass Institute for Applied Analysis and Stochastics (WIAS)
Topology Optimization subject to Additive Manufacturing Constraints

In Topology Optimization the goal is to find the ideal material distribution in a domain subject to external forces. The structure is optimal if it has the highest possible stiffness. A volume constraint ensures filigree structures, which are controlled via a Ginzburg-Landau term. During 3D Printing overhangs lead to instabilities, which have only been tackled unsatisfactorily. The novel idea is to incorporate an Additive Manufacturing Constraint into the phase field method. Stability during 3D Printing is assured, which solves a common additive manufacturing problem.

Dietmar Hömberg, Weierstrass Institute (joint work with Manuel Arenas, Robert Lasarzik)
Optimal pre-heating strategies for the flame cutting of steel plates

We consider a mathematical model for the flame cutting of steel. It is known that for high-strength steel grades this technology is prone to develop cracks at the cutting surface. To mitigate this effect new strategies for inductive pre-heating have been investigated within the European Industrial Doctorate project "MIMESIS – Mathematics and Materials Science for Steel Production and Manufacturing". In the talk we formulate a quasi-stationary optimal control problem for this problem, derive the optimality system and discuss preliminary numerical results.

Models and Algorithms for Dynamic Decision Making Under Uncertainty

Organizer: Man-Chung Yue
Chair: Man-Chung Yue

Kilian Schindler, EPFL (joint work with Daniel Kuhn, Napat Rujeerapaiboon, Wolfram Wiesemann)
A Day-Ahead Decision Rule Method for Multi-Market Multi-Reservoir Management

Peak/off-peak spreads in European electricity spot markets are eroding due to the nuclear phaseout and the recent growth in photovoltaic capacity. The reduced profitability of peak/off-peak arbitrage forces hydropower producers to participate in the reserve markets. We propose a two-layer stochastic programming framework for the optimal operation of a multi-reservoir hydropower plant which sells energy on both the spot and the reserve markets. The backbone of this approach is a combination of decomposition and decision rule techniques. Numerical experiments demonstrate its effectiveness.

Cagil Kocyigit, École polytechnique fédérale de Lausanne (joint work with Daniel Kuhn, Napat Rujeerapaiboon)
A Two-Layer Multi-Armed Bandit Approach for Online Multi-Item Pricing

The revenue-maximizing mechanism for selling $I$ items to a buyer with additive and independent values is unknown, but the better of separate item pricing and grand-bundle pricing extracts a constant fraction of the optimal revenue. We study an online version of this pricing problem, where the items are sold to (each of) $T$ identical and independent buyers arriving sequentially. We propose a two-layer multi-armed bandit algorithm that is reminiscent of the UCB algorithm and offers an asymptotic constant-factor approximation guarantee relative to the (unknown) best offline mechanism.

Daniel Kuhn, EPFL (joint work with Peyman Mohajerin Esfahani, Viet Anh Nguyen, Soroosh Shafieezadeh Abadeh)
On the Connection between Chebyshev and Wasserstein Ambiguity Sets in Distributionally Robust Optimization

Existing tractability results for distributionally robust optimization problems with Wasserstein ambiguity sets require the nominal distribution to be discrete. In this talk we derive tractable conservative approximations for problems with continuous nominal distributions by embedding Wasserstein ambiguity sets into larger Chebyshev ambiguity sets. We identify interesting situations in which these approximations are exact.
**Advances in Modeling Uncertainty via Budget-Constrained Uncertainty Sets in Robust and Distributionally Robust Optimization**

Organizer: Karthyek Murthy  
Chair: Karthyek Murthy

Bradley Sturt, Massachusetts Institute of Technology (joint work with Dimitris Bertsimas, Shimrit Shtern)

**A Data-Driven Approach for Multi-Stage Linear Optimization**

We propose a novel data-driven framework for multi-stage stochastic linear optimization where uncertainty is correlated across stages. The proposed framework optimizes decision rules by averaging over historical sample paths, and to avoid overfitting, each sample path is slightly perturbed by an adversary. We show that this new framework is asymptotically optimal (even if uncertainty is arbitrarily correlated across stages) and can be tractably approximated using techniques from robust optimization. We also present new results and limitations of possible Wasserstein alternatives.

Omar El Housni, Columbia University (joint work with Vineet Goyal)

**On the Optimality of Affine Policies for Budgeted Uncertainty Sets**

We study the performance of affine policies for two-stage adjustable robust optimization problem under budget of uncertainty sets. This problem is hard to approximate within a factor better than $\Omega(\log n/\log \log n)$ where $n$ is the number of decision variables. We show that surprisingly affine policies provide the optimal approximation for this class of uncertainty sets that matches the hardness of approximation; thereby, further confirming the power of affine policies. Our analysis also gives a significantly faster algorithm to compute near-optimal affine policies.

Rui Gao, University of Texas at Austin

**Wasserstein distributionally robust optimization and statistical learning**

In this talk, we consider a framework, called Wasserstein distributionally robust optimization, that aims to find a solution that hedges against a set of distributions that are close to some nominal distribution in Wasserstein metric. We will discuss the connection between this framework and regularization problems in statistical learning, and study its generalization error bound.
Stochastic Approximation and Reinforcement Learning (Part III)
Organizer: Alec Koppel
Chair: Alec Koppel
Andrzej Ruszczynski, Rutgers University (joint work with Saeed Ghadimi, Mengdi Wang)
A Single Time-scale Stochastic Approximation Method for Nested Stochastic Optimization

We propose a new stochastic approximation algorithm to find an approximate stationary point of a constrained nested stochastic optimization. The algorithm has two auxiliary averaged sequences (filters) which estimate the gradient of the composite objective function and the inner function value. By using a special Lyapunov function, we show the sample complexity of $O(1/\epsilon^2)$ for finding an $\epsilon$-approximate stationary point, thus outperforming all extant methods for nested stochastic approximation. We discuss applications to stochastic equilibria and learning in dynamical systems.

Vivak Patel, University of Wisconsin-Madison
Using Statistical Filters for Stochastic Optimization

Stochastic optimization methods fall into three general paradigms: the Monte-Carlo (MC)/Sample Average Approximation (SAA) approach, the Bayesian Optimization (BO) approach, and the Stochastic Approximation (SA) approach. While these paradigms enjoy strong theoretical support, these methods are often not always practical for well-documented reasons. In this talk, we introduce a fourth paradigm for solving such optimization problems using statistical filters.

Angeliki Kamoutsi, ETH Zürich (joint work with John Lygeros, Tobias Sutter)
Randomized methods and PAC bounds for data-driven inverse stochastic optimal control

This work studies discrete-time Markov decision processes (MDPs) with continuous state and action spaces and addresses the inverse problem of inferring a cost function from observed optimal behavior. We propose a method that avoids solving repeatedly the forward problem and at the same time provides probabilistic performance guarantees on the quality of the recovered solution. Our approach is based on the LP formulation of MDPs, complementary slackness optimality conditions, recent developments in convex randomized optimization and uniform finite sample bounds from statistical learning theory.
**Parallel Sessions Abstracts Tue.2 13:15–14:30**

**Tue.2 H 1012**

**Applications in Energy (Part II)**
Chair: Kristina Janzen
Felipe Atenas, University of Chile (joint work with Claudia Sagastizábal)

**Planning Energy Investment under Uncertainty**

We consider risk-averse stochastic programming models for the Generation and Expansion Planning problem for energy systems with here-and-now investment decisions and generation variables of recourse. The resulting problem is coupled both along scenarios and along power plants. To achieve decomposition, we combine the Progressive Hedging algorithm to deal with scenario separability, and an inexact proximal bundle method to handle separability for different power plants in each scenario subproblem. By suitably combining these approaches, a solution to the original problem is obtained.

Gopika Geetha Jayadev, University of Texas at Austin (joint work with Erhan Kutanoglu, Benjamin Leibowicz)

**U.S. Energy Infrastructure Of The Future: Electricity Capacity Planning Through 2050**

We develop a large-scale linear programming framework that optimizes long-term capacity investment decisions and operational schedules for energy supply and end-use technologies. Our methodology extends an energy-economic modeling framework that simultaneously optimizes generation investments, the locations of these investments as well as the underlying transmission network linking generation facilities to different demand regions. We study the evolution of technology mix and transmission infrastructure for the US electricity market over the span of 2016-2050.

Kristina Janzen, TU Darmstadt (joint work with Stefan Ulbrich)

**Cost-optimal design of decentralized energy networks with coupling of electricity, gas and heat networks including renewable energies**

The optimal design of energy networks is a decisive prerequisite for the realization of future decentralized supply structures including renewable energy. The different energy carriers must be planned simultaneously with regard to generation and load conditions. Our aim is to minimize the costs of the various acquisition opportunities, while satisfying the heat and power demands. The design decisions and the detailed description of the flow dynamics within each network result in a mixed integer nonconvex optimization problem. Furthermore numerical results for different instances are presented.

**Tue.2 H 2013**

**Optimization for Data Science (Part II)**
Organizers: Ying Cui, Jong-Shi Pang
Chair: Jong-Shi Pang

Kim-Chuan Toh, National University of Singapore (joint work with Xudong Li, Defeng Sun)

**An asymptotically superlinear convergent semismooth Newton augmented Lagrangian method for LP**

Powerful interior-point methods (IPM) based commercial solvers have been hugely successful in solving large-scale linear programming problems. Unfortunately, the natural remedy, although can avoid the explicit computation of the coefficient matrix and its factorization, are not practically viable due to the inherent extreme ill-conditioning of the large scale normal equation arising in each interior-point iteration. To provide a better alternative choice for solving large scale LPs with dense data, we propose a semismooth Newton based inexact proximal augmented Lagrangian method.

Zhengling Qi, The George Washington University (joint work with Yufeng Liu, Jong-Shi Pang)

**Learning Optimal Individualized Decision Rules with Risk Control**

With the emergence of precision medicine, estimation of optimal individualized decision rules (IDRs) has attracted tremendous attentions in many scientific areas. Motivated by complex decision making procedures and the popular conditional value at risk, we propose a robust criterion to evaluate IDRs to control the lower tails of each subject’s outcome. The resulting optimal IDRs are robust in controlling adverse events. The related nonconvex optimization algorithm will be discussed. Finally, I will present some optimization challenges about learning optimal IDRs in the observational studies.

Meisam Razaviyayn, University of Southern California

**First and Second Order Nash Equilibria of Non-Convex Min-Max Games: Existence and Computation**

Recent applications that arise in machine learning have surged significant interest in solving min-max saddle point games. While this problem has been extensively studied in the convex-concave regime, our understanding of non-convex case is very limited. In this talk, we discuss existence and computation of first and second order Nash Equilibria of such games in the non-convex regime. Then, we see applications of our theory in training Generative Adversarial Networks.
Recent Advances in Algorithms for Large-Scale Structured Nonsmooth Optimization (Part I)
Organizer: Xudong Li
Chair: Xudong Li
Yangjing Zhang, National University of Singapore (joint work with Defeng Sun, Kim-Chuan Toh, Ning Zhang)

An Efficient Linearly Convergent Regularized Proximal Point Algorithm for Fused Multiple Graphical Lasso Problems

This paper focuses on the fused multiple graphical Lasso model. For solving the model, we develop an efficient regularized proximal point algorithm, where the subproblem in each iteration of the algorithm is solved by a superlinearly convergent semismooth Newton method. To implement the method, we derive an explicit expression for the generalized Jacobian of the proximal mapping of the fused multiple graphical Lasso regularizer. Our approach has exploited the underlying second order information. The efficiency and robustness of our proposed algorithm are shown by numerical experiments.

Xin-Yee Lam, National University of Singapore (joint work with Defeng Sun, Kim-Chuan Toh)

A semi-proximal augmented Lagrangian based decomposition method for primal block angular convex composite quadratic conic programming problems

We propose a semi-proximal augmented Lagrangian based decomposition method for convex composite quadratic conic programming problems with primal block angular structures. Using our algorithmic framework, we are able to naturally derive several well-known augmented Lagrangian based decomposition methods for stochastic programming such as the diagonal quadratic approximation method of Mulvey and Ruszczynski. We also propose a semi-proximal symmetric Gauss-Seidel based alternating direction method of multipliers for solving the corresponding dual problem.

Lei Yang, National University of Singapore (joint work with Jia Li, Defeng Sun, Kim-Chuan Toh)

A Fast Globally Linearly Convergent Algorithm for the Computation of Wasserstein Barycenters

In this talk, we consider the problem of computing a Wasserstein barycenter for a set of discrete distributions with finite supports. When the supports in the barycenter are prespecified, this problem is essentially a large-scale linear programming (LP). To handle this LP, we derive its dual problem and adapt a symmetric Gauss-Seidel based ADMM. The global linear convergence rate is also given without any condition. All subproblems involved can be solved exactly and efficiently. Numerical experiments show that our method is more efficient than two existing representative methods and Gurobi.
Signomial Optimization and Log-Log Convexity
Organizers: Venkat Chandrasekaran, Riley Murray
Chair: Venkat Chandrasekaran

Berk Ozturk, Massachusetts Institute of Technology
Methods and applications for signomial programming in engineering design

In this talk we motivate further research in signomial programming (SP) for the solution of conceptual engineering design problems. We use examples from aerospace engineering, from aircraft design to network design and control, to demonstrate the modeling capabilities and solution quality of SPs, and identify areas for future work. We introduce GPkit, a toolkit that provides abstractions, modeling tools and solution methods to use SPs to explore complex tradespaces. Additionally, we present methods to solve SPs under uncertainty, called robust SPs, to trade off risk and performance.

Riley Murray, Caltech (joint work with Venkat Chandrasekaran, Adam Wierman)
Solving Signomial Programs with SAGE Certificates and Partial Dualization

We show how SAGE nonnegativity certificates are compatible with a technique known as partial dualization, whereby computationally tractable constraints are incorporated into a dual problem without being moved to the Lagrangian. We consider the resulting “generalized SAGE cone” as it pertains to signomial programming (SP). Matters such as coordinate system invariance, sparsity preservation, and error bounds are addressed. Our provided implementation shows that this approach can solve many SPs from the literature to global optimality, without resorting to cutting planes, or branch-and-bound.

Akshay Agrawal, Stanford University (joint work with Stephen Boyd, Steven Diamond)
Log-Log Convexity

We introduce log-log convex programs (LLCPs): optimization problems with positive variables that become convex when the variables, objective functions, and constraint functions are replaced with their logs. LLCPs strictly generalize geometric programming, and include interesting problems involving non-negative matrices, and integral inequalities. We discuss the basic calculus for this class of functions, and show when a given LLCP can be cast to a format that is acceptable by modern conic solvers. Illustrative examples are provided with CVXPY’s new “disciplined geometric programming” feature.
Disjunctive Structures in Mathematical Programming
Organizer: Matúš Benko
Chair: Matúš Benko
Patrick Mehlitz, Brandenburgische Technische Universität Cottbus-Senftenberg (joint work with Christian Kanzow, Daniel Steck)
Switching-constrained mathematical programs: Applications, optimality conditions, and a relaxation method

Mathematical programs with switching constraints are characterized by restrictions requiring the product of two functions to be zero. Switching structures appear frequently in the context of optimal control and can be used to reformulate semi-continuity conditions on variables or logical or-constraints. In this talk, these applications of switching-constrained optimization are highlighted. Moreover, first- and second-order optimality conditions for this problem class will be investigated. Finally, a relaxation method is suggested and results of computational experiments are presented.

Matúš Benko, Johannes Kepler University Linz
New verifiable sufficient conditions for metric subregularity of constraint systems with application to disjunctive programs and pseudo-normality

In this talk, we present a directional version of pseudo-normality for very general constraints. This condition implies the prominent error bound property/MSCQ. Moreover, it is naturally milder than its standard (non-directional) counterpart, in particular GMFCQ, as well as the directional FOSCMS. We apply the obtained results to the disjunctive programs, where pseudo-normality assumes a simplified form, resulting in verifiable point-based sufficient conditions for this property and hence also for MSCQ. In particular, we recover SOSCMS and the Robinson’s result on polyhedral multifunctions.

Michal Červinka, Czech Academy of Sciences (joint work with Matúš Benko, Tim Hoheisel)
Ortho-disjunctive programs: constraint qualifications and stationarity conditions

We introduce a class of ortho-disjunctive programs (ODPs), which includes MPCCs, MPVCs and several further recently introduced examples of disjunctive programs. We present a tailored directional version of quasi-normality introduced for general constraint systems which implies error bound property/metric subregularity CQ. Thus, we effectively recover or improve some previously established results. Additionally, we introduce tailored OD-versions of stationarity concepts and strong CQs (LICQ, MFCQ etc) and provide a unifying framework for further results on stationarity conditions for all ODPs.

Recent Advances in First-Order Methods for Constrained Optimization and Related Problems (Part IV)
Organizers: Ion Necoara, Quoc Tran-Dinh
Chair: Ion Necoara
Stephen Becker, University of Colorado Boulder (joint work with Alireza Doostan, David Kozak, Luis Tenorio)
Stochastic Subspace Descent

Some optimization settings, such as certain types of PDE-optimization, do not give easy access to the gradient of the objective function. We analyze a simple 0th-order derivative-free stochastic method that computes the directional derivative in a stochastically chosen subspace, and also develop and analyze a variance-reduced version. Under an error bound condition we show convergence, and under strong convexity we show almost-sure convergence of the variables. Numerical experiments on problems from Gaussian Processes and PDE shape-optimization show good results even on non-convex problems.

Qihang Lin, University of Iowa (joint work with Mingrui Liu, Hassan Rafique, Tianbao Yang)
Solving Weakly-Convex-Weakly-Concave Saddle-Point Problems as Successive Strongly Monotone Variational Inequalities

In this paper, we consider first-order algorithms for solving a class of non-convex non-concave min-max problems, whose objective function is weakly convex (resp. weakly concave) in the minimization (resp. maximization). It has many important applications in machine learning such as training Generative Adversarial Networks. Our method is an inexact proximal point method which solves the weakly monotone variational inequality corresponding to the min-max problem. Our algorithm finds a nearly ϵ-stationary point of the min-max problem with a provable iteration complexity.

Phan Tu Vuong, University of Vienna
The Boosted DC Algorithm for nonsmooth functions

The Boosted Difference of Convex functions Algorithm (BDCA) was recently proposed for minimizing smooth DC functions. BDCA accelerates the convergence of the classical DCA thanks to an additional line search step. The purpose of this paper is twofold: to show that this scheme can be generalized and successfully applied to certain types of nonsmooth DC functions, and to show that there is complete freedom in the choice of the trial step size for the line search. We prove that any limit point of BDCA sequence is a critical point of the problem. The convergent rate is obtained under KL property.
Recent Advances in Derivative-Free Optimization (Part II)
Organizers: Ana Luisa Custodio, Sébastien Le Digabel, Margherita Porcelli, Francesco Rinaldi, Stefan Wild
Chair: Sébastien Le Digabel
Clément Royer, University of Wisconsin-Madison (joint work with Serge Gratton, Luis Nunes Vicente)
A decoupled first/second-order steps technique and its application to nonconvex derivative-free optimization

In this talk, we describe a technique that separately computes first- and second-order steps, in order to better relate each step to its corresponding stationarity criterion. Such an approach can lead to larger steps and decreases in the objective, which positively impacts both the complexity analysis and the practical behavior. Although its applicability is wider, we present our concept within a trust-region framework without derivatives. This allows us to highlight interesting connections between our decoupling paradigm and the criticality steps used to guarantee convergence of such methods.

Francesco Rinaldi, Università di Padova (joint work with Andrea Cristofari)
Derivative-free optimization for structured problems

In this talk, we describe a new approach for minimizing a black-box function over a structured convex set. We analyze the theoretical properties of the method. Furthermore, we report some numerical results showing that the algorithm scales up well when the dimensions of the problems get large.

Jan Feiling, Porsche AG (joint work with Christian Ebenbauer)
Multi-Variable Derivative-Free Optimization Based on Non-Commutative Maps

A novel class of derivative-free optimization algorithms based on non-commutative maps for multi-variable optimization problems is presented. The main idea is to utilize certain non-commutative maps in order to approximate the gradient of the objective function. We show how these maps can be constructed by so-called generating functions incorporated with either single- or two-point objective evaluation polices and how periodic exploration sequences can be designed to approximate gradients. Finally, we analyze the convergence of the proposed class of algorithms and present benchmarking results.

Peiran Yu, The Hong Kong Polytechnic University (joint work with Guoyin Li, Ting Kei Pong)
Deducing Kurdyka-Łojasiewicz exponent via inf-projection

KL exponent plays an important role in inducing the local convergence rates of many first-order methods. These methods are applied to solve large-scale optimization problems encountered in fields like compressed sensing and machine learning. However, KL exponent is hard to estimate explicitly and few results are known. In this talk, we study when inf-projection preserves KL exponent. This enables us to deduce the KL exponent of some SDP-representable functions and some nonconvex models such as least squares with rank constraint.

Rujun Jiang, Fudan University (joint work with Duan Li)
Novel Reformulations and Efficient Algorithms for the Generalized Trust Region Subproblem

We present a new solution framework to solve the generalized trust region subproblem (GTRS) of minimizing a quadratic objective over a quadratic constraint. More specifically, we derive a convex quadratic reformulation of minimizing the maximum of the two convex quadratic functions for the case under our investigation. We develop algorithms corresponding to two different line search rules. We prove for both algorithms their global sublinear convergence rates. The first algorithm admits a local linear convergence rate by estimating the Kurdyka-Łojasiewicz exponent at any optimal solution.

Tran Nghia, Oakland University
Metric subregularity of the subdifferentials with applications to well-posedness and linear convergence

Metric subregularity of subdifferentials is an important property to study linear convergence of many first-order methods for solving convex and nonconvex optimization problems. This talk reviews recent achievements and provides some new developments in this direction. Moreover, we will show how metric subregularity of subdifferentials could play significant roles in investigating well-posedness of optimization problems via second-order variational analysis. Applications to some structured optimization problems such as $\ell_1$, nuclear normed, Poisson regularized problems will be discussed.
Recent Developments in Set Optimization (Part II)
Organizers: Akhtar A. Khan, Elisabeth Köbis, Christiane Tammer
Chair: Elisabeth Köbis
Christiane Tammer, Martin-Luther-University of Halle-Wittenberg (joint work with Truong Q. Bao)
Subdifferentials and SNC property of scalarization functionals with uniform level sets and applications

In this talk, we are dealing with necessary conditions for minimal solutions of constrained and unconstrained optimization problems with respect to general domination sets by using well-known nonlinear scalarization functionals with uniform level sets. The primary objective of this work is to establish revised formulas for basic and singular subdifferentials of the nonlinear scalarization functionals. The second objective is to propose a new way to scalarize a set-valued optimization problem.

Tamaki Tanaka, Niigata University
Sublinear-like scalarization scheme for sets and its applications

This paper is concerned with a certain historical background on set relations and scalarization methods for sets. Based on a basic idea of sublinear scalarization in vector optimization, we introduce a scalarization scheme for sets in a real vector space such that each scalarizing function has an order-monotone property for set relation and inherited properties on cone-convexity and cone-continuity. Accordingly, we show a certain application for this idea to establish some kinds of set-valued inequalities. Moreover, we shall mention another application to fuzzy theory.

Marius Durea, Alexandru Ioan Cuza University of Iasi (joint work with Radu Strugariu)
Barrier methods for optimization problems with convex constraint

In this talk, we consider some barrier methods for vector optimization problems with geometric and generalized inequality constraints. Firstly, we investigate some constraint qualification conditions and we compare them to the corresponding ones in literature, and then we introduce some barrier functions and we prove several of their basic properties in fairly general situations. Finally, we derive convergence results of the associated barrier method, and to this aim we restrict ourselves to convex case and finite dimensional setting.
Nonlinear and Stochastic Optimization (Part IV)
Organizers: Albert Berahas, Geovani Grapiglia
Chair: Albert Berahas

Michael Overton, New York University (joint work with Azam Asl)
Behavior of L-BFGS on Nonsmooth Problems in Theory and in Practice

When applied to minimize nonsmooth functions, the "full" BFGS method works remarkably well, typically converging linearly to Clarke stationary values, with no counterexamples to this behavior known in the convex case, though its theoretical behavior is not yet well understood. In contrast, limited-memory BFGS may converge to non-stationary values, even on a simple convex function, but this seems to be rare. We summarize our experience with L-BFGS in both theory and practice.

Anton Rodomanov, UCLouvain
Greedy Quasi-Newton Method with Explicit Superlinear Convergence

We propose a new quasi-Newton method for unconstrained minimization of smooth functions. Our method is based on the famous BFGS scheme but it uses a greedily selected coordinate vector for updating the Hessian approximation at each iteration instead of the previous search direction. We prove that the proposed method has local superlinear convergence and establish a precise bound for its rate. To our knowledge, this result is the first explicit non-asymptotic rate of superlinear convergence for quasi-Newton methods. All our conclusions are confirmed by numerical experiments.

Albert Berahas, Lehigh University (joint work with Frank E. Curtis, Baoyu Zhou)
Limited-Memory BFGS with Displacement Aggregation

We present a displacement aggregation strategy for the curvature pairs stored in a limited-memory BFGS method such that the resulting (inverse) Hessian approximations are equal to those derived from a full-memory BFGS method. Using said strategy, an algorithm employing the limited-memory method can achieve the same convergence properties as when full-memory Hessian approximations are employed. We illustrate the performance of an LBFGS algorithm that employs the aggregation strategy.

Interplay of Linear Algebra and Optimization (Part I)
Organizers: Robert Luce, Yuji Nakatsukasa
Chair: Yuji Nakatsukasa

Henry Wolkowicz, University of Waterloo
Completions for Special Classes of Matrices: Euclidean Distance, Low Rank, sparse, and Toeplitz

We consider the matrix completion problem for special classes of matrices. This includes EDM, low rank, robust PCA, and Toeplitz. We consider both the exact and noisy cases. We include theoretical results as well as efficient numerical techniques. Our tools are semidefinite programming, facial reduction, and trust region subproblems.

Dominik Garmatter, TU Chemnitz (joint work with Margherita Porcelli, Francesco Rinaldi, Martin Stoll)
An Improved Penalty Algorithm for mixed integer and PDE constrained optimization problems

We present a novel Improved Penalty Algorithm (IPA) designed for large-scale problems. The Algorithm utilizes the framework of an existing Exact Penalty Algorithm to correctly increase the penalization throughout its iteration, while, in each iteration, it tries to find an iterate that decreases the current objective function value. Such a decrease can be achieved via a problem-specific perturbation strategy. Based on a numerical toy problem, we will compare the IPA to existing penalization strategies, simple rounding schemes, and a Branch and Bound routine of Cplex.

Robert Luce, Gurobi
Regularization of binary quadratic programming problems

We consider the solution of binary quadratic programming (BQP) problems in the standard branch-and-bound framework. The idempotency of binary variables allows for regularization of the objective function without altering the set of optimal solutions. Such regularization can serve two purposes. First, it can be applied to ensure the convexity of the continuous relaxation, and secondly to strengthen the root relaxation of (convex) BQP problems. Computing such a regularization can be achieved by the solution of an auxiliary SDP, for which we compare different computational techniques.
Advances in Interior Point Methods
Organizer: Coralia Cartis
Chair: Margherita Porcelli
Renke Kuhlmann, University of Wisconsin-Madison
Learning to Steer Nonlinear Interior-Point Methods

Interior-point methods handle nonlinear programs by sequentially solving barrier subprograms with a decreasing sequence of barrier parameters. In practice, adaptive barrier updates have been shown to lead to superior performance. In this talk we interpret the adaptive barrier update as a reinforcement learning task and train a deep Q-learning to solve it. Numerical results based on an implementation within the nonlinear programming solver WORHP show that the agent successfully learns to steer the barrier parameter and additionally improves WORHP’s performance on the CUTEst test set.

Andre Tits, University of Maryland College Park (joint work with M. Paul Laiu)
Constraint Reduction in Infeasible-Start Interior-Point for Imbalanced Large Sparse Convex Quadratic Optimization

A framework for accommodating infeasible starts, given a user-supplied feasible-start “base” iteration for CQP, is proposed and analyzed. Requirements to be satisfied by the base iteration allow for inexact computation of search directions. The framework is applied to a recent feasible-start “constraint-reduced” MPC algorithm, involving a small “working set” of constraints, updated at each iteration. In early numerical tests with Matlab/CVX, a speedup of up to 10x over SDPT3/SeDuMi was observed, on both randomly generated and data fitting problems with many more constraints than variables.

Margherita Porcelli, University of Bologna (joint work with Stefania Bellavia, Jacek Gondzio)
A new interior point approach for low-rank semidefinite programs

We address the solution of semidefinite programming (SDP) problems in which the primal variable $X$ is expected to be low-rank at optimality, a common situation in relaxations of combinatorial optimization (maximum cut) or in matrix completion. SDPs are solved efficiently using interior-point methods (IPMs), but such algorithms typically converge to a maximum-rank solution. We propose a new IPM approach which works with a low-rank $X$ and gradually reveals the optimal (minimum) rank. Preliminary results show that using alternating directions improves the efficiency of the linear algebra.
On the volume formulation for the shape Hessian

The shape Hessian is usually formulated as a boundary operator, which is even symmetric in the Riemannian variant. However, it might be advantageous to use its volume formulation for analytical and also numerical reasons. This has the drawback of a severe lack of definiteness. This talk discusses an approach to deal with the quite large null space of the volumic shape Hessian within an overall shape optimization algorithm utilizing second order information.

Kathrin Welker, Helmut-Schmidt-Universität Hamburg
Computational investigations of shape optimization problems constrained by variational inequalities of the first kind

In this talk, we consider shape optimization problems constrained by variational inequalities (VI) in shape spaces. These problems are in particular highly challenging because of two main reasons: First, one needs to operate in inherently non-linear, non-convex and infinite-dimensional spaces. Second, one cannot expect the existence of the shape derivative, which implies that the adjoint state cannot be introduced and, thus, the problem cannot be solved directly without any regularization techniques. We investigate computationally a VI constrained shape optimization problem of the first kind.

Peter Gangl, Graz University of Technology (joint work with Kevin Sturm)
Shape and Topology Optimization subject to 3D Nonlinear Magnetostatics – Part II: Numerics

We present the application of design optimization algorithms based on the shape and topological derivative for 3D nonlinear magnetostatics to the optimization of an electric motor. The topological derivative for this quasilinear problem involves the solution of two transmission problems on the unbounded domain for each point of evaluation. We present a way to efficiently evaluate this quantity on the whole design domain. Moreover, we present optimization results obtained by a level set algorithm which is based on the topological derivative, as well as shape optimization results.

 Constantin Christof, Technical University of Munich (joint work with Boris Vexler)
New Regularity Results for a Class of Parabolic Optimal Control Problems with Pointwise State Constraints

This talk is concerned with parabolic optimal control problems that involve pointwise state constraints. We show that, if the bound in the state constraint satisfies a suitable compatibility condition, then optimal controls enjoy $L^\infty(L^2)$, $L^2(H^1)$ and (with a suitable Banach space $Y$) $BV(Y^*)$-regularity. In contrast to classical approaches, our analysis requires neither a Slater point nor additional control constraints nor assumptions on the spatial dimension nor smoothness of the objective function.

Axel Kröner, Humboldt-Universität zu Berlin (joint work with Maria Soledad Aronna, Frederic Bonnans)
Optimal control of a semilinear heat equation with bilinear control-state terms subject to state and control constraints

In this talk we consider an optimal control problem governed by a semilinear heat equation with bilinear control-state terms and subject to control and state constraints. The state constraints are of integral-type, the integral being with respect to the space variable. The control is multidimensional. The cost functional is of a tracking-type and contains a linear term in the control variables. We derive second order necessary and sufficient conditions relying on the Goh transformation, the concept of alternative costates, and quasi-radial critical directions.
Optimal Control and Dynamical Systems (Part II)
Organizers: Cristopher Hermosilla, Michele Palladino
Chair: Cristopher Hermosilla

Nathalie T. Khalil, Universidade do Porto Faculdade de Engenharia
Numerical solutions for regular state-constrained optimal control problems via an indirect approach

We present an indirect method to solve state-constrained optimal control problems. The presented method is based on the maximum principle in Gamkrelidze’s form. We focus on a class of problems having a certain regularity condition, which will ensure the continuity of the measure Lagrange multiplier associated with the state constraint. This property of the multiplier will play a key role in solving the two-point boundary value problem resulting from the maximum principle. Several illustrative applications to time optimal control problems are considered.

Luis Briceño-Arias, Universidad Tecnica Federico Santa Maria (joint work with Dante Kalise, Francisco Silva-Alvarez)
Mean Field Games with local couplings: numerical approaches

We address the numerical approximation of Mean Field Games with local couplings. For power-like Hamiltonians, we consider both unconstrained and constrained stationary systems with density constraints in order to model hard congestion effects. For finite difference discretizations of the Mean Field Game system, we follow a variational approach. We prove that the aforementioned schemes can be obtained as the optimality system of suitably defined optimization problems. Next, we study and compare several efficiently convergent first-order methods.

Daria Ghilli, University of Padua
Inverse problem of crack identification by shape optimal control

We study an inverse problem of crack identification formulated as an optimal control problem with a PDE constraint describing the anti-plane equilibrium of an elastic body with a stress-free crack under the action of a traction force. The optimal control problem is formulated by minimizing the $L^2$-distance between the displacement and the observation and then is solved by shape optimization techniques via a Langrangian approach. An algorithm is proposed based on a gradient step procedure and several numerical experiments are carried out to show its performance in diverse situations.

Advances in Data-Driven and Robust Optimization
Organizer: Velibor Misic
Chair: Velibor Misic

Vishal Gupta, USC Marshall School of Business (joint work with Nathan Kallus)
Data-Pooling in Stochastic Optimization

Applications often involve solving thousands of potentially unrelated stochastic optimization problems, each with limited data. Intuition suggests decoupling and solving these problems separately. We propose a novel data-pooling algorithm that combines problems and outperforms decoupling, even if data are independent. Our method does not require strong distributional assumptions and applies to constrained, possibly non-convex problems. As the number of problems grows large, our method learns the optimal amount to pool, even if the expected amount of data per problem is bounded and small.

Andrew Li, Carnegie Mellon University (joint work with Jackie Baek, Vivek Farias, Deeksha Sinha)
Toward a Genomic Liquid Biopsy

The cost of DNA sequencing has recently fallen to the point that an affordable blood test for early-stage cancer is nearly feasible. What remains is a massive variable selection problem. We propose an efficient algorithm, based on a decomposition at the gene level, that scales to full genomic sequences across thousands of patients. We contrast our selected variables against DNA panels from two recent, high-profile studies and demonstrate that our own panels achieve significantly higher sensitivities at the same cost, along with accurate discrimination between cancer types for the first time.

Velibor Misic, UCLA (joint work with Yi-Chun Chen)
Decision Forests: A Nonparametric Model for Irrational Choice

Most choice models assume that customers obey the weak rationality property, but increasing empirical evidence suggests that customers. We propose a new model, the decision forest model, which models customers via a distribution over trees. We characterize its representational power, study the model complexity needed to fit a data set and present a practical estimation algorithm based on randomization and linear optimization. We show using real transaction data that this approach yields improvements in predictive accuracy over mainstream models when customers behave irrationally.
Parallel Sessions Abstracts  Tue.2  13:15–14:30  83

**Tue.2 H 3012**

**ROB** Applications of Data-Driven Robust Design  
Organizer: Man-Chung Yue  
Chair: Man-Chung Yue  
Ihsan Yanikoglu, Ozyegin University

**Robust Parameter Design and Optimization for Injection Molding**

The aim of this study is to propose an optimization methodology to determine the values of the key decision parameters of an injection molding machine such that the desired quality criteria are met in a shorter production cycle time. The proposed robust parameter design and optimization approach utilizes the Taguchi methodology to find critical parameters for use in the optimization, and it utilizes robust optimization to immunize the obtained solution against estimation errors. The ‘optimal’ designs found by the robust parameter design and optimization approach are implemented in real-life.

Shubhechyya Ghosal, Imperial College Business School (joint work with Wolfram Wiesemann)

**The Distributionally Robust Chance Constrained Vehicle Routing Problem**

We study a variant of the capacitated vehicle routing problem (CVRP), where demands are modelled as a random vector with ambiguous distribution. We require the delivery schedule to be feasible with a probability of at least $1 - \epsilon$, where $\epsilon$ is the risk tolerance of the decision maker. We argue that the emerging distributionally robust CVRP can be solved efficiently with standard branch-and-cut algorithms whenever the ambiguity set satisfies a subadditivity condition. We derive efficient cut generation schemes for some widely used moment ambiguity sets, and obtain favourable numerical results.

Marek Petrik, University of New Hampshire (joint work with Chin Pang Ho, Wolfram Wiesemann)

**Robust Bellman Updates in Log-Linear Time**

Robust Markov decision processes (RMDPs) are a promising framework for reliable data-driven dynamic decision-making. Solving even medium-sized problems, however, can be quite challenging. Rectangular RMDPs can be solved in polynomial time using linear programming but the computational complexity is cubic in the number of states. This makes it computationally prohibitive to solve problems of even moderate size. We describe new methods that can compute Bellman updates in quasi-linear time for common types of rectangular ambiguity sets using novel bisection and homotopy techniques.

**Tue.2 H 3007**

**SPA** Nonlinear Optimization Algorithms and Applications in Data Analysis (Part II)  
Organizers: Xin Liu, Cong Sun  
Chair: Cong Sun  
Xin Liu, Academy of Mathematics and Systems Science, Chinese Academy of Sciences

**Multipliers Correction Methods for Optimization Problems with Orthogonality Constraints**

We establish an algorithm framework for solving optimization problems with orthogonality constraints. The new framework combines a function value reduction step with a multiplier correction step. The multiplier correction step minimizes the objective function in the range space of the current iterate. We also propose three algorithms which are called gradient reflection (GR), gradient projection (GP) and columnwise block coordinate descent (CBCD), respectively. Preliminary numerical experiments demonstrate that our new framework is of great potential.

Xiaoyu Wang, Academy of Mathematics and Systems Science, Chinese Academy of Sciences (joint work with Yaxiang Yuan)

**Stochastic Trust Region Methods with Trust Region Radius Depending on Probabilistic Models**

We present a stochastic trust region scheme in which the trust region radius is directly related to the probabilistic models. Especially, we show a specific algorithm STRME in which the trust region radius is selected as depending linearly on model gradient. Moreover, the complexity of STRME in nonconvex, convex and strongly convex settings has all been analyzed. Finally, some numerical experiments are carried out to reveal the benefits of the proposed methods compared to the existing stochastic trust region methods and other relevant stochastic gradient methods.

Yanfei Wang, Chinese Academy of Sciences

**Regularization and optimization methods for micro pore structure analysis of shale based on neural networks with deep learning**

With the CT image segmentation, the images of shale micropores can be obtained, especially the pore type, shape, size, spatial distribution and connectivity. In this work, based on the reconstructed synchrotron radiation X-ray shale CT data, we develop a neural network image segmentation technique with deep learning based on multi-energy CT image data in order to obtain the 3D structural characteristics and spatial distribution of shale. Since it is an ill-posed inverse problem, regularization and optimization issues are discussed.
Large-Scale Stochastic First-Order Optimization (Part I)
Organizers: Filip Hanzely, Samuel Horvath
Chair: Samuel Horvath
Zheng Qu, The University of Hong Kong (joint work with Fei Li)
Adaptive primal-dual coordinate descent methods for non-smooth composite minimization with linear operator

We propose and analyse an inexact augmented Lagrangian (I-AL) algorithm for solving large-scale composite, non-smooth and constrained convex optimization problems. Each subproblem is solved inexactly with self-adaptive stopping criteria, without requiring the target accuracy a priori as in many existing variants of I-AL methods. In addition, each inner problem is solved by applying accelerated coordinate descent method, making the algorithm more scalable when the problem dimension is high.

Pavel Dvurechensky, Weierstrass Institute for Applied Analysis and Stochastics (WIAS) (joint work with Alexander Gasnikov, Alexander Tiurin)
A Unifying Framework for Accelerated Randomized Optimization Methods

We consider smooth convex optimization problems with simple constraints and inexactness in the oracle information such as value, partial or directional derivatives of the objective function. We introduce a unifying framework, which allows to construct different types of accelerated randomized methods for such problems and to prove convergence rate theorems for them. We focus on accelerated random block-coordinate descent, accelerated random directional search, accelerated random derivative-free method.

Xun Qian, KAUST (joint work with Robert Gower, Nicolas Loizou, Peter Richtárik, Alibek Sailanbayev, Egor Shulgin)
SGD: General Analysis and Improved Rates

We propose a general yet simple theorem describing the convergence of SGD under the arbitrary sampling paradigm. Our analysis relies on the recently introduced notion of expected smoothness and does not rely on a uniform bound on the variance of the stochastic gradients. By specializing our theorem to different mini-batching strategies, such as sampling with replacement and independent sampling, we derive exact expressions for the stepsize as a function of the mini-batch size.
**Applications in Energy (Part III)**

Chair: Alberto J. Lamadrid L.

Güray Kara, Norwegian University of Science and Technology (joint work with Hossein Farahmand, Asgeir Tomasgard)

**Optimal Scheduling and Bidding of Flexibility for a Portfolio of Power System Assets in a Multi-Market Setting**

Flexibility is an important concept to cope with uncertainty in energy systems. In this paper, we consider the problem of an actor that manages a portfolio of flexible assets. We present a Stochastic Programming model for the dynamic scheduling of a portfolio for which energy and flexibility products can be delivered into multiple markets like day-ahead, intraday, and flexibility markets. Some of these products are locations specific, while others are system-wide or even cross-border. The purpose in the short-term is to remove bottlenecks and ensure security of supply at the minimum cost.

Clovis Gonzaga, LACTEC (joint work with Elizabeth Karas, Gislaine Periçaro)

**Optimal non-anticipative scenarios for non-linear hydro-thermal power systems**

The long-term operation of hydro-thermal power systems is modeled by a large-scale stochastic optimization problem with non-linear constraints due to the head computation in hydroelectric plants. We state the problem as a non-anticipative scenario analysis, leading to a large-scale non-linear programming problem. This is solved by a Filter-SQP algorithm whose iterations minimize quadratic Lagrangian approximations using exact Hessians in $L_\infty$ trust regions. The method is applied to the long-term planning of the Brazilian system, with over 100 hydroelectric and 50 thermoelectric plants.

Alberto J. Lamadrid L., Lehigh University (joint work with Luis Zuluaga)

**Equilibrium prices for competitive electricity markets**

We consider an electricity market in which uncertainty arises from the presence of renewable energy sources. We consider a robust model for the market using chance constraints together with a proportional control law for power generation. We prove that in this framework, market clearing prices yielding a robust competitive market equilibrium, as well as revenue adequate prices, can be computed and used for uncertain market settlements by risk-aware system operators. We contrast our results to methods using a sample average stochastic program from desired prices can be obtained in each scenario.

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**Recent Advancements in Optimization Methods for Machine Learning (Part I)**

Organizers: Albert Berahas, Paul Grigas, Martin Takáč

Chair: Albert Berahas

Alexandre d’Aspremont, CNRS / École Normale Supérieure (joint work with Thomas Kerdreux, Sebastian Pokutta)

**Restarting Frank-Wolfe**

The vanilla Frank-Wolfe algorithm only ensures a worst-case complexity of $O(1/\epsilon)$. Various recent results have shown that for strongly convex functions, the method can be slightly modified to achieve linear convergence. However, this still leaves a huge gap between sublinear $O(1/\epsilon)$ convergence and linear $O(\log 1/\epsilon)$ convergence. Here, we present a new variant of Conditional Gradients, that can dynamically adapt to the function’s geometric properties using restarts and smoothly interpolates between the sublinear and linear regimes.

Heyuan Liu, University of California, Berkeley (joint work with Paul Grigas)

[moved] **New Methods for Regularization Path Optimization via Differential Equations**

We develop and analyze several different second order algorithms for computing an approximately optimal solution/regularization path of a parameterized convex optimization problem with smooth Hessian. Our algorithms are inspired by a differential equations perspective on the parametric solution path and do not rely on the specific structure of the regularizer. We present computational guarantees that bound the oracle complexity to achieve an approximately optimal solution path under different sets of smoothness assumptions and that also hold in the presence of approximate subproblem solutions.

Lin Xiao, Microsoft Research (joint work with Junyu Zhang)

**A Composite Randomized Incremental Gradient Method**

We consider the problem of minimizing the composition of a smooth function (which can be nonconvex) and a smooth vector mapping, where both of them can be expressed as the average of a large number of components. We propose a composite randomized incremental gradient method based on a SAGA-type of gradient estimator. The gradient sample complexity of our method matches that of several recently developed methods based on SVRG in the general case. However, for structured problems where linear convergence rates can be obtained, our method has much better complexity for ill-conditioned problems.
Quasi-Variational Inequalities and Generalized Nash Equilibrium Problems (Part I)
Organizers: Amal Alphonse, Carlos Rautenberg
Chair: Amal Alphonse

Christian Kanzow, University of Würzburg (joint work with Daniel Steck)
Quasi-Variational Inequalities in Banach Spaces: Theory and Augmented Lagrangian Methods

This talk deals with quasi-variational inequality problems (QVIs) in a generic Banach space setting. We provide a theoretical framework for the analysis of such problems based on the pseudomonotonicity (in the sense of Brezis) of the variational operator and a Mosco-type continuity of the feasible set mapping. These assumptions can be used to establish the existence of solutions and their computability via suitable approximation techniques. An augmented Lagrangian technique is then derived and shown to be convergent both theoretically and numerically.

Steven-Marian Stengl, WIAS/HU Berlin
On the Convexity of Optimal Control Problems involving Nonlinear PDEs or VIs

In recent years, generalized Nash equilibrium problems in function spaces involving control of PDEs have gained increasing interest. One of the central issues arising is the question of existence, which requires the topological characterization of the set of minimizers for each player. In this talk, we propose conditions on the operator and the functional, that guarantee the reduced formulation to be a convex minimization problem. Subsequently, we generalize the results of convex analysis to derive optimality systems also for nonsmooth operators. Our findings are illustrated with examples.

Rafael Arndt, Humboldt-Universität zu Berlin (joint work with Michael Hintermüller, Carlos Rautenberg)
On quasi-variational inequality models arising in the description of sandpiles and river networks

We consider quasi-variational inequalities with pointwise constraints on the gradient of the state, that arise in the modeling of sandpile growth, where the constraint depends on local properties of the supporting surface and the solution. We will demonstrate an example where multiple solutions exist in the unregularized problem but not after regularization. Solution algorithms in function space are derived, considering two approaches: a variable splitting method and a semismooth Newton method. The application can further be extended to regarding water-drainage as the limiting case.

Augmented Lagrangian Approaches for Solving Doubly Nonnegative Programming Problems

Augmented Lagrangian methods are among the most popular first-order approaches to handle large scale semidefinite programming problems. We focus on doubly nonnegative problems, namely semidefinite programming problems where elements of the matrix variable are constrained to be nonnegative. Starting from two methods already proposed in the literature on conic programming, we introduce Augmented Lagrangian methods with the possibility of employing a factorization of the dual variable. We present numerical results for instances of the DNN relaxation of the stable set problem.

Christoph Helmberg, TU Chemnitz
The Bundle Approach – Scaling in ConicBundle 1.0 for Convex and Conic Optimization

Bundle methods form a cutting model from collected subgradient information and determine the next candidate as the minimizer of the model augmented with a proximal term. The choice of cutting model and proximal term offers a lot of flexibility and may even allow to move towards second order behavior. After a short introduction to bundle methods in general, we discuss the current approach for integrating such choices in the forthcoming ConicBundle 1.0 for the general and the semidefinite case and report on experience gathered on several test instances.

Georgina Hall, INSEAD
Semidefinite Programming-Based Consistent Estimators for Shape-Constrained Regression

In this talk, I consider the problem of shape-constrained regression, where response variables are assumed to be a function $f$ of some features (corrupted by noise) and $f$ is constrained to be monotonous or convex with respect to these features. Problems of these type occur in many areas, such as, e.g., pricing. Using semidefinite programming, I construct a regressor for the data which has the same monotonicity and convexity properties as $f$. I further show that this regressor is a consistent estimator of $f$. 
Advances in Interior Point Methods for Convex Optimization
Organizer: Etienne de Klerk
Chair: Etienne de Klerk

Mehdi Karimi, University of Waterloo (joint work with Levent Tunçel)
Convex Optimization Problems in Domain-Driven Form: Theory, Algorithms, and Software

In this talk, we introduce the Domain-Driven form for convex optimization problems and show how general it is by several examples. We have designed infeasible-start primal-dual interior-point algorithms for the Domain-Driven form, which accepts both conic and non-conic constraints. Our algorithms enjoy many advantages of primal-dual interior-point techniques available for conic formulations, such as the current best complexity bounds. At the end, we introduce our software package DDS created based on our results for many classes of convex optimization problems.

Riley Badenbroek, Tilburg University (joint work with Etienne de Klerk)
Simulated Annealing with Hit-and-Run for Convex Optimization

We analyze the simulated annealing algorithm by Kalai and Vempala [Math of OR 31.2 (2006): 253-266] using the temperature schedule put forward by Abernethy and Hazan [arXiv 1507.02528v2, 2015]. This algorithm only assumes a membership oracle of the feasible set, and returns a solution in polynomial time which is near-optimal with high probability. Moreover, we propose a number of modifications to improve the practical performance of this method. Numerical examples show the method has an application to convex problems where no other method is readily available, such as copositive programming.

David Papp, North Carolina State University (joint work with Sercan Yıldız)
alfonso: A new conic solver for convex optimization over non-symmetric cones

Many optimization problems can be conveniently written as conic programs over non-symmetric cones; however, these problems are lacking the solver support that symmetric conic optimization problems have. We propose alfonso, a highly general Matlab-based interior point solver for non-symmetric conic optimization. Alfonso can solve optimization problems over a cone as long as the user can supply the gradient and Hessian of a logarithmically homogeneous self-concordant barrier for either the cone or its dual. We demonstrate its efficiency using general examples. We have designed infeasible-start primal-dual interior-point algorithms for the Domain-Driven form, which accepts both conic and non-conic constraints. Our algorithms enjoy many advantages of primal-dual interior-point techniques available for conic formulations, such as the current best complexity bounds. At the end, we introduce our software package DDS created based on our results for many classes of convex optimization problems.

Yu Du, University of Colorado Denver
An outer-inner linearization method for non-convex and non-differentiable composite regularization problems

We propose a new outer-inner linearization method for non-convex statistical learning problems involving nonconvex structural penalties and nonconvex loss. It linearizes the outer concave functions and solves the resulting convex, but still nonsmooth, subproblems by a special alternating linearization method. We provide proof of convergence of the method under mild conditions. Finally, numerical examples involving nonconvex structural penalties and nonconvex loss functions demonstrate the efficacy and accuracy of the method.

Maicon Marques Alves, Federal University of Santa Catarina - UFSC (joint work with Jonathan Eckstein, Marina Geremia)
Relative-Error Inertial-Relaxed Inexact Versions of Douglas-Rachford and ADMM Splitting Algorithms

This paper derives new inexact variants of the Douglas-Rachford splitting method for maximal monotone operators and the alternating direction method of multipliers (ADMM) for convex optimization. The analysis is based on a new inexact version of the proximal point algorithm that includes both an inertial step and overrelaxation. We apply our new inexact ADMM method to LASSO and logistic regression problems and obtain better computational performance than earlier inexact ADMM methods.

Jonathan Eckstein, Rutgers University (joint work with Patrick Johnstone)
Projective Splitting with Co-coercive Operators

This talk describes a new variant of monotone operator projective splitting in which co-coercive operators can be processed with a single forward step per iteration. This result establishes a symmetry between projective splitting algorithms, the classical forward-backward method, and Tseng’s forward-backward-forward method: In a situation in which Lipschitz monotone operators require two forward steps, co-coercive operators may be processed with a single forward step. The single forward step may be interpreted as a single step of the classical forward-backward method for the standard “prox” problem associated with the cocoercive operator, starting at the previous known point in the operator graph. Proving convergence of the algorithm requires some departures from the usual proof framework for projective splitting. We have also developed a backtracking variant of the method for cases in which the co-coercivity constant is unknown, and present some computational tests of this method on large-scale optimization problems from data fitting and portfolio applications.
**Matrix Optimization Problems: Theory, Algorithms and Applications**  
Organizer: Chao Ding  
Chair: Chao Ding  
Xinyuan Zhao, Beijing University of Technology (joint work with Chao Ding, Zhuoxuan Jiang)  
**A DC algorithm for quadratic assignment problem**

We show that the quadratic assignment problem (QAP) is equivalent to the doubly nonnegative (DNN) problem with a rank constraint. A DC approach is developed to solve that DNN problem. And its subproblems are solved by the semi-proximal augmented Lagrangian method. The sequence generated by the proposed algorithm converges to a stationary point of the DC problem with a suitable parameter. Numerical results demonstrate: for some examples of QAPs, the optimal solutions can be found directly; for the others, good upper bounds with the feasible solutions are provided.

Xudong Li, Fudan University (joint work with Liang Chen, Defeng Sun, Kim-Chuan Toh)  
**On the Equivalence of Inexact Proximal ALM and ADMM for a Class of Convex Composite Programming**

In this talk, we show that for a class of linearly constrained convex composite optimization problems, an (inexact) symmetric Gauss-Seidel based majorized multi-block proximal alternating direction method of multipliers (ADMM) is equivalent to an inexact proximal augmented Lagrangian method (ALM). This equivalence not only provides new perspectives for understanding some ADMM-type algorithms but also supplies meaningful guidelines on implementing them to achieve better computational efficiency.

Chao Ding, AMSS, Chinese Academy of Sciences  
**Perturbation analysis of matrix optimization**

The nonsmooth composite matrix optimization problem, in particular, the matrix norm optimization problem, is a generalization of the matrix conic program with wide applications in numerical linear algebra, computational statistics and engineering. This talk is devoted to study some perturbation properties of matrix optimization problems.

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**Emerging Trends in Derivative-Free Optimization (Part I)**  
Organizers: Ana Luisa Custodio, Sébastien Le Digabel, Margherita Porcelli, Francesco Rinaldi, Stefan Wild  
Chair: Anne Auger  
Christine Shoemaker, National University of Singapore (joint work with Yichi Shen)  
**Global optimization of noisy multimodal functions with RBF surrogates**

We consider the optimization of multimodal, computationally expensive noisy functions $f(x)$ with the assistance of a Radial Basis Function (RBF) surrogate approximation of $f(x)$. This RBF surrogate is then used to help guide the optimization search to reduce the number of evaluations required. Because the function is noisy, it is necessary to resample some points to estimate the mean variance of $f(x)$ at each location. The results compare favorably to Bayesian Optimization methods for noisy functions and can be more flexible in the choice of objective function.

Nikolaus Hansen, Inria / Ecole Polytechnique (joint work with Youhei Akimoto)  
**Diagonal acceleration for covariance matrix adaptation evolution strategies**

We introduce an acceleration for covariance matrix adaptation evolution strategies (CMA-ES) by means of adaptive diagonal decoding. This diagonal acceleration endows the default CMA-ES with the advantages of separable CMA-ES without inheriting its drawbacks. Diagonal decoding can learn a rescaling of the problem in the coordinates within linear number of function evaluations. It improves the performance, and even the scaling, of CMA-ES on classes of non-separable test functions that reflect, arguably, a landscape feature commonly observed in practice.

Giacomo Nannicini, IBM T.J. Watson  
**The evolution of RBFOpt: improving the RBF method, with one eye on performance**

This talk will discuss several improvements to the open-source library RBFOpt for surrogate model based optimization. RBFOpt is used in commercial applications and practical needs drove its development. We will discuss efficient model selection, local search, parallel optimization and – time permitting – multi objective optimization. Part of this talk is devoted to engineering issues, but we will try to be precise regarding the mathematics for efficient model selection and local search. This is based on results scattered in various recent papers; some details are currently unpublished.
Akiko Takeda, The University of Tokyo/RIKEN (joint work with Jun-ya Gotoh, Katsuya Tono)

**DC Formulations and Algorithms for Sparse Optimization Problems**

We address the minimization of a smooth objective function under an $L^0$-norm constraint and simple constraints. Some efficient algorithms are available when the problem has no constraints except the $L^0$-norm constraint, but they often become inefficient when the problem has additional constraints. We reformulate the problem by employing a new DC (difference of two convex functions) representation of the $L^0$-norm constraint, so that DC algorithm can retain the efficiency by boiling down its subproblems to the projection operation onto a simple set.

Hongbo Dong, Washington State University (joint work with Min Tao)

**On the Linear Convergence of DC Algorithms to Strong Stationary Points** [canceled]

We consider the linear convergence of algorithms for structured DC optimization. We allow nonsmoothness in both of the convex and concave components, with a finite max structure in the concave component, and focus on algorithms computing d(directional)-stationary points. Our results are based on standard error bounds assumptions and a new locally linear regularity regarding the intersection of certain stationary sets and dominance regions. A by-product of our work is a unified description of strong stationary points and global optimum by using the notion of approximate subdifferential.

Markus Arthur Köbis, Free University Berlin

**Set optimization in systems biology: application to dynamic resource allocation problems**

We will address how set-valued optimization can be used to approach problems from systems biology and that way opens doorways to simplifying and systematizing many, often pragmatic frameworks in this field. We will concentrate on problems concerning the dynamic simulation of metabolic networks with potential applications ranging from personalized medicine over bio-fuel production to ecosystem biology. From the mathematical modeling viewpoint, we will underline how evolutionary principles may in this regard be interpreted as a regularization and illustrate this by some small-scale examples.

Elisabeth Köbis, Martin Luther University Halle-Wittenberg (joint work with César Gutiérrez, Lidia Huerga, Christiane Tammer)

**A scalarization scheme in ordered sets with applications to set-valued and robust optimization**

In this talk, a method for scalarizing optimization problems whose final space is an ordered set is stated without assuming any additional assumption on the data of the problem. By this approach, nondominated and minimal solutions are characterized in terms of solutions of scalar optimization problems whose objective functions are the post-composition of the original objective with scalar functions satisfying suitable properties. The obtained results generalize some recent ones stated in quasi ordered sets and real topological linear spaces.

Akhtar A. Khan, Rochester Institute of Technology

**Analysing the Role of the Inf-Sup Condition in Inverse Problems for Saddle Point Problems**

We will discuss the inverse problem of parameter identification in general saddle point problems that frequently appear in applied models. We focus on examining the role of the inf-sup condition. Assuming the saddle point problem is solvable, we study the differentiability of the set-valued parameter-to-solution map by using the first-order and the second-order contingent derivatives. We investigate the inverse problem by using the nonconvex output least-squares and the convex modified output least-squares objectives. Numerical results and applications will be presented.
Recent Advances in First-Order Methods (Part II)
Organizers: Guanghui Lan, Yuyuan Ouyang, Yi Zhou
Chair: Yuyuan Ouyang

Mert Gurbuzbalaban, Rutgers University
A Universally Optimal Multistage Accelerated Stochastic Gradient Method

We study the problem of minimizing a strongly convex and smooth function when we have noisy estimates of its gradient. We first provide a framework that can systematically trade-off acceleration and robustness to gradient errors. Building on our framework, we propose a novel multistage accelerated algorithm that is universally optimal in the sense that it achieves the optimal rate both in the deterministic and stochastic case and operates without knowledge of noise characteristics.

Hilal Asi, Stanford University (joint work with John Duchi)
The importance of better models in stochastic optimization

Standard stochastic optimization methods are brittle, sensitive to algorithmic parameters, and exhibit instability outside of well-behaved families of objectives. To address these challenges, we investigate models that exhibit better robustness to problem families and algorithmic parameters. With appropriately accurate models, which we call the aProx family, stochastic methods can be made stable, provably convergent and asymptotically optimal. We highlight the importance of robustness and accurate modeling with a careful experimental evaluation of convergence time and algorithm sensitivity.

Damien Scieur, SAIT Montreal (joint work with Raghu Bollapragada, Alexandre d’Aspremont)
Nonlinear Acceleration of Momentum and Primal-Dual Algorithms

We describe a convergence acceleration scheme for multistep optimization algorithms. The extrapolated solution is written as a nonlinear average of the iterates produced by the original optimization algorithm. Our scheme handles algorithms with momentum terms such as Nesterov’s accelerated method, or primal-dual methods. The weights are computed via a simple linear system and we analyze performance in both online and offline modes. We use Crouzeix’s conjecture to show that acceleration performance is controlled by the solution of a Chebyshev problem.

Stochastic Methods for Nonsmooth Optimization
Organizer: Konstantin Mishchenko
Chair: Konstantin Mishchenko
Tianyi Lin, University of California, Berkeley
Improved oracle complexity for stochastic compositional variance reduced gradient

We propose an accelerated stochastic compositional variance reduced gradient method for optimizing the sum of a composition function and a convex nonsmooth function. We provide an incremental first-order oracle (IFO) complexity analysis for the proposed algorithm and show that it is provably faster than all the existing methods. In particular, we show that our method achieves an asymptotic IFO complexity of $O((m + n) \log(1/\epsilon) + 1/\epsilon)$, where $m$ and $n$ are the number of inner/outer component functions, improving the best-known results of $O(m + n + (m + n)^{2/3}/\epsilon^2)$ for convex composition problem.

Adil Salim, King Abdullah University of Science and Technology (KAUST)
On the Convergence of some Stochastic Primal-Dual Algorithms

Primal-dual algorithms, like Chambolle-Pock or Vu-Condat algorithms, are suitable methods to solve nonsmooth optimization problems involving linear constraints. In this talk, we will consider stochastic versions of these algorithms where every function used to define the problem is written as an expectation, including the constraints. Asymptotic and non-asymptotic convergence results involving the expected primal-dual gap will be provided. These results cover some recent findings regarding stochastic proximal (gradient) algorithms.

Konstantin Mishchenko, KAUST (joint work with Peter Richtárik)
Variance Reduction for Sums with Smooth and Nonsmooth Components with Linear Convergence

We present a stochastic variance reduction method for convex sums with smooth and nonsmooth entries. In the case where the smooth part is strongly convex and the nonsmooth entries are of the form $g_j(A_j x)$, the method achieves linear convergence with rate $O(\max(n, \kappa, \lambda_{\text{min}}(A)) \log(1/\epsilon))$, where $n$ is the number of smooth terms, $\kappa$ is the conditioning and $\lambda_{\text{min}}(A)$ is the smallest eigenvalue of the matrix constructed from the rows of $A_1, A_2, \text{etc}$. Without this assumption, the method has rate $O(1/t)$ which improves to $O(1/t^2)$ under strong convexity.
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**NON**

**Interplay of Linear Algebra and Optimization (Part II)**
Organizers: Robert Luce, Yuji Nakatsukasa
Chair: Robert Luce

Yuji Nakatsukasa, University of Oxford (joint work with Paul Goulart, Nikitas Rontsis)

Eigenvalue perturbation theory in optimization: accuracy of computed eigenvectors and approximate semidefinite projection

Eigenvalue perturbation theory is a classical subject in matrix analysis and numerical linear algebra, but seemingly has had little impact in optimization. This talk presents recent progress in eigenvalue perturbation theory, highlighting its roles in optimization. We first derive sharp perturbation and error bounds for Ritz vectors (approximate eigenvectors) and approximate singular vectors, which are used e.g. in SDP, PCA and trust-region subproblems. We also present bounds on the accuracy of approximate semidefinite projection, motivated by operator splitting methods in optimization.

Zsolt Csizmadia, FICO

Eliminations and cascading in nonlinear optimization

The talk explores the numerical implications of using variable eliminations in nonlinear problems versus applying intermediate variables; looking at implications on feasibility, formula sizes or the size of the auto differentiation stacks. For bounded cases when eliminations are not applicable, the talk will present cascading, a technology originating from classical refinery optimization models but recently successfully applied to financial problems. Detection methods of elimination candidates and cascading structures will be presented.

John Pearson, University of Edinburgh

Interior point methods and preconditioners for PDE-constrained optimization

In this talk we consider the effective numerical solution of PDE-constrained optimization problems with additional box constraints on the state and control variables. Upon discretization, a sensible solution strategy is to apply an interior point method, provided one can solve the large and structured matrix systems that arise at each Newton step. We therefore consider fast and robust preconditioned iterative methods for these systems, examining two cases: (i) with $L^2$ norms arising within the cost functional; (ii) with an additional $L^1$ norm term promoting sparsity in the control variable.

**IMP**

**Advances in Linear Programming**
Chair: Daniel Rehfeldt

Julian Hall, University of Edinburgh

HiGHS: a high-performance linear optimizer

This talk will present HiGHS, a growing open-source repository of high-performance software for linear optimization based on award-winning computational techniques for the dual simplex method. The talk will give an insight into the work which has led to the creation of HiGHS and then set out the features which allows it to be used in a wide range of applications. Plans to extend the class of problems which can be solved using HiGHS will be set out.

Ivet Galabova, University of Edinburgh

Solution of quadratic programming problems for fast approximate solution of linear programming problems

Linear programming problems (LP) are widely solved in practice and reducing the solution time is essential for many applications. This talk will explore solving a sequence of unconstrained quadratic programming (QP) problems to derive an approximate solution and bound on the optimal objective value of an LP. Techniques for solving these QP problems fast will be discussed.

Daniel Rehfeldt, Technische Universität Berlin (joint work with Ambros Gleixner, Thorsten Koch)

Solving large-scale doubly bordered block diagonal LPs in parallel

We consider LPs of block diagonal structure with linking variables and additional box constraints, motivated by energy system applications. To solve these problems, we have extended the interior-point solver PIPS-IPM (for stochastic QPs). This talk focuses on methods to handle large numbers of linking variables and constraints. A preconditioned iterative approach and a hierarchical algorithm will be presented, both of which exploit structure within the linking part. The extensions allow us to solve real-world problems with over 500 million variables and constraints in a few minutes on a supercomputer.
Computational Design Optimization (Part III)
Organizers: Martin Siebenborn, Kathrin Welker
Chair: Martin Siebenborn

Estefania Loayza-Romero, Chemnitz University of Technology (joint work with Ronny Bergmann, Roland Herzog)
A discrete shape manifold and its use in PDE-constrained shape optimization

This work aims to present the novel notion of discrete shape manifold, which will allow solving PDE-constrained shape optimization problems using a discretize-then-optimize approach. This manifold will be endowed with a complete Riemannian metric that prevents mesh destruction. The computation of discrete shape derivatives and its relation with the optimize-then-discretize approach will be discussed. Finally, we will present the application of this approach to the solution of simple 2D optimization problems.

Veronika Schulze, Paderborn University (joint work with Benjamin Jurgelucks, Andrea Walther)
Increasing Sensitivity of Piezoelectric Ceramics by Electrode Shape Optimization

Piezoelectricity defines the relation between electrical and mechanical changes in a specimen and can be described by a damped PDE system. Often material parameters of given piezoelectrics are not known precisely, but are required to be accurate. The solution of an inverse problem provides these values. For this purpose, sensitivities with respect to the material parameters can be calculated. In order to compute all parameters the sensitivities of some specific parameters must be increased. This is achieved by adjusting the electrode shapes with shape and topology optimization techniques.

The phase field approach for topology optimization

In a given domain $\Omega$ we search for a fluid domain $E$, such that an objective depending on $E$ and the velocity and the pressure field in $E$ is minimized. We describe the distribution of the fluid and void domain by a phase field variable $\varphi \in H^1(\Omega) \cap L^\infty(\Omega)$ that encodes the subdomains by $\varphi(x) = \pm 1$. Additionally we use a porosity approach to extend the Navier–Stokes equation from $E$ to $\Omega$. As solution algorithm we apply the variable metric projection type method from [L. Blank and C. Rupprecht, SICON 2017, 55(3)].

Optimal Control and Dynamical Systems (Part III)
Organizers: Cristopher Hermosilla, Michele Palladino
Chair: Cristopher Hermosilla

Matthias Knauer, Universität Bremen (joint work with Christof Büskens)
Real-Time Approximations for Discretized Optimal Control Problems using Parametric Sensitivity Analysis

In many industrial applications solutions of optimal control problems are used, where the need for low computational times outweighs the need for absolute optimality. For solutions of fully discretized optimal control problems we propose two methods to approximate the solutions of problems with modified parameter values in real-time by using sensitivity derivatives. Using the NLP solver WORHP, the quality and applicability of both methods are illustrated by the application of an oscillation free movement of a container crane in a high rack warehouse.

Tan Cao, State University of New York–Korea (joint work with Boris Mordukhovich)
Optimal Control for a Nonconvex Sweeping Process with Applications to the Crowd Motion Model [canceled]

The talk concerns the study a new class of optimal control problems of (Moreau) sweeping process. A major motivation for our study of such challenging optimal control problems comes from the application to the crowd motion model in a practically adequate planar setting with nonconvex but prox-regular sweeping sets. Based on a constructive discrete approximation approach and advanced tools of variational analysis and generalized differentiation, we derive necessary optimality conditions for discrete-time and continuous-time sweeping control systems expressed entirely via the problem data.

Gerardo Sanchez Licea, Facultad de Ciencias UNAM
Sufficiency for purely essentially bounded singular optimal controls

In this talk we study certain classes of fixed end-point optimal control problems of Lagrange with nonlinear dynamics, inequality and equality isoperimetric restraints and pointwise mixed time-state-control inequality and equality constraints. The diminishing of the gap between the classical necessary and sufficient conditions for optimality becomes the main novelty of the talk. In fact, we illustrate the properties of the new theory by exhibiting some singular and purely essentially bounded optimal controls satisfying all conditions of the corresponding sufficiency theorems.
Recent Advances in PDE Constrained Optimization (Part II)
Organizer: Axel Kröner
Chair: Axel Kröner

Meenarli Sharma, Indian Institute of Technology Bombay (joint work with Sven Leyffer, Lars Ruthotto, Bart van Bloemen Waanders)

Inversion of Convection-Diffusion PDE with Discrete Sources

We aim to find the number and location of sources from discrete measurements of concentration on computational domain. We formulate a forward PDE model and then invert it for the unknown sources by reformulating the latter as a MINLP, resulting in mixed-integer PDE constrained optimization (MIPDECO). For MINLP solvers, solving such MINLPs is computationally prohibitive for fine meshes and 3D cases. We propose a trust-region improvement heuristic that uses continuous relaxation of MIPDECO problem with different rounding schemes.

Johanna Katharina Biehl, TU Darmstadt (joint work with Stefan Ulbrich)

Adaptive Multilevel Optimization with Application to Fluid-Structure Interaction

We present a multilevel optimization algorithm for PDE-constrained problems. The basis of the algorithm is an adaptive SQP method, using adaptive grid refinement to reduce the computational cost. This method is extended by introducing a level build with reduced order models (ROM) for state and adjoint equation. For this algorithm we can show convergence, when suitable a posteriori error estimators on the discretization and the ROM are available. The algorithm is applied to a benchmark problem of fluid-structure interaction, which is a problem of interest in many engineering applications.

Johann Michael Schmitt, TU Darmstadt (joint work with Stefan Ulbrich)

Optimal boundary control of hyperbolic balance laws with state constraints

We study optimal control problems governed by balance laws with initial and boundary conditions and pointwise state constraints. The boundary data switch between smooth functions at certain points, where we consider the smooth parts and the switching points as control. State constraints are challenging in this context since solutions of nonlinear hyperbolic balance laws may develop shocks after finite time which prohibits the use of standard methods. We derive optimality conditions and prove convergence of the Moreau-Yosida regularization that is used to treat the state constraints.

Distributionally Robust Optimization: Computation and Insights
Organizer: Karthik Natarajan
Chair: Karthik Natarajan

Jianqiang Cheng, University of Arizona
Computationally Efficient Approximations for Distributionally Robust Optimization [canceled]

Many distributionally robust optimization (DRO) instances can be formulated as semidefinite programming (SDP) problems. However, SDP problems in practice are computationally challenging. In this talk, we present computationally efficient (inner and outer) approximations for DRO problems based on the idea of the principal component analysis (PCA). We also derive theoretical bounds on the gaps between the original problem and its PCA approximations. Furthermore, an extensive numerical study shows the strength of the proposed approximations in terms of solution quality and runtime.

Divya Padmanabhan, Singapore University of Technology and Design (joint work with Karthik Natarajan, Arjun Ramachandra)

Bounds on Sums of Dependent Random Variables: An Optimization Approach

Computing tight bounds for the probability of sums of dependent variables is a fundamental problem with several applications. In this work we study the problem of computing the probability of a sum of dependent Bernoulli random variables exceeding k, from a DRO perspective. We study the problem under known univariate and bivariate marginals with tree structure, where a consistent joint distribution is guaranteed to exist. We propose exact and compact linear programming formulations for these sparse forms. This is based on joint work with Arjun Ramachandra and Karthik Natarajan at SUTD.

Karthik Natarajan, Singapore University of Technology and Design (joint work with Bikramjit Das, Anulekha Dhara)

On the Heavy-Tail Behavior of the Distributionally Robust Newsvendor

Since the seminal work of Scarf (1958) on the newsvendor problem with ambiguity in the demand distribution, there has been a growing interest in the study of the distributionally robust newsvendor problem. A simple observation shows that the optimal order quantity in Scarf’s model with known first and second moment is also optimal for a heavy-tailed censored student-t distribution with degrees of freedom 2. In this paper, we generalize this “heavy-tail optimality” property of the distributionally robust newsvendor to a more general ambiguity set.
Data-driven Approximate Dynamic Programming

We consider linear programming (LP) problems in infinite dimensional spaces and develop an approximation bridge from the infinite-dimensional LP to tractable finite convex programs in which the performance of the approximation is quantified explicitly. We illustrate our theoretical results in the optimal control problem for Markov decision processes on Borel spaces when the dynamics are unknown and learned from data and derive a probabilistic explicit error bound between the data-driven finite convex program and the original infinite linear program.

Asymptotic Normality and Optimal Confidence Regions in Wasserstein Distributionally Robust Optimization

We provide a theory of confidence regions for Wasserstein distributionally robust optimization (DRO) formulations. In addition to showing the asymptotic normality of these types of estimators (under natural convex constraints), we also characterize optimal confidence regions (in a certain sense informed by the underlying DRO formulation) and study the asymptotic shape of these regions in a suitable topology defined for convergence of sets.

Iterative regularisation of continuous inverse problems via an entropic projection method

In this talk, we discuss iterative regularisation of continuous, linear ill-posed problems via an entropic projection method. We present a detailed convergence analysis of the scheme that respects the continuous nature of the underlying problem and we present numerical results for continuous and ill-posed inverse problems to support the theory.
Large-Scale Stochastic First-Order Optimization (Part II)

Organizers: Filip Hanzely, Samuel Horvath
Chair: Samuel Horvath

Nidham Gazagnadou, Télécom ParisTech (joint work with Robert Gower, Joseph Salmon)

Optimal mini-batch and step sizes for SAGA

Recently, it has been shown that the step sizes of a family of stochastic variance reduced gradient methods, called the JacSketch methods, depend on the expected smoothness constant. We provide closed form expressions for this constant, leading to larger step sizes and thus to faster convergence, and numerical experiments verifying these bounds. We suggest a new practice for setting the mini-batch and step sizes for SAGA, part of the JacSketch family. Furthermore, we can now show that the total complexity of the SAGA algorithm decreases linearly in the mini-batch size up to an optimal value.

Hamed Sadeghi, Lund University (joint work with Pontus Giselson)

Acceleration of reduced variance stochastic gradient method [canceled]

We propose a convergence acceleration scheme for optimization problems in stochastic settings. We use Anderson acceleration in combination with a reduced variance stochastic gradient method and show that the iterates are stochastically quasi-Fejér monotone. This allows us to prove almost sure convergence of the method. We apply the acceleration technique to reduced variance stochastic gradient algorithms SVRG and SAGA to show its performance gains.

Samuel Horvath, King Abdullah University of Science and Technology

Stochastic Distributed Learning with Gradient Quantization and Variance Reduction

We consider distributed optimization where the objective function is spread among different devices, each sending incremental model updates to a central server. To alleviate the communication bottleneck, recent work proposed various schemes to compress (e.g., quantize or sparsify) the gradients, thereby introducing additional variance, that might slow down convergence. We provided a unified analysis of these approaches in strongly/weakly convex and non-convex frameworks and provide the first methods that achieve linear convergence for arbitrary quantized updates.
Memorial Session

Andrew R. Conn passed away on March 14, 2019. He played a pioneering role in nonlinear optimization and remained very active in the field until shortly before his death. At this session, five of his friends and colleagues will give 10 minutes tributes to his work and his life. These will be followed by 30 minutes where everyone will have the opportunity to contribute a few words in memory of Andy, as he was always known. The five speakers are:

- Philippe L. Toint, University of Namur
- Katya Scheinberg, Lehigh University
- Annick Sartenaer, University of Namur
- Henry Wolkowicz, University of Waterloo
- James Burke, University of Washington

More information about this memorial session on page 15.

Applications in Energy (Part IV)

Chair: Orcun Karaca

Julien Vaes, University of Oxford (joint work with Raphael Hauser)

**Optimal Execution Strategy Under Price and Volume Uncertainty**

In the seminal paper on optimal execution of portfolio transactions, Almgren and Chriss define how to liquidate a fixed volume of a single security under price uncertainty. Yet sometimes, as in the power market, the volume to be traded can only be estimated and becomes more accurate when approaching the delivery time. We propose a model that accounts for volume uncertainty and show that a risk-averse trader has benefit in delaying trades. With the incorporation of a risk, we avoid the high complexity associated to dynamic programming solutions while yielding to competitive performance.

Harald Held, Siemens, Corporate Technology (joint work with Christoph Bergs)

**MINLP to Support Plant Operators in Energy Flexibilization**

Many production industries require energy, e.g. in form of electricity, heat, or compressed air. With the rise of renewable energies and storage technologies, the question arises how such industries can take advantage of it, and to get an idea of energy flexibilization potentials at all. In this talk, we will introduce a software tool that is currently being developed at Siemens that allows industry users to assess their flexibilization potentials, and also to ensure cost-optimal operation of production systems. The underlying optimization problem is a Mixed-Integer NonLinear Program (MINLP).

Orcun Karaca, ETH Zürich (joint work with Maryam Kamgarpour)

**Core-Selecting Stochastic Auctions**

Core-selecting auctions are well-studied in the deterministic case for their coalition-proofness and competitiveness. Recently, stochastic auctions have been proposed as a method to integrate intermittent participants in electricity markets. In this talk, we define core-selecting stochastic auctions and show their properties depending on the way uncertainty is accounted for in the payment mechanism. We illustrate a trade-off between achieving desirable properties, such as cost-recovery and budget-balance, in expectation or in every scenario. Our results are verified with case studies.
Recent Advancements in Optimization Methods for Machine Learning (Part II)
Organizers: Albert Berahas, Martin Takáč
Chair: Albert Berahas

Communication Efficient Variants of SGD for Distributed Training

The communication overhead is a key bottleneck that hinders perfect scalability of distributed optimization algorithms. Various recent works proposed to use quantization or sparsification techniques to reduce the amount of data that needs to be communicated. We analyze Stochastic Gradient Descent (SGD) with compression of all exchanges messages (like e.g. sparsification or quantization) and show that these schemes converge at the same rate as vanilla SGD when equipped with error compensation technique (i.e. keeping track of accumulated errors in memory).

Martin Takáč, Lehigh University (joint work with Albert Berahas, Majid Jahani)
Quasi-Newton Methods for Deep Learning: Forget the Past, Just Sample

We present two sampled quasi-Newton methods for deep learning: sampled LBFGS (S-LBFGS) and sampled LSR1 (S-LSR1). Contrary to the classical variants of these methods that sequentially build Hessian or inverse Hessian approximations as the optimization progresses, our proposed methods sample points randomly around the current iterate at every iteration to produce these approximations. As a result, the approximations constructed make use of more reliable (recent and local) information, and do not depend on past iterate information that could be significantly stale.

Nicolas Loizou, The University of Edinburgh (joint work with Mahmoud Assran, Nicolas Ballas, Mike Rabbat)
Stochastic Gradient Push for Distributed Deep Learning

Distributed data-parallel algorithms aim to accelerate the training of deep neural networks by parallelizing the computation of large mini-batch gradients across multiple nodes. In this work, we study Stochastic Gradient Push (SGP) which combines PushSum gossip protocol with stochastic gradient updates. We prove that SGP converges to a stationary point of smooth, non-convex objectives at the same sub-linear rate as SGD, that all nodes achieve consensus, and that SGP achieves a linear speedup with respect to the number of nodes. Finally, we empirically validate the performance of SGP.

Recent Advances in Algorithms for Large-Scale Structured Nonsmooth Optimization (Part II)
Organizer: Xudong Li
Chair: Xudong Li

A New Homotopy Proximal Variable-Metric Framework for Composite Convex Minimization

This paper suggests a novel idea to develop new proximal variable-metric methods for solving a class of composite convex problems. The idea is to utilise a new optimality condition parameterization to design a class of homotopy proximal variable-metric methods that can achieve linear convergence and finite global iteration-complexity bounds. Moreover, rigorous proofs of convergence results are also provided. Numerical experiments on several applications are given to illustrate our theoretical and computational advancements when compared to other state-of-the-art algorithms.

Meixia Lin, National University of Singapore (joint work with Defeng Sun, Kim-Chuan Toh, Yancheng Yuan)
On the Closed-form Proximal Mapping and Efficient Algorithms for Exclusive Lasso Models

The exclusive lasso regularization based on the $\ell_{1,2}$ norm has become popular due to its superior performance, which results in both inter-group and intra-group sparsity. In this paper, we derive a closed-form solution for the proximal mapping of the $\ell_{1,2}$ norm and its generalized Jacobian. Then we design efficient first and second order algorithms for machine learning models involving the exclusive lasso regularization.

Krishna Pillutla, University of Washington (joint work with Zaid Harchaoui, Sham Kakade, Vincent Roulet)
Large-scale optimization of structured prediction models by inf-convolution smoothing of max-margin inference

We consider the problem of optimizing the parameters of a maximum-margin structured prediction model at a large-scale. We show how an appropriate smoothing by infimal convolution of such non-smooth objectives paves the way to the development of large-scale smooth optimization algorithms making calls to smooth inference oracles, comparable in complexity to the regular inference oracles. We present such an algorithm called Casimir, establish its worst-case information-based complexity, and demonstrate its effectiveness on several machine learning applications.
Semismoothness for Set-Valued Mappings and Newton Method (Part I)
Organizer: Helmut Gfrerer
Chair: Helmut Gfrerer
Ebrahim Sarabi, Miami University, Ohio (joint work with Boris Mordukhovich)
A Semismooth Inverse Mapping Theorem via Tilt Stability and Its Applications in the Newton Method

We present a semismooth inverse mapping theorem for tilt-stable local minimizers of a function. Then we discuss a Newton method for a tilt-stable local minimum of an unconstrained optimization problem.

Jiri Outrata, The Institute of Information Theory and Automation (joint work with Helmut Gfrerer)
On semismooth sets and mappings

The talk is devoted to a new notion of semismoothness which pertains both sets as well as multifunctions. In the case of single-valued maps it is closely related with the standard notion of semismoothness introduced by Qi and Sun in 1993. Semismoothness can be equivalently characterized in terms of regular, limiting and directional limiting coderivatives and seems to be the crucial tool in construction of Newton steps in case of generalized equations. Some basic classes of semismooth sets and mappings enabling us to create an elementary semismooth calculus will be provided.

Helmut Gfrerer, Johannes Kepler University Linz (joint work with Jiri Outrata)
On a semismooth Newton method for generalized equations

The talk deals with a semismooth Newton method for solving generalized equations (GEs), where the linearization concerns both the single-valued and the multi-valued part and it is performed on the basis of the respective coderivatives. Two conceptual algorithms will be presented and shown to converge locally superlinearly under relatively weak assumptions. Then the second one will be used in order to derive an implementable Newton-type method for a frequently arising class of GEs.

Advances in Polynomial Optimization
Organizer: Luis Zuluaga
Chair: Luis Zuluaga
Olga Kuryatnikova, Tilburg University (joint work with Renata Sotirov, Juan Vera)
New SDP upper bounds for the maximum k-colorable subgraph problem

For a given graph with \( n \) vertices, we look for the largest induced subgraph that can be colored in \( k \) colors such that no two adjacent vertices have the same color. We propose several new SDP upper bounds for this problem. The matrix size in the basic SDP relaxations grows with \( k \). To avoid this growth, we use the invariance of the problem under the color permutations. As a result, the matrix size reduces to order \((n + 1)\), independently of \( k \) or the graph considered. Numerical experiments show that our bounds are tighter than the existing SDP and IP-based bounds for about a half of tested graphs.

Benjamin Peters, Otto von Guericke University Magdeburg
Convexification by means of monomial patterns

A novel convexification strategy based on relaxing monomial relationships is presented. We embed both currently popular strategies, general approaches rooted in nonlinear programming and approaches based on sum-of-squares or moment relaxations, into a unified framework. Within this framework we are able to trade off the quality of relaxation against computational expenses. Our computational experiments show that a combination with a prototype cutting-plane algorithm gives very encouraging results.

Timo de Wolff, TU Braunschweig (joint work with Adam Kurpisz)
New Dependencies of Hierarchies in Polynomial Optimization

We compare four key hierarchies for solving Constrained Polynomial Optimization Problems (CPOP): Sum of Squares (SOS), Sum of Diagonally Dominant (SDSOS), Sum of Nonnegative Circuits (SONC), and the Sherali Adams (SA) hierarchies. We prove a collection of dependencies among these hierarchies. In particular, we show on the Boolean hypercube that Schmüdgen-like versions SDSOS*, SONC*, and SA* of the hierarchies are polynomially equivalent. Moreover, we show that SA* is contained in any Schmüdgen-like hierarchy that provides a \( O(n) \) degree bound.
Geometry and Algorithms for Conic Optimization
Organizer: Fatma Kilinc-Karzan
Chair: Fatma Kilinc-Karzan
Levent Tuncel, University of Waterloo (joint work with Lieven Vandenberghe)
Recent progress in primal-dual algorithms for convex optimization

We will present new primal-dual algorithms for hyperbolic programming problems. Our algorithms have many desired properties including polynomial-time iteration-complexity for computing an approximate solution (for well-posed instances). In the special case of dense SDPs (as well as for symmetric cone programming problems with self-scaled barriers), our algorithms specialize to Nesterov-Todd algorithm. However, for certain sparse SDPs, our algorithms are new and have additional desired properties.

Leonid Faybusovich, University of Notre Dame (joint work with Cunlu Zhou)
Self-concordance and matrix monotonicity with applications to quantum entanglement problem

We construct a new class of objective functions on a symmetric cone compatible in the sense of Nesterov and Nemirovsky with the standard self-concordant barrier attached to the symmetric cone. The construction involves a matrix monotone scalar function on a positive semi-line. This allows us to develop a long-step path-following algorithm for symmetric programming problems with both equality and inequality constraints and objective functions from the class. In particular, the objective function arising in quantum entanglement problem belongs to this class. Numerical results are presented.

Fatma Kilinc-Karzan, Carnegie Mellon University (joint work with C.J. Argue)
On Sufficient and Necessary Conditions for Rank-1 Generatedness Property of Cones

A convex cone $K$ that is a subset of the positive semidefinite (PSD) cone is rank-one generated (ROG) if all of its extreme rays are generated by rank 1 matrices. ROG property is closely related to the characterizations of exactness of SDP relaxations, e.g., of nonconvex quadratic programs. We consider the case when $K$ is obtained as the intersection of the PSD cone with finitely many linear (or conic) matrix inequalities, and identify sufficient conditions that guarantee that $K$ is ROG. In the case of two linear matrix inequalities, we also establish the necessity of our sufficient condition.
Performance Estimation of First-Order Methods
Organizers: François Glineur, Adrien Taylor
Chair: Adrien Taylor
Yoel Drori, Google (joint work with Ohad Shamir)
Performance estimation of stochastic first-order methods

We present an extension to the performance estimation methodology, allowing for a computer-assisted analysis of stochastic first-order methods. The approach is applicable in the convex and non-convex settings, and for various suboptimality criteria including the standard minimal gradient norm of the iterates. We describe the approach, new numerical and analytical bounds on the stochastic gradient method, and a construction of a worst-case example establishing tightness of the analyses.

Donghwan Kim, KAIST
Accelerated Proximal Point Method for Maximally Monotone Operators

This work proposes an accelerated proximal point method for maximally monotone operators. The proof is computer-assisted via the performance estimation problem approach. The proximal point method includes many well-known convex optimization methods, such as the alternating direction method of multipliers and the proximal method of multipliers, and thus the proposed acceleration has wide applications. Numerical experiments will be presented to demonstrate the accelerating behaviors.

François Glineur, Université catholique de Louvain (joint work with Antoine Daccache, Julien Hendrickx)
On the Worst-Case of the Fixed-Step Gradient Method for Arbitrary Stepsizes

The problem of computing the worst-case performance of a given optimization algorithm over a given class of objective functions can in some cases be formulated exactly as a semidefinite optimization problem, whose solution provides both the sought worst-case performance and a description the corresponding objective function. We use this methodology to study the gradient method performing N steps with fixed but arbitrary stepsizes, applied to a smooth convex function. Results suggest the existence of an exponential (in N) number of distinct worst-case behaviours depending on the stepsizes.

Phillipe Rodrigues Sampaio, Veolia Research and Innovation (joint work with Stephane Couturier, Thomas Lecomte, Vincent Martin, David Mouquet, Gabriela Naves Maschietto)
Optimization of district heating networks using a grey-box MINLP approach

District heating networks (DHN) are a driving force for decarbonization and energy efficiency. A DHN produces thermal energy and delivers it over distribution networks to buildings. We propose a production scheduling optimization tool that considers heat production and distribution. We use mixed-integer nonlinear models where heat-only and cogeneration units are handled. The network dynamics is addressed by a black-box simulation model. We employ RBF models for time series forecasting that replace the black-box function to obtain an approximate solution. Results on a real case study are shown.

Miguel Munoz Zuniga, IFPEN (joint work with Delphine Sinquet)
Kriging based optimization of a complex simulator with mixed variables: A randomized exploration of the categorical variables in the Expected Improvement suboptimization

Real industrial studies often boils down to complex optimization problems involving mixed variables and time consuming simulators. To deal with these difficulties we propose the use of a Gaussian process regression surrogate with a suitable kernel able to capture simultaneously the output correlations with respect to continuous and categorical/discrete inputs without relaxation of the categorical variables. The surrogate is integrated in the Efficient Global Optimization method based on the maximization of the Expected Improvement criterion. This maximization is a Mixed Integer Non-Linear problem which we tackle with an adequate optimizer : the Mesh Adaptive Direct Search, integrated in the NOMAD library. We introduce a random exploration of the categorical space with a data-based probability distribution and we illustrate the full strategy accuracy on a toy problem. Finally we compare our approach with other optimizers on a benchmark of functions.
Techniques in Global Optimization
Organizers: Jon Lee, Emily Speakman
Chair: Jon Lee

Daphne Skipper, United States Naval Academy (joint work with Jon Lee, Emily Speakman)

Gaining and losing perspective

We discuss MINLO formulations of the disjunction \( x \in \{0\} \cup [l, u] \), where \( z \) is a binary indicator of \( x \in [l, u] \), and \( y \) captures the behavior of \( x^p \), for \( p > 1 \). This model is useful when activities have operating ranges and we pay a fixed cost for carrying out each activity. Using volume as a measure to compare convex bodies, we investigate a family of relaxations for this model, employing the inequality \( yz^q \geq x^p \), parameterized by the “lifting exponent” \( q \in [0, p - 1] \). We analytically determine the behavior of these relaxations as functions of \( l, u, p \) and \( q \).

Claudia D’Ambrosio, CNRS / École Polytechnique (joint work with Jon Lee, Daphne Skipper, Dimitri Thomopoulos)

Handling separable non-convexities with disjunctive cuts

The Sequential Convex Mixed Integer Non Linear Programming (SC-MINLP) method is an algorithmic approach for handling separable nonconvexities in the context of global optimization. The algorithm is based on a sequence of convex MINLPs providing lower bounds on the optimal solution value. Solving at each iteration a convex MINLP is the main bottleneck of SC-MINLP. We propose to improve this phase by employing disjunctive cuts and solving instead a sequence of convex NLPs. Computational results show the viability of our approach.

Leo Liberti, CNRS / École Polytechnique (joint work with Claudia D’Ambrosio, Pierre-Louis Poirion, Ky Vu)

Random projections for quadratic optimization

Random projections are used as dimension reduction techniques in many situations. They project a set of points in a high dimensional space to a lower dimensional one while approximately preserving all pairwise Euclidean distances. Usually, random projections are applied to numerical data. In this talk we present a successful application of random projections to quadratic programming problems. We derive approximate feasibility and optimality results for the lower dimensional problem, and showcase some computational experiments illustrating the usefulness of our techniques.

Recent Developments in Set Optimization (Part IV)
Organizers: Akhtar A. Khan, Elisabeth Köbis, Christiane Tammer
Chair: Elisabeth Köbis

Radu Strugariu, Gheorghe Asachi Technical University of Iasi (joint work with Marius Durea, Marian Pantiruc)

Stability of the directional regularity

We introduce a type of directional regularity for mappings, making use of a special kind of minimal time function. We devise a new directional Ekeland Variational Principle, which we use to obtain necessary and sufficient conditions for directional regularity, formulated in terms of generalized differentiation objects. Stability of the directional regularity with respect to compositions and sums is analyzed. Finally, we apply this study to vector and scalar optimization problems with single and set-valued maps objectives.

Teodor Chelmus, Alexandru Ioan Cuza University of Iasi (joint work with Marius Durea, Elena-Andreea Florea)

Directional Pareto efficiency

We study a notion of directional Pareto minimality that generalizes the classical concept of Pareto efficiency. Then, considering several situations concerning the objective mapping and the constraints, we give necessary and sufficient conditions for the directional efficiency. We investigate different cases and we propose some adaptations of well-known constructions of generalized differentiation. In this way, the connections with some recent directional regularities come into play. As a consequence, several techniques from the study of genuine Pareto minima are considered in our setting.

Diana Maxim, Alexandru Ioan Cuza University of Iasi (joint work with Elena-Andreea Florea)

Directional minimality concepts in vector optimization

We study sufficient conditions for directional metric regularity of an epigraphical mapping in terms of generalized differentiation objects. The main feature proposed by our approach is the possibility to avoid the demanding assumption on the closedness of the graph of such a mapping. To this aim, we prove a version of Ekeland Variational Principle adapted to the situation we consider. Then, we apply our directional openness result to derive optimality conditions for directional Pareto minimality.
**Computational Optimization**  
Chair: Spyridon Pougkakiotis

Steven Diamond, Stanford University (joint work with Akshay Agrawal)  
**A Rewriting System for Convex Optimization Problems**  
We present a modular rewriting system for translating optimization problems written in a domain-specific language to forms compatible with low-level solver interfaces. Translation is facilitated by reductions, which accept a category of problems and transform instances of that category to equivalent instances of another category. The proposed system is implemented in version 1.0 of CVXPY, a widely used domain-specific language for convex optimization. We illustrate how the system facilitated CVXPY’s extension to disciplined geometric programming, a generalization of geometric programming.

Spyridon Pougkakiotis, University of Edinburgh (joint work with Jacek Gondzio, Kresimir Mihic, John Pearson)  
**Exploiting Circulant Properties of Matrices in Structured Optimization Problems**  
Circulant matrices are prevalent in many areas of mathematics. Their eigenvalue decomposition can be computed expeditiously, using the Fast Fourier Transform (FFT). In this talk, we discuss advantages of exploiting circulant properties of matrices arising in certain structured optimization problems.

Harun Aydilek, Gulf University for Science and Technology (joint work with Ali Allahverdi, Asiye Aydilek)  
**[moved] Minimizing Total Tardiness in a No-Wait Flowshop Scheduling Problem with Separate Setup Times with bounded Makespan**  
No-wait flowshop scheduling problem is addressed to minimize total tardiness where the Cmax is bounded. A new simulated annealing algorithm (NSA) utilizing a block insertion and exchange operators is proposed. NSA is combined with an iterated search where the block SA explores the search space for a smaller total tardiness while the iterated search satisfies the constraint, called PA. PA is compared with 6 closely related and best algorithms. Computational experiments based on simulations reveal that PA reduces the error of the best algorithm by 50 %. The results are statistically tested.

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**Computational Design Optimization (Part IV)**  
Organizers: Martin Siebenborn, Kathrin Welker  
Chair: Kathrin Welker

Martin Berggren, Umeå Universitet (joint work with Anders Bernland, André Massing, Eddie Wadbro)  
**3D acoustic shape optimization including visco-thermal boundary-layer losses**  
When applying shape optimization to design certain acoustic devices, a challenge is to account for effects of the visco-thermal boundary layers that appear in narrow channels and cavities. An accurate model of this phenomenon uses a so-called Wentzell boundary condition together with the Helmholtz equation for the acoustic pressure. For the first time, this model is here used to successfully design such a device, a compression driver feeding a loudspeaker horn. The computations make use of a level-set description of the geometry and the CutFEM framework implemented in the FEniCS platform.

Martin Siebenborn, Universität Hamburg (joint work with Andreas Vogel)  
**A shape optimization algorithm for cellular composites**  
In this talk we present a mesh deformation technique for PDE constrained shape optimization. Introducing a gradient penalization to the inner product for linearized shape spaces, mesh degeneration can be prevented and the scalability of employed solvers can be retained. We illustrate the approach by a shape optimization for cellular composites with respect to linear elastic energy under tension. The influence of the gradient penalization is evaluated and the parallel scalability of the approach demonstrated employing a geometric multigrid solver on hierarchically distributed meshes.

Christian Vollmann, Trier University (joint work with Volker Schulz)  
**Shape optimization for interface identification in nonlocal models**  
Shape optimization has been proven useful for identifying interfaces in models governed by partial differential equations. For instance, shape calculus can be exploited for parameter identification of problems where the diffusivity is structured by piecewise constant patches. On the other hand, nonlocal models, which are governed by integral operators instead of differential operators, have attracted increased attention in recent years. We bring together these two fields by considering a shape optimization problem which is constrained by a nonlocal convection-diffusion equation.
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PDE

Tue.4 H 0107
Optimal Control and Dynamical Systems (Part IV)
Organizers: Cristopher Hermosilla, Michele Palladino
Chair: Cristopher Hermosilla
Maria Soledad Aronna, Fundação Getúlio Vargas (joint work with Monica Motta, Franco Rampazzo)
A higher-order maximum principle for impulsive optimal control problem
We consider a nonlinear control system, affine with respect to an unbounded control $u$ taking values in a closed cone of $\mathbb{R}^m$, and with drift depending on a second, ordinary control $a$, ranging in a bounded set. We provide first and higher order necessary optimality conditions for a Bolza problem associated to this system. We illustrate how the chance of using impulse perturbations, makes it possible to derive a Maximum Principle which includes both the usual maximum condition and higher order conditions involving Lie brackets of drift and non-drift vector fields.

Jorge Becerril, Universidade do Porto
On optimal control problems with irregular mixed constraints
First order necessary conditions for optimal control problems with mixed constraints are well-known when a regularity criterion is satisfied. On the contrary, problems involving non-regular mixed constraints have received little attention, except for some isolated works, despite being relevant in many areas such as robotics and problems involving sweeping systems. We present necessary conditions for problems involving nonregular mixed constraints derived via infinite dimensional optimization. Moreover, we present a form of regularity which leads to the usual first order necessary conditions.

Michele Palladino, Gran Sasso Science Institute
Handling Uncertainty in Optimal Control
The talk discusses one possible model problem for certain tasks in reinforcement learning. The model provides a framework to deal with situations in which the system dynamics are not known and encodes the available information about the state dynamics as a measure on the space of functions. Such a measure updates in time, taking into account all the previous measurements and extracting new information from them. Technical results about the value function of such a problem are stated, and several possible applications to reinforcement learning and the exploration-exploitation tradeoff are discussed.

PDE

Tue.4 H 0112
Fractional/Nonlocal PDEs: Applications, Control, and Beyond (Part I)
Organizers: Harbir Antil, Carlos Rautenberg, Mahamadi Warma
Chair: Harbir Antil
Ekkehard Sachs, Universität Trier
Economic Models with Nonlocal Operators
The Ramsey model is one of the most popular neoclassical growth models in economics. The basic time-dependent model has been extended by a spatial component in recent years, i.e. capital accumulation is modeled as a process not only in time but in space as well. We consider a Ramsey economy where the value of capital depends not only on the respective location but is influenced by the surrounding areas as well. Here, we do not only take spatially local effects modeled by a diffusion operator into account but we also include a nonlocal diffusion term in integral form leading to control PIDEs.

Mahamadi Warma, University of Puerto Rico, Rio Piedras Campus
Controllability of fractional heat equations under positivity constraints
We analyze the controllability properties under positivity constraints of the heat equation involving the fractional Laplacian on the interval $(-1, 1)$. We prove the existence of a minimal (strictly positive) time $T_{\min}$ such that the fractional heat dynamics can be controlled from any non-negative initial datum to a positive steady state, when $s > 1/2$. Moreover, we prove that in this minimal time constrained, controllability can also be achieved through a control that belongs to a certain space of Radon measures. We also give some numerical results.

Carlos Rautenberg, Humboldt-Universität zu Berlin / WIAS
A nonlocal variational model in image processing associated to the spatially variable fractional Laplacian
We propose a new variational model in weighted Sobolev spaces with non-standard weights and applications to image processing. We show that these weights are, in general, not of Muckenhoupt type and therefore the classical analysis tools may not apply. For special cases of the weights, the resulting variational problem is known to be equivalent to the fractional Poisson problem. We propose a finite element scheme to solve the Euler-Lagrange equations, and for the image denoising application we propose an algorithm to identify the unknown weights. The approach is illustrated on several test problems and it yields better results when compared to the existing total variation techniques.
**Recent Advances in Distributionally Robust Optimization**  
Organizer: Peyman Mohajerin Esfahani  
Chair: Peyman Mohajerin Esfahani

Jose Blanchet, Stanford University (joint work with Peter Glynn, Zhengqing Zhou)  
**Distributionally Robust Performance Analysis with Martingale Constraints**

We consider distributionally robust performance analysis of path-dependent expectations over a distributional uncertainty region which includes both a Wasserstein ball around a benchmark model, as well as martingale constraints. These types of constraints arise naturally in the context of dynamic optimization. We show that these problems (which are infinite dimensional in nature) can be approximated with a canonical sample complexity (i.e. square root in the number of samples). We also provide various statistical guarantees (also in line with canonical statistical rates).

John Duchi, Stanford University (joint work with Hongseok Namkoong)  
**Distributional Robustness, Uniform Predictions, and applications in Machine Learning**

A common goal in statistics and machine learning is to learn models that can perform well against distributional shifts, such as latent heterogeneous subpopulations, unknown covariate shifts, or unmodeled temporal effects. We develop and analyze a distributionally robust stochastic optimization framework that learns a model that provides good performance against perturbations to the data-generating distribution. We give a convex optimization formulation for the problem, providing several convergence guarantees, including finite sample upper and lower minimax bounds.

Peyman Mohajerin Esfahani, TU Delft (joint work with Daniel Kuhn, Viet Anh Nguyen, Soroosh Shafieezadeh Abadeh)  
**Wasserstein Distributionally Robust Optimization: Theory and Applications in Machine Learning**

In this talk, we review recent developments in the area of distributionally robust optimization, with particular emphasis on a data-driven setting and robustness to the so-called Wasserstein ambiguity set. We argue that this approach has several conceptual and computational benefits. We will also show that Wasserstein distributionally robust optimization has interesting ramifications for statistical learning and motivates new approaches for fundamental learning tasks such as classification, regression, maximum likelihood estimation or minimum mean square error estimation, among others.
Embracing Extra Information in Distributionally Robust Models  
Organizer: Rui Gao  
Chair: Rui Gao

Zhenzhen Yan, Nanyang Technological University (joint work with Louis Chen, Will Ma, Karthik Natarajan, David Simchi-Levi)

**Distributionally Robust Linear and Discrete Optimization with Marginals**

In this paper, we study the class of linear and discrete optimization problems in which the objective coefficients are chosen randomly from a distribution, and the goal is to evaluate robust bounds on the expected optimal value as well as the marginal distribution of the optimal solution. The set of joint distributions is assumed to be specified up to only the marginal distributions. Though the problem is NP-Hard, we establish a primal-dual analysis that yields sufficiency conditions for poly-time solvability as well as computational procedures. Application problems are also explored.

Mathias Pohl, University of Vienna

**Robust risk aggregation with neural networks**

We consider settings in which the distribution of a multivariate random variable is partly ambiguous: The ambiguity lies on the level of dependence structure, and that the marginal distributions are known. We work with the set of distributions that are both close to a given reference measure in a transportation distance and additionally have the correct marginal structure. The goal is to find upper and lower bounds for integrals of interest with respect to distributions in this set. The described problem appears naturally in the context of risk aggregation.

Zhiping Chen, Xi’an Jiaotong University

**Stability analysis of optimization problems with distributionally robust dominance constraints induced by full random recourse**

We derive the quantitative stability results, under the appropriate pseudo metric, for stochastic optimization problems with distributionally robust dominance constraints induced by full random recourse. To this end, we first establish the qualitative and quantitative stability results of the optimal value function and the optimal solution set for optimization problem with k-th order stochastic dominance constraints under the Hausdorff metric, which extend the present results to the locally Lipschitz continuity case.

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Sparse Optimization and Information Processing - Contributed Session I

Organizer: Shoham Sabach  
Chair: Jordan Ninin

Nikolaos Ploskas, University of Western Macedonia (joint work with Nikolaos Sahinidis, Nikolaos Samaras)

**An advanced initialization procedure for the simplex algorithm**

This paper addresses the computation of an initial basis for the simplex algorithm for linear programming. We propose six algorithms for constructing an initial basis that is sparse and will reduce the fill-in and computational effort during LU factorization and updates. Over a set of 62 large benchmarks, the best proposed algorithm produces remarkably sparse starting bases. Taking into account only the hard instances, the proposed algorithm results in 23% and 30% reduction of the geometric mean of the execution time of CPLEX’s primal and dual simplex algorithm, respectively.

Jordan Ninin, ENSTA-Bretagne (joint work with Ramzi Ben Mhenni, Sebastien Bourguignon)

**Global Optimization for Sparse Solution of Least Squares Problems**

Finding low-cardinality solutions to least-squares problems has found many applications in signal processing. We propose a branch-and-bound algorithm for global optimization of cardinality-constrained and cardinality-penalized least-squares, and cardinality minimization under quadratic constraints. A tree-search exploration strategy is built based on forward selection heuristics, and the continuous relaxation problems are solved with a dedicated algorithm inspired by homotopic methods. On all conducted experiments, our algorithms at least equal and often outperform the MIP solver CPLEX.

Montaz Ali, WITS (joint work with Ahdam Stoltz)

**Call Center’s Optimization Problem**

The special and unique features of this problem are then shown to be: the need to perform scheduling on a batch basis every day, without knowledge of what will occur the following day and also the requirement that resources (call centre capacity) are fully utilized and not exceeded. The result of the research is that a new mathematical model called the Critical Time Window Resource Levelling Problem (CTWRLP) with the Continual Rescheduling method is developed and proposed as a method for solving the real world scheduling problem.
Regularized Tensor Methods for Minimizing Functions with Hölder Continuous Higher-Order Derivatives

In this work, we propose p-order methods for minimization of convex functions that are p-times differentiable with \( \nu \)-Hölder continuous p-th derivatives. For the schemes without acceleration, we establish iteration complexity bounds of \( O(\epsilon^{-(p+\nu-1)}) \). Assuming that \( \nu \) is known, we obtain an improved complexity bound of \( O(\epsilon^{-(p+\nu)}) \) for the corresponding accelerated scheme. For the case in which \( \nu \) is unknown, we present a universal accelerated tensor scheme with complexity of \( O(\epsilon^{-p/(p+1)(p+\nu-1)}) \). A lower complexity bound is also obtained.

Yadan Chen, Academy of Mathematics and System Science, Chinese Academy of Sciences (joint work with Xin Liu, Yaxiang Yuan)

Alternating Direction Method of Multipliers to Solve Two Continuous Models for Graph-based Clustering

Clustering is an important topic in data science. The popular approaches including K-means algorithm and nonnegative matrix factorization (NMF) directly use data points as input and consider problems in Euclidean space. In this paper, we propose a new approach which considers Gaussian kernel based on graph construction. Moreover, the final cluster labels can be directly obtained without post-processing. The experimental results on real data sets have shown that the proposed approach achieves better clustering results in terms of accuracy and mutual information.
Structural Design Optimization (Part I)
Organizer: Tamás Terlaky
Chair: Tamás Terlaky
Jacek Gondzio, The University of Edinburgh (joint work with Alemseged Gebrehiwot Weldeyesus)
Computational Challenges in Structural Optimization
We address challenges related to solving real-world problems in structural optimization. Such problems arise, for example, in layout optimization of tall buildings, long bridges, or large-spanning roofs. We propose to solve such problems with a highly specialized primal-dual interior point method. The problems may be formulated as (very large) linear or, if additional stability concerns are addressed, semidefinite programs. In this talk, we will focus on computational challenges arising in such problems and efficient ways to overcome them.

Alexander Brune, University of Birmingham (joint work with Michal Kočvara)
Modified Barrier Multigrid Methods for Topology Optimization
One of the challenges of topology optimization lies in the size of the problems, which easily involve millions of variables. We consider the example of the variable thickness sheet (VTS) problem and propose a Penalty-Barrier Multiplier (PBM) method to solve it. In each iteration, we minimize a generalized augmented Lagrangian by the Newton method. The arising large linear systems are reduced to systems suitable for a standard multigrid method. We apply a multigrid preconditioned MINRES method. The algorithm is compared with the optimality criteria (OC) method and an interior point (IP) method.

Tamás Terlaky, Lehigh University, Bethlehem, PA (joint work with Ramin Fakhimi, Sicheng He, Weiming Lei, Joaquim Martins, Mohammad Shahabsafa, Luis Zuluaga)
Truss topology design and sizing optimization with kinematic stability
We propose a novel mathematical optimization model for Truss Topology Design and Sizing Optimization (TTDSO) problem with Euler buckling constraints. We prove that the proposed model, with probability 1, is delivering a kinematically stable structure. Computational experiments, using an adaptation of our MILO-moving neighborhood search strategy, show that our model and computational approach is superior when compared to other approaches.

Mathematical Optimization in Signal Processing (Part I)
Organizers: Ya-Feng Liu, Zhi-Quan Luo
Chair: Zhi-Quan Luo
Sergiy A. Vorobyov, Aalto University (joint work with Mihai I. Florea)
Accelerated majorization based optimization for large-scale signal processing: Some new theoretical concepts and applications
Numerous problems in signal processing are cast or approximated as large-scale convex optimization problems. Because of their size, such problems can be solved only using first-order methods. Acceleration is then becomes the main feature of the methods. We will overview some of our recent results on the topic (the majorization minimization framework appears to be an umbrella for many such methods including Nesterov’s FGM, FISTA, our ACGM, and others) and give a number of successful applications in signal processing (LASSO, NNLS, L1LR, RR, EN, radar waveform design with required properties).

Yang Yang, Fraunhofer ITWM (joint work with Marius Pesavento)
Parallel best-response algorithms for nonsmooth nonconvex optimization with applications in matrix factorization and network anomaly detection
Block coordinate descent algorithms based on nonlinear best-response, or Gauss-Seidel algorithm, is one of the most popular algorithm in large-scale nonsmooth optimization. In this paper, we propose a parallel (Jacobi) best-response algorithm, where a stepsize is introduced to guarantee the convergence. Although the original problem is nonsmooth, we propose a simple line search method carried out over a properly designed smooth function. The proposed algorithm, evaluated for the nonsmooth nonconvex sparsity-regularized rank minimization problem, exhibits fast convergence and low complexity.

Bo Jiang, Nanjing Normal University (joint work with Shiqian Ma, Anthony Man-Cho So, Shuzhong Zhang)
Vector Transport-Free SVRG with General Retraction for Riemannian Optimization: Complexity Analysis and Practical Implementation
We propose a vector transport-free stochastic variance reduced gradient (TF-SVRG) method for empirical risk minimization over Riemannian manifold. The TF-R-SVRG method handles general retraction operations and does not need additional vector transport evaluations as done by most existing manifold SVRG methods. We analyze the iteration complexity of TF-R-SVRG for obtaining an ε-stationary point and its local linear convergence by assuming the Lojasiewicz inequality. We also incorporate the Barzilai-Borwein step size and design a very practical TF-R-SVRG-BB method.
**Wed.1 H 0104**

**BIG**

**Distributed Algorithms for Constrained Nonconvex Optimization: Clustering, Network Flows, and Two-Level Algorithms**

**Organizers:** Andy Sun, Wotao Yin  
**Chair:** Wotao Yin  
**Kaizhao Sun, Georgia Institute of Technology (joint work with Andy Sun)**

**A two-level distributed algorithm for constrained nonconvex programs with global convergence**

This work is motivated by the desire to solve network constrained nonconvex programs with convergence guarantees. We propose a two-level algorithm with an inner level of ADMM in an augmented Lagrangian framework that can guarantee global convergence for a wide range of smooth and nonsmooth nonconvex constrained programs. We demonstrate the effectiveness of the algorithm with comparison to existing algorithms on some important classes of problems and discuss its convergence rate properties.

**Tsung-Hui Chang, The Chinese University of Hong Kong, Shenzhen**

**Large-Scale Clustering by Distributed Orthogonally Constrained NMF Model**

The non-negative matrix factorization (NMF) model with an additional orthogonality constraint on one of the factor matrices, called the orthogonal NMF (ONMF), has been found to provide improved clustering performance over the $K$-means. We propose an equivalent problem reformulation that transforms the orthogonality constraint into a set of norm-based non-convex equality constraints. We then apply one smooth and one non-smooth penalty approach to handle these non-convex constraints, which result in desirable separable structures for efficient parallel computations.

**Tao Jiang, University of Waterloo (joint work with Stephen Vavasis, Chen Wen (Sabrina) Zhai)**

**Recovery of a mixture of Gaussians by sum-of-norms clustering**

Sum-of-norms clustering is a novel clustering method using convex optimization. Recently, Panahi et al. proved that sum-of-norms clustering is guaranteed to recover a mixture of Gaussians under the restriction that the sample size is not too large. This paper lifts the restriction and shows that sum-of-norms clustering with equal weights recovers a mixture of Gaussians even as the number of samples tends to infinity. Our proof relies on an interesting characterization of clusters computed by sum-of-norms clustering developed inside a proof of the agglomeration conjecture by Chiquet et al.

**Wed.1 H 0110**

**BIG**

**Modern Optimization Methods in Machine Learning**

**Organizer:** Qingna Li  
**Chair:** Qingna Li  
**Chengjing Wang, Southwest Jiaotong University (joint work with Defeng Sun, Peipei Tang, Kim-Chuan Toh)**

**A sparse semismooth Newton based proximal majorization-minimization algorithm for nonconvex square-root-loss regression problems**

In this paper, we consider high-dimensional nonconvex square-root-loss regression problems. We shall introduce a proximal majorization-minimization (PMM) algorithm for these problems. Our key idea for making the proposed PMM to be efficient is to develop a sparse semismooth Newton method to solve the corresponding subproblems. By using the Kurdyka-Lojasiewicz property exhibited in the underlying problems, we prove that the PMM algorithm converges to a $d$-stationarity point. Extensive numerical experiments are presented to demonstrate the high efficiency of the proposed PMM algorithm.

**Peipei Tang, Zhejiang University City College (joint work with Dunbiao Niu, Enbin Song, Chengjing Wang, Qingsong Wang)**

**A semismooth Newton based augmented Lagrangian method for solving the support vector machine problems**

In this talk, we propose a highly efficient semismooth Newton based augmented Lagrangian method for solving a large-scale convex quadratic programming problem generated by the dual of the SVM with constraints consisting of one linear equality constraint and a simple box constraint. By leveraging on available error bound results to realize the asymptotic superlinear convergence property of the augmented Lagrangian method, and by exploiting the second-order sparsity of the problem through the semismooth Newton method, the algorithm we propose can efficiently solve these difficult problems.

**Qingna Li, Beijing Institute of Technology (joint work with Juan Yin)**

**A Semismooth Newton Method for Support Vector Classification and Regression**

SVM is an important and fundamental technique in machine learning. In this talk, we apply a semismooth Newton method to solve two typical SVM models: the $L^2$-loss SVC model and the $\epsilon$-$L^2$-loss SVR model. A common belief on the semismooth Newton method is its fast convergence rate as well as high computational complexity. Our contribution is that by exploring the sparse structure of the models, we significantly reduce the computational complexity, meanwhile keeping the quadratic convergence rate. Extensive numerical experiments demonstrate the outstanding performance of the method.
Parallel Sessions Abstracts Wed.1 11:30–12:45

**VIS**

**Complementarity and Variational Inequalities - Contributed Session I**

Chair: Felipe Lara

Gayatri Pany, Singapore University of Technology and Design

A variational inequality approach to model green transport network

We aim to develop a transport network model that maximizes societal benefits and minimizes environmental effects in terms of energy use and GHG emissions. The model pertains to the use of different modes of transport, like automated vehicles, electric vehicles. Based on different modes of travel, a multi-criteria transport model will be formulated. The proposed approach will be to derive the optimality and the equilibrium conditions, which will satisfy a variational inequality. The equilibrium will be characterized by analyzing the continuity and strict monotonicity of the underlying operator.

Pankaj Gautam, Indian Institute of Technology (BHU) Varanasi (joint work with Tanmoy Som Tanmoy)

Common zero of lower semicontinuous function and monotone operator

In this talk, we consider the problem to find the common zero of a non-negative lower semicontinuous function and a maximal monotone operator in a real Hilbert space. Algorithms permit us to solve the problem when the operators are not the projection operator, or the projection is not easy to compute. As an application, the result presented is used to study the strong convergence theorem for split equality variational problem. Some numerical examples are included to demonstrate the efficiency and applicability of the method.

Felipe Lara, Getulio Vargas Foundation

Existence results for equilibrium problems and mixed variational inequalities

We use asymptotic analysis for studying noncoercive pseudomonotone equilibrium problems and noncoercive mixed variational inequalities, both in the nonconvex case. We provide general necessary and sufficient optimality conditions for the set of solutions to be nonempty and compact for both problems. As a consequence, a characterization of the nonemptiness and compactness of the solution sets is given. Finally, a comparison between our results with previous ones presented in the literature is given.

This talk is based on two papers in collaboration with Alfredo Iusem from IMPA, Brazil.

**VIS**

**Semismoothness for Set-Valued Mappings and Newton Method (Part II)**

Organizer: Helmut Gfrerer
Chair: Helmut Gfrerer

Martin Brokate, TU München

Sensitivity of rate-independent evolutions

Rate independent evolutions are inherently nonsmooth. In this talk we present results concerning weak differentiability properties of such evolutions resp. the solution operator of the associated variational inequality. In particular, we discuss whether these operators are semismooth.

Nico Strasdat, TU Dresden (joint work with Andreas Fischer)

A Newton-type method for the solution of complementarity problems

Recently, a Newton-type method for the solution of Karush-Kuhn-Tucker system has been developed, that builds on the reformulation of the system as system of nonlinear equations by means of the Fischer-Burmeister function. Based on a similar idea, we propose a constrained Levenberg-Marquardt-type method for solving a general nonlinear complementarity problem. We show that this method is locally superlinear convergent under certain conditions which allow nonisolated and degenerate solutions.

Anna Walter, TU Darmstadt (joint work with Stefan Ulbrich)

Numerical Solution Strategies for the Elastoplasticity Problem with Finite Deformations

We consider the optimal control of elastoplasticity problems with large deformations motivated by engineering applications. To solve the optimal control problem, we need to handle the occurring flow rule within the simulation. Therefore we analyze different solution approaches which are motivated by methods applied in linear elastoplasticity but extended to the case of a multiplicative split of the deformation gradient. Due to the high complexity of the resulting model, we include reduced order models to speed up the simulation process. We present theoretical as well as computational aspects.
Semidefinite Approaches to Combinatorial Optimization
Organizer: Renata Sotirov
Chair: Renata Sotirov
Hao Hu, Tilburg University (joint work with Renata Sotirov, Henry Wolkowicz)
Combining symmetry reduction and facial reduction for semidefinite programming

For specially structured SDP instances, symmetry reduction is an application of representation theory to reduce the dimension of the feasible set. For an SDP instance that fails Slater’s condition, facial reduction technique can be employed to find the smallest face of the PSD cone containing the feasible region. The resulting SDP instance is of smaller dimension and satisfies Slater’s condition. In this talk, we show that symmetry reduction and facial reduction can be exploited at the same time. Our method is simple to implement, and is applicable for a wide variety of applications of SDPs.

Christian Truden, Alpen-Adria-Universität Klagenfurt (joint work with Franz Rendl, Renata Sotirov)
Lower Bounds for the Bandwidth Problem

The bandwidth problem asks for a simultaneous permutation of the rows and columns of the adjacency matrix of a graph such that all nonzero entries are as close as possible to the diagonal. We present novel approaches to obtain lower bounds on the bandwidth problem and introduce a vertex partition problem to bound the bandwidth of a graph. By varying sizes of partitions, we have a trade-off between quality of bounds and efficiency of computing them. To compute lower bounds, we derive several SDP relaxations. Finally, we evaluate our approach on a carefully selected set of benchmark instances.

Daniel Brosch, Tilburg University (joint work with Etienne de Klerk)
A new look at symmetry reduction of semidefinite relaxations of the quadratic assignment problem

The Jordan reduction, a symmetry reduction method for semidefinite programming, was recently introduced for symmetric cones by Parrilo and Permenter. We extend this method to the doubly nonnegative cone and investigate its application to a strong relaxation of the quadratic assignment problem. This reduction is then used to efficiently calculate better bounds for certain discrete energy minimization problems, which initially have the form of semidefinite programs too large to be solved directly.

Polynomial Optimization (Part I)
Organizer: Grigoriy Blekherman
Chair: Grigoriy Blekherman
Oguzhan Yuruk, TU Braunschweig (joint work with E. Feliu, N. Kainha, B. Sturmfels, Timo de Wolff)
An analysis of multistationarity in n-site phosphorylation cycle using circuit polynomials

Parameterized ordinary differential equation systems are crucial for modeling in biochemical reaction networks under the assumption of mass-action kinetics. Various questions concerning the signs of multivariate polynomials in positive orthant arise from studying the solutions’ qualitative behavior with respect to parameter values. In this work, we utilize circuit polynomials to find symbolic certificates of nonnegativity to provide further insight into the number of positive steady states of the n-site phosphorylation cycle model.

João Gouveia, University of Coimbra (joint work with Mina Saeed Bostanabad, Alexander Kovacec)
Matrices of bounded factor width and sums of $k$-nomial squares

In 2004, Boman et al introduced the concept of factor width of a semidefinite matrix $A$. This is the smallest $k$ for which one can write the matrix as $A = VV^T$ with each column of $V$ containing at most $k$ non-zeros. In the polynomial optimization context, these matrices can be used to check if a polynomial is a sum of squares of polynomials of support at most $k$. We will prove some results on the geometry of the cones of matrices with bounded factor widths and their

Grigoriy Blekherman, Georgia Institute of Technology
Symmetry and Nonnegativity

I will discuss several recent results on symmetric nonnegative polynomials and their approximations by sums of squares. I will consider several types of symmetry, but the situation is especially interesting in the limit as the number of variables tends to infinity. There are diverse applications to quantum entanglement, graph density inequalities and theoretical computer science.
New Frontiers in Splitting Algorithms for Optimization and Monotone Inclusions (Part I)
Organizer: Patrick L. Combettes
Chair: Patrick L. Combettes
Bang Cong Vu, École Polytechnique Fédérale de Lausanne (EPFL)
A splitting method for three operators involving Lipschitzian operators

We investigate the problem of finding a zero point of the sum of 3 operators where one of them is monotone Lipschitzian. We propose a new splitting method for solving this inclusion in real Hilbert spaces. The proposed framework unifies several splitting method existing in the literature. The weak convergence of the iterates is proved. The strong convergence is also obtained under an additional assumption. Applications to sums of composite monotone inclusions and composite minimization problems are demonstrated.

Saverio Salzo, Istituto Italiano di Tecnologia
Parallel random block-coordinate forward-backward algorithm: A complete convergence analysis

We study the block coordinate forward-backward algorithm where the blocks are updated in a random and possibly parallel manner. We consider the convex case and provide a unifying analysis of the convergence under different hypotheses, advancing the state of the art in several aspects.

Patrick L. Combettes, North Carolina State University (joint work with Minh N. Bui)
A general Bregman-based splitting scheme for monotone inclusions

We present a unifying framework for solving monotone inclusions in general Banach spaces using Bregman distances. This is achieved by introducing a new property that includes in particular the standard cocoercivity property. Several classical and recent algorithms are featured as special cases of our framework. The results are new even in standard Euclidean spaces. Applications are discussed as well.

Convex and Nonsmooth Optimization - Contributed Session I
Chair: Vladimir Shikhman
Igor Konnov, Kazan Federal University
Gradient Methods with Regularization for Optimization Problems in Hilbert spaces

We suggest simple implementable modifications of gradient type methods for smooth convex optimization problems in Hilbert spaces, which may be ill-posed. At each iteration, the selected method is applied to some perturbed optimization problem, but we change the perturbation only after satisfying a simple estimate inequality, which allows us to utilize mild rules for the choice of the parameters. Within these rules we prove strong convergence and establish complexity estimates for the methods. Preliminary results of computational tests confirm efficiency of the proposed modification.

Ali Dorostkar, Isfahan Mathematics House (IMH)
An Introduction to Fractional Dimensional Optimization Problem

A general framework for fractional dimensional optimization method is introduced. It is shown that there is a tangent line of function in fractional dimensions which directly passes through the root. The method is presented to investigate a possibility of direct solution of optimization problem, however; analysis of fractional dimension needs further investigation. Beside method has a possibility to use for convex and non-convex and also local and global optimization problems. As a point, fractional dimensional optimization method opens a different view and direction for optimization problem.

Vladimir Shikhman, Chemnitz University of Technology (joint work with David Müller, Yurii Nesterov)
Discrete choice prox-functions on the simplex

We derive new prox-functions on the simplex from additive random utility models of discrete choice. They are convex conjugates of the corresponding surplus functions. We explicitly derive the convexity parameter of discrete choice prox-functions associated with generalized extreme value models, and specifically with generalized nested logit models. Incorporated into subgradient schemes, discrete choice prox-functions lead to natural probabilistic interpretations of the iteration steps. As illustration we discuss an economic application of discrete choice prox-functions in consumption cycle.
Emerging Trends in Derivative-Free Optimization (Part II)
Organizers: Ana Luisa Custodio, Sébastien Le Digabel, Margherita Porcelli, Francesco Rinaldi, Stefan Wild
Chair: Nikolaus Hansen

Anne Auger, Inria (joint work with Dimo Brockhoff, Nikolaus Hansen, Cheikh Touré)
COMO-CMA-ES: a linearly convergent derivative free multi-objective solver

We present a new multi-objective optimization solver, COMO-CMA-ES that aim at converging towards \( p \) points of the Pareto set solution of a multi-objective problem. Denoting \( n \) the search space dimension, the solver approaches the \( p \times n \)-dimensional problem of finding \( p \) solutions maximizing the hypervolume by a dynamic subspace optimization. Each subspace optimization is performed with the CMA-ES solver. We show empirically that COMO-CMA-ES converges linearly on bi-convex-quadratic problems and that it has better performance than the MO-CMA-ES, NSGA-II and SMS-EMOA algorithms.

Ludovic Salomon, Polytechnique Montréal (joint work with Jean Béjean, Sébastien Le Digabel)
MADMS: Mesh adaptive direct multisearch for blackbox constrained multiobjective optimization

Derivative-free multiobjective optimization involves the presence of two or more conflicting objective functions, considered as blackboxes for which no derivative information is available. This talk describes a new extension of the Mesh Adaptive Direct Search (MADS) algorithm, called MADMS. This algorithm keeps a list of non-dominated points which converges to the Pareto front. As for the single-objective MADS algorithm, this method is built around an optional search step and a poll step. Convergence results and promising computational experiments will be described.

Ana Luisa Custodio, Universidade Nova de Lisboa (joint work with Maria do Carmo Brás)
On the use of quadratic polynomial models in multiobjective directional direct search

Polynomial interpolation or regression models are an important tool in Derivative-free Optimization, acting as surrogates of the real function. In this work we propose the use of these models in a multiobjective framework, namely the one of Direct Multisearch. Previously evaluated points are used to build quadratic polynomial models, which are minimized in an attempt of generating nondominated points of the true function, defining a search step for the algorithm. We will detail the proposed methodology and report compelling numerical results, stating its competitiveness.
**Wed.1 H 0105**

**Geometry in Non-Convex Optimization (Part I)**

*Organizers*: Nicolas Boumal, André Uschmajew, Bart Vandereycken  
*Chair*: André Uschmajew

**Suovit Sra**, MIT

**Riemannian optimization for some problems in probability and statistics**

Non-convex optimization is typically intractable. This intractability can be surmounted if the problem possesses enough structure. This hidden convexity not only yields proofs not only of tractability but also suggests practical algorithmic approaches. I will highlight several examples from machine learning and statistics, where non-Euclidean geometry plays a valuable role in obtaining efficient solutions to fundamental tasks (e.g., eigenvector computation, gaussian mixtures, Wasserstein barycenters, etc.).

**Nick Vandevenhoven**, KU Leuven (joint work with Paul Breiding)

**Riemannian optimization for computing canonical polyadic decompositions**

The canonical tensor rank approximation problem consists of approximating a real-valued tensor by one of low canonical rank, which is a challenging non-linear, non-convex, constrained optimization problem, where the constraint set forms a non-smooth semi-algebraic set. We discuss Riemannian optimization methods for solving this problem for small-scale, dense tensors. The proposed method displayed up to two orders of magnitude improvements in computational time for challenging problems, as measured by the condition number of the tensor rank decomposition.

**Nicolas Boumal**, Princeton University

**Complexity of optimization on manifolds, and cubic regularization**

Unconstrained optimization can be framed generally within the framework of optimization on Riemannian manifolds. Over the years, standard algorithms such as gradient descent, trust regions and cubic regularization (to name a few) have been extended to the Riemannian setting, with excellent numerical success. I will show how, under appropriately chosen assumptions, their worst-case iteration complexity analyses carry over seamlessly from the Euclidean to the Riemannian case, then I will discuss finer points related to these assumptions.

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**Wed.1 H 1012**

**Nonlinear Optimization Methods and Their Global Rates of Convergence**

*Organizer*: Geovani Grapiglia  
*Chair*: Geovani Grapiglia

**Oliver Hinder**, Stanford Univ. (joint work with Yair Carmon, John Duchi, Aaron Sidford)

**The complexity of finding stationary points of nonconvex functions**

We investigate the complexity of finding stationary points of smooth (potentially) nonconvex functions. We provide both new algorithms, adapting Nesterov’s accelerated methods to the nonconvex setting (achieving faster convergence than gradient descent), and fundamental algorithm-independent lower bounds on the complexity of finding stationary points. Our bounds imply that gradient descent and cubic-regularized Newton’s method are optimal within their natural function classes.

**Philippe L. Toint**, University of Namur (joint work with Stefania Bellavia, Coralia Cartis, Nick Gould, Gianmarco Gurioli, Bendetta Morini)

**Recent results in worst-case evaluation complexity for smooth and non-smooth, exact and inexact, nonconvex optimization**

We present a review of results on the worst-case complexity of minimization algorithm for nonconvex problems using potentially high-degree models. Global complexity bound are presented that are valid for any model’s degree and any order of optimality, thereby generalizing known results for first- and second-order methods. An adaptive regularization algorithm using derivatives up to degree p will produce an \( \epsilon \)-approximate \( q \)-th order minimizer in at most \( O(\epsilon^{(p+1)/(p-q+1)}) \) evaluations. We will also extend these results to the case of inexact objective function and derivatives.

**Ernesto G. Birgin**, Universidade de São Paulo (joint work with J. M. Martinez)

**A Newton-like method with mixed factorizations and cubic regularization and its usage in an Augmented Lagrangian framework**

A Newton-like method for unconstrained minimization is introduced that uses a single cheap factorization per iteration. Convergence and complexity results, even in the case in which the subproblems’ Hessians are far from being Hessians of the objective function, are presented. When the Hessian is Lipschitz-continuous, the proposed method enjoys \( O(\epsilon^{-3/2}) \) evaluation complexity for first-order optimality and \( O(\epsilon^{-3}) \) for second-order optimality. The usage of the introduced method for bound-constrained minimization and for nonlinear programming is reported.
Practical Aspects of Nonlinear Optimization
Organizer: Coralia Cartis
Chair: Tim Mitchell

Hiroshige Dan, Kansai University (joint work with Koei Sakiyama)
Automatic Differentiation Software for Large-scale Nonlinear Optimization Problems

Automatic differentiation (AD) is essential for solving large-scale nonlinear optimization problems. In this research, we implement an AD software which is particularly designed for large-scale nonlinear optimization problems (NLPs). Large-scale NLPs are usually expressed by indexed variables and functions and our AD software can deal with such indexed elements effectively. Numerical experiments show the superiority of our AD software for large-scale NLPs. Moreover, our AD software can compute partial derivatives with arbitrary precision arithmetic.

Michael Feldmeier, The University of Edinburgh
structure detection in generic quadratic programming

Benders’ decomposition is a popular choice when solving optimization problems with complicating variables. Implementations are often problem dependent, or at least require the user to specify the master and sub-problems. In the past, attempts have been made to detect automatically suitable structure in the constraint matrix of generic (mixed-integer) linear programmes. In this talk we discuss an extension of this approach to quadratic programming and will cover different approaches to finding suitable structure in the constraint and Hessian matrices. Initial numerical results will be given.

Tim Mitchell, Max Planck Institute for Dynamics of Complex Technical Systems (joint work with Frank E. Curtis, Michael Overton)
Relative Minimization Profiles: A Different Perspective for Benchmarking Optimization and Other Numerical Software

We present relative minimization profiles (RMPs) for benchmarking general optimization methods and other numerical algorithms. Many other visualization tools, e.g., performance profiles, consider success as binary: was a problem "solved" or not. RMPs instead consider degrees of success, from obtaining solutions to machine precision to just finding feasible ones. RMPs concisely show how methods compare in terms of the amount of minimization or accuracy attained, finding feasible solutions, and speed of progress, i.e., how overall solution quality changes for different computational budgets.
Efficient Numerical Solution of Nonconvex Problems
Organizers: Serge Gratton, Elisa Riccietti
Chair: Elisa Riccietti
Serge Gratton, INP-IRIT
Minimization of nonsmooth nonconvex functions using inexact evaluations and its worst-case complexity

An adaptive regularization algorithm using inexact function and derivatives evaluations is proposed for the solution of composite nonsmooth nonconvex optimization. It is shown that this algorithm needs at most $O(\log(\varepsilon)\varepsilon^{-2})$ evaluations of the problem’s functions and their derivatives for finding an $\varepsilon$-approximate first-order stationary point. This complexity bound is within a factor $|\log(\varepsilon)|$ of the optimal bound known for smooth and nonsmooth nonconvex minimization with exact evaluations.

Selime Gurol, IRT Saint Exupéry / CERFACS (joint work with Francois Gallard, Serge Gratton, Benoit Pauwels, Philippe L. Toint)
Preconditioning of the L-BFGS-B algorithm for aerodynamic shape design

The classical L-BFGS-B algorithm, used to minimize an objective function depending on variables that must remain within given bounds, is generalized to the case where the algorithm accepts a general preconditioner. We will explain the main ingredients of the preconditioned algorithm especially focusing on the efficient computation of the so-called generalized Cauchy point. This algorithm is implemented in Python and is applied to the aerodynamic shape design problem, which consists of solving several optimization problems, to reduce the number of expensive objective function evaluations.

Elisa Riccietti, University of Toulouse (joint work with Henri Calandra, Serge Gratton, Xavier Vasseur)
Multilevel optimization methods for the training of artificial neural networks

We investigate the use of multilevel methods (recursive procedures that exploit the knowledge of a sequence of approximations to the original objective function, defined on spaces of reduced dimension, to build alternative models to the standard Taylor one, cheaper to minimize) to solve problems that do not have an underlying geometrical structure. Specifically, we focus on an important class of such problems, those arising in the training of artificial neural networks. We propose a strategy based on algebraic multigrid techniques to build the sequence of coarse problems.

Optimal Control of Nonsmooth Systems (Part I)
Organizers: Constantin Christof, Christian Clason
Chair: Christian Clason
Daniel Walter, RICAM
Accelerated generalized conditional gradient methods

We present a generalized version of the well-known Frank-Wolfe method for minimizing a composite functional $j(u) = f(u) + g(u)$. Here, $f$ is a smooth function and $g$ is in general nonsmooth but convex. The optimization space is given as the dual of a separable, generally non-reflexive, Banach space. We address theoretical properties of the method, such as worst-case convergence rates and mesh-independence results. For specific instances of the problem we further show how additional acceleration steps eventually lead to optimal convergence rates.

Lukas Hertlein, Technische Universität München (joint work with Michael Ulbrich)
Optimal control of elliptic variational inequalities using bundle methods in Hilbert space

Motivated by optimal control problems for elliptic variational inequalities we develop an inexact bundle method for nonsmooth nonconvex optimization subject to general convex constraints. The proposed method requires only inexact evaluations of the cost function and of an element of Clarke’s subdifferential. A global convergence theory in a suitable infinite-dimensional Hilbert space setting is presented. We discuss the application of our framework to optimal control of the (stochastic) obstacle problem and present numerical results.

Sebastian Engel, Technische Universität München (joint work with Philip Trautmann, Boris Vexler)
Variational discretization for an optimal control problem governed by the wave equation with time depending BV controls

We will consider a control problem $(P)$ for the wave equation with a standard tracking-type cost functional and a semi-norm in the space of functions with bounded variations ($BV$) in time. The considered controls in $BV$ act as a forcing function on the wave equation. This control problem is interesting for practical applications because the semi-norm enhances optimal controls which are piecewise constant. In this talk we focus on a variationally discretized version of $(P)$. Under specific assumptions we can present optimal convergence rates for the controls, states, and cost functionals.
A general sufficient condition for avoiding infimum-gaps when the domain of an optimal control problem is densely embedded in a larger family of processes is here presented. This condition generalizes some recently established criteria for convex or impulsive embedding, and is based on “abundantness,” a dynamics-related notion of density introduced by J. Warga.

Peter Wolenski, Louisiana State University
Optimality conditions for systems with piecewise constant dynamics

We will present results on the minimal time function where the velocity sets are locally the same.

Piernicola Bettiol, Université de Bretagne Occidentale (joint work with Carlo Mariconda)
Some regularity results for minimizers in dynamic optimization

We consider the classical problem of the Calculus of Variations, and we formulate a new Weierstrass-type condition for local minimizers of the reference problem. It allows to derive important properties for a broad class of problems involving a nonautonomous, possibly extended-valued, Lagrangian. A first consequence is the validity of a Du Bois-Reymond type necessary condition, expressed in terms of convex subgradients. If the Lagrangian satisfies an additional growth condition (weaker than coercivity), this Weierstrass-type condition yields the Lipschitz regularity of the minimizers.
Yuanlu Bai, Columbia University (joint work with Henry Lam)

We discuss approaches using distributionally robust conventional extreme value theory. Statistical connections and comparisons of our framework with different conservativeness-variance tradeoff, can mitigate some optimization as a nonparametric alternative that, through a counter difficulties in confining both estimation biases and fit data using justified parametric distributions, but often en-

Huajie Qian, Columbia University (joint work with Henry Lam)

Optimization formulations to handle data-driven decision-making under uncertain constraints, such as robust optimization, often encounter a statistical trade-off between feasibility and optimality that potentially leads to over-conservative solutions. We exploit the intrinsic low dimensionality of the solution sets possibly output from these formulations to enhance this trade-off. For several common paradigms of data-driven optimization, we demonstrate the dimension-free performance of our strategy in obtaining solutions that are, in a sense, both feasible and asymptotically optimal.

Yuanlu Bai, Columbia University (joint work with Henry Lam)

A bottleneck in analyzing extreme events is that, by their own nature, tail data are often scarce. Conventional approaches fit data using justified parametric distributions, but often encounter difficulties in confining both estimation biases and variances. We discuss approaches using distributionally robust optimization as a nonparametric alternative that, through a different conservativeness-variance tradeoff, can mitigate some of the statistical challenges in estimating tails. We explain the statistical connections and comparisons of our framework with conventional extreme value theory.

Yini Gao, Singapore Management University (joint work with Chung-Piaw Teo, Huan Zheng)

Full-cut promotion is a type of promotion where customers spend a minimum threshold amount in a single order to enjoy a fixed amount of discount for that order. In this paper, we propose a sequential choice model to model consumer’s choice of multiple items in a single transaction, which generalizes the traditional choice model which assumes at most one item chosen in one transaction. Base on the sequential choice model, we further propose a data driven approach to optimize the cut amount. We test the approach using both synthetic data and a real transaction data set from an e-commerce company.
Complexity of Sparse Optimization for Subspace Identification
Organizer: Julien Mairal
Chair: Julien Mairal
Guillaume Garrigos, Université Paris Diderot (joint work with Jalal Fadili, Jerome Malick, Gabriel Peyré)
Model Consistency for Learning with low-complexity priors

We consider supervised learning problems where the prior on the coefficients of the estimator is an assumption of low complexity. An important question in that setting is the one of model consistency, which consists of recovering the correct structure by minimizing a regularized empirical risk. Under some conditions, it is known that deterministic algorithms succeed in recovering the correct structure, while a simple stochastic gradient method fails to do so. In this talk, we provide the theoretical underpinning of this behavior using the notion of mirror-stratifiable regularizers.

Yifan Sun, UBC Vancouver (joint work with Halyun Jeong, Julie Nutini, Mark Schmidt)
Are we there yet? Manifold identification of gradient-related proximal methods

In machine learning, models that generalize better often generate outputs that lie on a low-dimensional manifold. Recently, several works have shown finite-time manifold identification by proximal methods. In this work, we provide a unified view by giving a simple condition under which any proximal method using a constant step size can achieve finite-iteration manifold detection. We provide iteration bounds for several key methods such as (FISTA, DRS, ADMM, SVRG, SAGA, and RDA).

Julien Mairal, Inria (joint work with Andrei Kulunchakov)
Estimate Sequences for Stochastic Composite Optimization: Variance Reduction, Acceleration, and Robustness to Noise

We propose a unified view of gradient-based algorithms for stochastic convex composite optimization based on estimate sequences. This point of view covers stochastic gradient descent (SGD), the variance-reduction approaches SAGA, SVRG, MISO, their proximal variants, and has several advantages: (i) we provide a generic proof of convergence for the aforementioned methods; (ii) we obtain new algorithms with the same guarantees (iii) we derive generic strategies to make these algorithms robust to stochastic noise (iv) we obtain new accelerated algorithms.

Stochastic Optimization and Its Applications (Part I)
Organizer: Fengmin Xu
Chair: Fengmin Xu
Xiaojun Chen, Hong Kong Polytechnic University
Two-stage stochastic variational inequalities and non-cooperative games

The two-stage stochastic variational inequality (SVI) provides a powerful modeling paradigm for many important applications in which uncertainties and equilibrium are present. This talk reviews some new theory and algorithms for the two-stage SVI. Moreover, we formulate a convex two-stage non-cooperative multi-agent game under uncertainty as a two-stage SVI. Numerical results based on historical data in crude oil market are presented to demonstrate the effectiveness of the two-stage SVI in describing the market share of oil producing agents.

Jianming Shi, Tokyo University of Science
A Facet Pivoting Algorithm for Solving Linear Programming with Box Constraints

Linear programming (LP) is fundamentally important in mathematical optimization. In this talk, we review the following two methods: the LP-Newton method for LPs with box constraints proposed by Fujishige et al., LPS-Newton method proposed by Kitahara et al. Inspired by the methods we develop a new method that uses facets information of the constraints for solving PLs with box constraints because an optimal solution can be found at an intersection between a zonotope and a line. We also report several results of preliminary experiments showing the efficiency of the proposed algorithm.

Fengmin Xu, Xi’an Jiaotong University
Worst-case CVaR portfolio rebalancing with cardinality and diversification constraints

In this paper, we attempt to provide a decision-practical foundation for optimal rebalancing strategies of an existing financial portfolio. Our main concern is the development of a sparse and diversified portfolio rebalancing model in the worst-case CVaR framework, considering transaction costs and double cardinality constraints that trade off between the limits of investment scale and industry coverage requirements simultaneously. We propose an efficient ADMM to conduct out-of-sample performance analysis of our proposed strategy on actual data from the Chinese stock market.
**Structural Design Optimization (Part II)**  
Organizer: Tamás Terlaky  
Chair: Tamás Terlaky

Michael Stingl, Friedrich-Alexander-Universität (FAU) Erlangen-Nürnberg (joint work with Lukas Pflug)  
**A new stochastic descent method for the efficient solution of structural optimization problems with infinitely many load cases**

A stochastic gradient method for the solution of structural optimization problems for which the objective function is given as an integral of a desired property over a continuous parameter set is presented. While the application of a quadrature rule leads to undesired local minima, the new stochastic gradient method does not rely on an approximation of the integral, requires only one state solution per iteration and utilizes gradients from previous iterations in an optimal way. Convergence theory and numerical examples including comparisons to the classical SG and SAG method are shown.

Alemseged Gebrehiwot Weldeyesus, The University of Edinburgh (joint work with Jacek Gondzio)  
**Re-optimization and warm-starting in semidefinite programming**

We focus on a semidefinite program arising in optimization of globally stable truss structures. These problems are known to be large-scale and very challenging to standard solution techniques. We solve the problems using a primal-dual interior point method, coupled with column generation procedure and warm-start strategy. The implementation of the algorithm extensively exploits the sparsity structure and low rank property of the involved matrices. We report on a solution of very large problems which otherwise would be prohibitively expensive for existing semidefinite programming solvers.

Jonas Holley, Robert Bosch GmbH (joint work with Michael Hintermüller)  
**Topological Derivatives for the Optimization of an Electrical Machine**

This talk is concerned with an adjoint-based topology optimization method for designing an electrical machine. In order to meet the requirements of real industrial applications, different objectives regarding energy efficiency, as well as mechanical robustness need to be addressed. The resulting optimization problem is challenging due to pointwise state constraints, which are tackled by a penalization approach. A line search type gradient descent scheme is presented for the numerical solution of the optimization problem, where the topological derivative serves as a descent direction.

**Mathematical Optimization in Signal Processing (Part II)**  
Organizers: Ya-Feng Liu, Zhi-Quan Luo  
Chair: Ya-Feng Liu

Zhi-Quan Luo, The Chinese University of Hong Kong, Shenzhen (joint work with Hamid Farmanbar, Navid Reyhanian)  
**A Decomposition Method for Optimal CapacityReservation in Stochastic Networks**

We consider the problem of reserving link capacity/resources in a network in such a way that a given set of scenarios (possibly stochastic) can be supported. In the optimal capacity/resource reservation problem, we choose the reserved link capacities to minimize the reservation cost. This problem reduces to a large nonlinear program, with the number of variables and constraints on the order of the number of links times the number of scenarios. We develop an efficient decomposition algorithm for the problem with a provable convergence guarantee.

Ya-Feng Liu, Chinese Academy of Sciences  
**Semidefinite Relaxations for MIMO Detection: Tightness, Tightness, and Beyond**

Multiple-input multi-output (MIMO) detection is a fundamental problem in modern digital communications. Semidefinite relaxation (SDR) based algorithms are a popular class of approaches to solving the problem. In this talk, we shall first develop two new SDRs for MIMO detection and show their tightness under a sufficient condition. This result answers an open question posed by So in 2010. Then, we shall talk about the tightness relationship between some existing SDRs for the problem in the literature. Finally, we shall briefly talk about the global algorithm based on the newly derived SDR.
Recent Advancements in Optimization Methods for Machine Learning (Part III)
Organizers: Albert Berahas, Martin Takáč
Chair: Martin Takáč

Peter Richtárik, King Abdullah University of science and technology (KAUST) (joint work with Filip Hanzely, Konstantin Mishchenko)
SEGA: Variance Reduction via Gradient Sketching

We propose a randomized first order optimization method—SEGA (SkEtched GrAdient method)—which progressively throughout its iterations builds a variance-reduced estimate of the gradient from random linear measurements (sketches) of the gradient obtained from an oracle. In each iteration, SEGA updates the current estimate of the gradient through a sketch-and-project operation using the information provided by the latest sketch, and this is subsequently used to compute an unbiased estimate of the true gradient through a random relaxation procedure.

Aaron Defazio, Facebook
Optimization, Initialization and Preconditioning of Modern ReLU Networks [canceled]

In this talk I will discuss a number of issues encountered when optimizing modern ReLU based deep neural networks such as the ResNet-50 model, and suggest some solutions. Topics include:
- Improving the conditioning of the Hessian using a careful initialization scheme.
- Guiding the design of networks by following a scaling rule that improves the conditioning of the Hessian, resulting in less guess work and faster optimization.
- Avoiding instability at the beginning of learning by using balanced ReLUs.
- Variance reduction for deep learning

Aurelien Lucchi, ETH Zürich
Continuous-time Models for Accelerated Stochastic Optimization Algorithms

We focus our discussion on accelerated methods for non-convex and stochastic optimization problems. The choice of how to memorize information to build the momentum has a significant effect on the convergence properties of an accelerated method. We first derive a general continuous-time model that can incorporate arbitrary types of memory. We then demonstrate how to discretize such process while matching the same rate of convergence as the continuous-time model. We will also discuss modern optimization techniques used in machine learning such as Adam and RMSprop.

Recent Advances in Convex and Non-Convex Optimization and Their Applications in Machine Learning (Part I)
Organizers: Qihang Lin, Tianbao Yang
Chair: Qihang Lin

Yiming Ying, SUNY Albany
Stochastic Optimization for AUC Maximization in Machine Learning

In this talk, I will present our recent work on developing novel SGD-type algorithms for AUC maximization. Our new algorithms can allow general loss functions and penalty terms which are achieved through the innovative interactions between machine learning and applied mathematics. Compared with the previous literature which requires high storage and per-iteration costs, our algorithms have both space and per-iteration costs of one datum while achieving optimal convergence rates.

Niao He, University of Illinois at Urbana-Champaign
Sample Complexity of Conditional Stochastic Optimization

We study a class of compositional stochastic optimization involving conditional expectations, which finds a wide spectrum of applications, particularly in reinforcement learning and robust learning. We establish the sample complexities of a modified Sample Average Approximation (SAA) and a biased Stochastic Approximation (SA) for such problems, under various structural assumptions such as smoothness and quadratic growth conditions. Our analysis shows that both modified SAA and biased SA achieve the same complexity bound, and our experiments further demonstrate that these bounds are tight.

Javier Pena, Carnegie Mellon University
A unified framework for Bregman proximal methods

We propose a unified framework for analyzing the convergence of Bregman proximal first-order algorithms for convex minimization. Our framework hinges on properties of the convex conjugate and gives novel proofs of the convergence rates of the Bregman proximal subgradient, Bregman proximal gradient, and a new accelerated Bregman proximal gradient algorithm under fairly general and mild assumptions. Our accelerated Bregman proximal gradient algorithm attains the best-known accelerated rate of convergence when suitable relative smoothness and triangle scaling assumptions hold.
In this paper, we study an inexact line search Newton method to solve a generalized Nash equilibrium problem (GNEP). The GNEP is an extension of classical Nash equilibrium problem, where feasible set depends on the strategies of the other players. In this paper, we have taken a particular class of GNEP in which the objective function and the constraint mappings are convex. The proposed method converges globally and also has a faster rate of convergence as compared to previous methods.

We consider compliant obstacle problems, where two elastic membranes enclose a constant volume. The existence of solutions to this quasi-variational inequality (QVI) is established building on fixed-point arguments and partly on Mosco-convergence. Founded on the analytical findings, the solution of the QVI is approached by solving a sequence of variational inequalities (VIs). Each of these VIs is tackled in function space via a path-following semismooth Newton method. The numerical performance of the algorithm is enhanced by using adaptive finite elements based on a posteriori error estimation.

We introduce a discontinuous finite volume method for the approximation of distributed optimal control problems governed by the Brinkman equations, where a force field is sought such that it produces a desired velocity profile. The discretisation of state and co-state variables follows a lowest-order scheme, whereas three different approaches are used for the control representation: a variational discretisation and approximation through piecewise constant or piecewise linear elements. We employ the optimise-then-discretise approach, resulting in a non-symmetric discrete formulation. A priori error estimates for velocity, pressure, and control in natural norms are derived, and a set of numerical examples is presented to illustrate the performance of the method and to confirm the predicted accuracy of the generated approximations under various scenarios.

Consider the ellipsoid method applied to compute a point in $P$ where $P$ is represented as the feasible solutions of a system of linear inequalities. When $P$ is empty, there exists a certificate of infeasibility (via a theorem of the alternative), yet the standard ellipsoid method does not automatically furnish such a certificate. In this talk we present a modified version of the ellipsoid method that computes a point in $P$ when $P$ is nonempty, and computes a certificate of infeasibility when $P$ is empty, and whose complexity depends on $\max(m, n)$ and on a natural condition number of the problem.

The aim of structured optimization is to assemble a solution, using a given set of atoms, to fit a model to data. Polarity, which generalizes the notion of orthogonality from linear sets to general convex sets, plays a special role in a simple and geometric form of convex duality. The atoms and their implicit “duals” share a special relationship, and their participation in the solution assembly depends on a notion of alignment. This geometric perspective leads to practical algorithms for large-scale problems.

We introduce a discontinuous finite volume method for the approximation of distributed optimal control problems governed by the Brinkman equations, where a force field is sought such that it produces a desired velocity profile. The discretisation of state and co-state variables follows a lowest-order scheme, whereas three different approaches are used for the control representation: a variational discretisation and approximation through piecewise constant or piecewise linear elements. We employ the optimise-then-discretise approach, resulting in a non-symmetric discrete formulation. A priori error estimates for velocity, pressure, and control in natural norms are derived, and a set of numerical examples is presented to illustrate the performance of the method and to confirm the predicted accuracy of the generated approximations under various scenarios.
Polynomial Optimization (Part II)
Organizer: Grigoriy Blekherman
Chair: Grigoriy Blekherman
Etienne de Klerk, Tilburg University (joint work with Monique Laurent)
Convergence analysis of a Lasserre hierarchy of upper bounds for polynomial minimization on the sphere

We study the convergence rate of a hierarchy of upper bounds for polynomial minimization problems, proposed by Lasserre (2011), for the special case when the feasible set is the unit (hyper)sphere. The upper bound at level \( r \) of the hierarchy is defined as the minimal expected value of the polynomial over all probability distributions on the sphere, when the probability density function is a sum-of-squares polynomial of degree at most \( 2r \) with respect to the surface measure. We show that the exact rate of convergence is of order \( 1/r^2 \). (Joint work with Monique Laurent.)

Cordian Riener, Uit (joint work with J. Rolfes, F. Vallentin, David de Laat)
Lower bounds for the covering problem of compact metric spaces

Let \((X, d)\) be a compact metric space. For a given positive number \( r \) we are interested in the minimum expected value of a polynomial over all probability distributions on \( X \). We provide a sequence of infinite-dimensional conic programs each of which yields a lower bound for this number and show that the resulting sequence of lower bounds converges in finitely many steps to the minimal number of balls needed. These programs satisfy strong duality and we can derive a finite dimensional semidefinite program to approximate the optimal solution to arbitrary precision.

Victor Magron, LAAS-CNRS (joint work with Jean-Bernard Lasserre, Mohab Safey El Din)
Two-player games between polynomial optimizers, semidefinite solvers and certifiers

We interpret some wrong results, due to numerical inaccuracies, observed when solving semidefinite programming (SDP) relaxations for polynomial optimization. The SDP solver performs robust optimization and the procedure can be viewed as a max-min problem with two players. Next, we consider the problem of finding exact sums of squares (SOS) decompositions with SDP solvers. We provide a perturbation-compensation algorithm computing exact decompositions for elements in the interior of the SOS cone. We prove that this algorithm has a polynomial boolean running time w.r.t. the input degree.
Accelerated Alternating Minimization Algorithms for Large-Scale Convex and Nonsmooth Optimization (Part I)

Organizer: Daniel Robinson
Chair: Daniel Robinson

Guilherme Franca, Johns Hopkins University (joint work with Daniel Robinson, Rene Vidal)
Conformal Symplectic Optimization

A promising direction to study accelerated methods has been emerging through connections with continuous dynamical systems. However, it is unclear whether main properties of the dynamical system is preserved by such algorithms. We will show that the classical momentum method is a conformal symplectic integrator, and it preserves the symplectic structure of the dynamical system. On the other hand, Nesterov’s accelerated gradient is not a structure preserving discretization. We will comment on generalizations of these methods and introduce a symplectic alternative to Nesterov’s method.

Zhihui Zhu, Johns Hopkins University (joint work with Daniel Robinson, Manolis Tsakiris, Rene Vidal)
A Linearly Convergent Method for Nonsmooth Nonconvex Optimization on the Sphere with Applications to Robust PCA and Orthogonal Dictionary Learning

We consider the minimization of a general nonsmooth function over the unit sphere. We show that if the objective satisfies a certain Riemannian regularity condition relative to a set \( B \), a Riemannian subgradient method with an appropriate initialization and geometrically diminishing step size converges at a linear rate to the set \( B \). We also show that this regularity condition holds for orthogonal dictionary learning (ODL) and Dual Principal Component Pursuit (DPCP) under suitable choices of \( B \). This leads to important improvements upon the known convergence results for both ODL and DPCP.

Sergey Guminov, IITP, Russian Academy of Sciences (joint work with Vladislav Elsukov, Alexander Gasnikov)
Accelerated Alternating Minimization

Alternating minimization (AM) optimization algorithms have known for a long time. These algorithms assume that the decision variable is divided into several blocks and minimization in each block can be done explicitly. AM algorithms have a number of applications in machine learning problems. In this paper, we are mostly motivated by optimal transport applications, which have become important for the machine learning community. The ubiquitous Sinkhorn algorithm can be seen as an alternating minimization algorithm for the dual to the entropy-regularized optimal transport problem. Sublinear \( 1/k \) convergence rate was proved for AM algorithm. Despite the same convergence rate as for the gradient descent method, AM-algorithms typically converge faster in practice as they are free of the choice of the step-size and are adaptive to the local smoothness of the problem. At the same time, there are accelerated gradient methods which use a momentum term to have a faster convergence rate of \( 1/k^2 \). We introduce an accelerated alternating minimization method with \( 1/k^2 \) convergence rate, where \( k \) is the iteration counter. We also show that the proposed method is primal-dual, meaning that if we apply it to a dual problem, we can reconstruct the solution of the primal problem with the same convergence rate. We apply our method to the entropy regularized optimal transport problem and show experimentally, that it outperforms Sinkhorn’s algorithm.
Global Optimization - Contributed Session I
Chair: Syuuji Yamada
Kuan Lu, Tokyo Institute of Technology (joint work with Shinji Mizuno, Jianming Shi)
Solving Optimization over the Efficient Set of a Multiobjective Linear Programming Problem as a Mixed Integer Problem

This research concerns an optimization problem over the efficient set of a multiobjective linear programming problem. We show that the problem is equivalent to a mixed integer programming (MIP) problem, and we propose to compute an optimal solution by solving the MIP problem. Compared with the previous mixed integer programming approach, the proposed approach relaxes a condition for the multiobjective linear programming problem and reduces the size of the MIP problem. The MIP problem can be efficiently solved by current MIP solvers when the objective function is convex or linear.

Francesco Romito, Sapienza University of Rome (joint work with Giampaolo Liuzzi, Stefano Lucidi, Veronica Piccialli)
Exploiting recursive non-linear transformations of the variables space in global optimization problems

Solving a global optimization problem is a hard task. We define recursive non-linear equations that are able to transform the variables space and allow us to tackle the problem in an advantageous way. The idea is to exploit the information obtained during a multi-start approach in order to define a sequence of transformations in the variables space. The aim is that of expanding the basin of attraction of global minimizers while shrinking those of already found local minima.

Syuuji Yamada, Niigata University
A global optimization algorithm by listing KKT points for a quadratic reverse convex programming problem

In this paper, we propose a procedure for listing KKT points of a quadratic reverse convex programming problem (QRC) whose feasible set is expressed as the area excluded the interior of a convex set from another convex set. Since it is difficult to solve (QRC), we transform (QRC) into a parametric quadratic programming problem (QP). In order to solve (QP) for each parameter, we introduce an algorithm for listing KKT points. Moreover, we propose an global optimization algorithm for (QRC) by incorporating our KKT listing algorithm into a parametric optimization method.

Geometry in Non-Convex Optimization (Part II)
Organizers: Nicolas Boumal, André Uschmajew, Bart Vandereyken
Chair: Bart Vandereycken
Marco Sutti, University of Geneva
Multilevel optimization on low-rank manifolds for optimal control problems

Large-scale finite-dimensional optimization problems sometimes admit solutions that can be well approximated by low-rank matrices and tensors. In this talk, we will exploit this low-rank approximation property by solving the optimization problem directly over the set of low rank matrices and tensors. In particular, we introduce a new multilevel algorithm, where the optimization variable is constrained to the Riemannian manifold of fixed-rank matrices, allowing to keep the ranks (and thus the computational complexity) fixed throughout the iterations. This is a joint work with Bart Vandereycken.

Max Pfeffer, Max Planck Institute for Mathematics in the Sciences
Optimization methods for computing low rank eigenspaces

We consider the task of approximating the eigenspace belonging to the lowest eigenvalues of a self adjoint operator on a space of matrices, with the condition that it is spanned by low rank matrices that share a common row space of small dimension. Such a problem arises for example in the DMRG algorithm in quantum chemistry. We propose a Riemannian optimization method based on trace minimization that takes orthogonality and low rank constraints into account simultaneously, and shows better numerical results in certain scenarios compared to other current methods.

Yuqian Zhang, Cornell University
Nonconvex geometry and algorithms for blind deconvolution

Blind deconvolution is an ill-posed problem aiming to recover a convolution kernel and an activation signal from their convolution. We focus on the short and sparse variant, where the convolution kernel is short and the activation signal is sparsely and randomly supported. This variant models convolutional signals in several important application scenarios. The observation is invariant up to some mutual scaling and shift of the convolutional pairs. This scaled-shift symmetry is intrinsic to the convolution operator and imposes challenges for reliable algorithm design. We normalize the convolution kernel to have unit Frobenius norm and then cast the blind deconvolution problem as a nonconvex optimization problem over the sphere. We demonstrate that (i) under conditions, every local optimum is close to some shift truncation of the ground truth, and (ii) for a generic filter of length k, when the sparsity of activation signal satisfies $\theta < k^{3/4}$ and number of measurements $m > \text{poly}(k)$, provable recovery of the ground truth signals can be obtained.
**Developments in Structured Nonconvex Optimization (Part I)**
Organizers: Jun-ya Gotoh, Yuji Nakatsukasa, Akiko Takeda
Chair: Yuji Nakatsukasa

Jun-ya Gotoh, Chuo University (joint work with Takumi Fukuda)

**Sparse recovery with continuous exact \( k \)-sparse penalties**

This paper presents efficient algorithms for \( k \)-sparse recovery problem on the basis of the Continuous Exact \( k \)-Sparse Penalties (CXPs). Each CXP is defined by a non-convex but continuous function and the equality forcing the function value to be zero is known to be equivalent to the \( k \)-sparse constraint defined with the so-called \( \ell_0 \)-norm. Algorithms based on the proximal maps of the \( \ell_1 \)-norm or \( \ell_2 \)-norm based CXPs will be examined for the sparse recovery problems with/without noise.

Shummin Nakayama, Chuo University

**Inexact proximal memoryless quasi-Newton methods based on Broyden family for minimizing composite functions**

In this talk, we consider proximal Newton-type methods for the minimization of a composite function that is the sum of a smooth function and a nonsmooth function. Proximal Newton-type methods make use of weighted proximal mappings whose calculations are much expensive. Accordingly, some researchers have proposed inexact Newton-type proximal methods, which calculate the proximal mapping inexactly. To calculate proximal mappings more easily, we propose an inexact proximal method based on memoryless quasi-Newton methods with the Broyden family. We analyze global and local convergence properties.

Takayuki Okuno, RIKEN AIP (joint work with Akihiro Kawana, Akiko Takeda)

**Hyperparameter optimization for \( l_q \) regularizer via bilevel optimization**

We propose a bilevel optimization strategy for selecting the best hyperparameter value for the nonsmooth \( l_p \) regularizer with \( 0 < p \leq 1 \). The concerned bilevel optimization problem has a nonsmooth, possibly nonconvex, \( \ell_p \)-regularized problem as the lower-level problem. For solving this problem, we propose a smoothing-type algorithm and show that a sequence generated by the proposed method converges to a point satisfying certain optimality conditions. We also conducted some numerical experiments to exhibit the efficiency by comparing it with Bayesian optimization.

**Advances in Nonlinear Optimization Algorithms (Part I)**
Chair: Mehiddin Al-Baali

Johannes Brust, Argonne National Laboratory (joint work with Roummel Marcia, Cosmin Petra)

**Large-Scale Quasi-Newton Trust-Region Methods with Low-Dimensional Equality Constraints**

For large-scale optimization problems, limited-memory quasi-Newton methods are efficient means to estimate Hessian matrices. We present two L-BFGS trust-region methods for large optimization problems with a low number of linear equality constraints. Both methods exploit a compact representation of the \((1,1)\) block of the inverse KKT matrix. One of the proposed methods uses an implicit eigendecomposition in order to compute search directions by an analytic formula, and the other uses a 1D root solver. We compare the methods to alternative quasi-Newton algorithms on a set of CUTEst problems.

Hardik Tankaria, Kyoto University (joint work with Nobuo Yamashita)

**Non-monotone regularized limited memory BFGS method with line search for unconstrained optimization**

Recently, Sugimoto and Yamashita proposed the regularized limited memory BFGS (RL-BFGS) with non-monotone technique for unconstrained optimization and reported that it is competitive to the standard L-BFGS. However, RL-BFGS does not use line search; hence it cannot take longer step. In order to take longer step, we propose to use line search with Wolfe condition when iteration of RL-BFGS is successful and the search direction is still descent direction. The numerical results shows that RL-BFGS with the proposed technique is more efficient and stable than the standard L-BFGS and RL-BFGS method.

Mehiddin Al-Baali, Sultan Qaboos University

**Conjugate Gradient Methods with Quasi-Newton Features for Unconstrained Optimization**

The recent class of symmetric conjugate gradient methods for large-scale unconstrained optimization will be considered. The quasi-Newton like condition will be introduced to this class of methods in a sense to be defined. It will be shown that the proposed methods converge globally and has some useful features. Numerical results will be described to illustrate the behavior of some new techniques for improving the performance of several conjugate gradient methods substantially.
We study the three examples in a setting, where a sequence (e.g., time-series forecasting). There has been a considerable recent progress in tackling such problems, via hierarchies of convexifications or otherwise, at a price of non-trivial run-time. This indicates that workhorses for solving problems in machine learning, but it is still unclear if they can have the same success solving inverse problems in imaging. In this talk, we explore the unique challenges that stochastic gradient methods face when solving imaging problems. We also propose a family of accelerated stochastic gradient methods with fast convergence rates. Our numerical experiments demonstrate that these algorithms can solve imaging and machine learning problems faster than existing methods.

Zhen Shao, University of Oxford (joint work with Coralia Cartis, Jan Fiala)

Sketching for sparse linear least squares

We discuss sketching techniques for sparse Linear Least Squares (LLS). We give theoretical bounds for the accuracy of the sketched solution/residual when hashing matrices are used for sketching, quantifying carefully the trade-off between the coherence of the original matrix and the sparsity of the hashing matrix. We use these to quantify the success of our algorithm that employs a sparse factorisation of the sketched matrix as a preconditioner for the original LLS before applying LSQR. We extensively compare our algorithm to state-of-the-art direct and iterative solvers for large sparse LLS.

Panos Parpas, Imperial College London

Distributed optimization with probabilistically consistent models

We introduce a framework for developing and analyzing distributed optimization algorithms that are guaranteed to converge under very general conditions. The conditions we consider include the use of reduced order and approximate models, and we only assume that the approximate models are consistent with a certain probability. To motivate the theory, we report preliminary results from using a particular instance of the proposed framework for solving large scale non-convex optimization models.
Optimal Control of Nonsmooth Systems (Part II)
Organizers: Constantin Christof, Christian Clason
Chair: Constantin Christof
Dorothee Knees, University of Kassel (joint work with Stephanie Thomas)
Optimal control of rate-independent systems

Rate independent systems can be formulated based on an energy functional and a dissipation potential that is assumed to be convex, lower semicontinuous and positively homogeneous of degree one. Here, we will focus on the nonconvex case meaning that the energy is not convex. In this case, the solution typically is discontinuous in time. There exist several (in general not equivalent) notions of weak solutions. We focus on so-called balanced viscosity solutions, discuss the properties of solution sets and discuss the well-posedness of an optimal control problem for such systems.

Vu Huu Nhu, University of Duisburg-Essen (joint work with Christian Clason, Arnd Rösch)
Optimal control of a non-smooth quasilinear elliptic equation

This talk is concerned with an optimal control problem governed by a non-smooth quasilinear elliptic equation with a nonlinear coefficient in the principal part that is locally Lipschitz continuous and directionally but not Fréchet differentiable. Based on a suitable regularization scheme, we derive C- and strong stationarity conditions. Under the additional assumption that the nonlinearity is a $PC^1$ function with countably many points of nondifferentiability, we show that both conditions are equivalent and derive a relaxed optimality system that is amenable to numerical solution using SSN.

Livia Betz, Universität Duisburg-Essen
Strong stationarity for the optimal control of non-smooth coupled systems

This talk is concerned with an optimal control problem governed by a non-smooth coupled system of equations. The non-smooth nonlinearity is Lipschitz-continuous and directionally differentiable, but not Fréchet-differentiable. We derive a strong stationary optimality system, i.e., an optimality system which is equivalent to the purely primal optimality condition saying that the directional derivative of the reduced objective in feasible directions is nonnegative.
Decomposition-Based Methods for Optimization of Time-Dependent Problems (Part I)
Organizers: Matthias Heinkenschloss, Carl Laird
Chair: Carl Laird

Sebastian Götschel, Zuse Institute Berlin (joint work with Michael L. Minion)
Towards adaptive parallel-in-time optimization of parabolic PDEs

Time-parallel methods have received increasing interest in recent years as they allow to obtain speedup when spatial parallelization saturates. In this talk, we exploit the state-of-the-art “Parallel Full Approximation Scheme in Space and Time” (PFASST) for the time-parallel solution of optimization problems with parabolic PDEs. As PFASST is based on spectral deferred correction methods their iterative nature provides additional flexibility, e.g., by re-using previously computed solutions. We focus especially on adapting the accuracy of state and adjoint solves to the optimization progress.

Stefan Ulbrich, TU Darmstadt
Time-domain decomposition for PDE-constrained optimization

We consider optimization problems governed by time-dependent parabolic PDEs and discuss the construction of parallel solvers based on time-domain decomposition. We propose an ADMM-based approach to decompose the problem in independent subproblems and combine it with a multigrid strategy. Moreover, we discuss a preconditioner for the solution of the subproblems that decouples into a forward and backward PDE solve on the time-subdomains. Numerical results are presented.

Denis Ridzal, Sandia National Laboratories (joint work with Eric Cyr)
A multigrid-in-time augmented-Lagrangian method for constrained dynamic optimization

To address the serial bottleneck of forward and adjoint time integration in solving dynamic optimization problems, we propose a parallel multigrid-in-time technique for the solution of optimality systems in a matrix-free trust-region sequential quadratic programming method for equality-constrained optimization. Additionally, to handle general inequality constraints, we develop and analyze an augmented-Lagrangian extension, which only augments simple bound constraints. We present scaling studies for large-scale fluid dynamics control problems and inverse problems involving Maxwell’s equations.

Recent Advances in Theories of Distributionally Robust Optimization (DRO)
Organizer: Zhichao Zheng
Chair: Zhichao Zheng

Karthikey Murthy, Singapore University of Technology and Design (joint work with Karthik Natarajan, Divya Padmanabhan)
Exploiting Partial Correlations in Distributionally Robust Optimization

We aim to identify partial covariance structures that allow polynomial-time instances for evaluating the worst-case expected value of mixed integer linear programs with uncertain coefficients. Assuming only the knowledge of mean and covariance entries restricted to block-diagonal patterns, we develop a reduced SDP formulation whose complexity is characterized by a suitable projection of the convex hull of rank 1 matrices formed by extreme points of the feasible region. These projected constraints lend themselves to polynomial-time instances in appointment scheduling and PERT network contexts.

Jingui Xie, University of Science and Technology of China (joint work with Melvyn Sim, Taozeng Zhu)
Joint Estimation and Robustness Optimization

Many real-world optimization problems have input parameters estimated from data whose inherent imprecision can lead to fragile solutions that may impede desired objectives and/or render constraints infeasible. We propose a joint estimation and robustness optimization (JERO) framework to mitigate estimation uncertainty in optimization problems by seamlessly incorporating both the parameter estimation procedure and the optimization problem.

Grani A. Hanasusanto, The University of Texas at Austin (joint work with Guanglin Xu)
Improved Decision Rule Approximations for Multi-Stage Robust Optimization via Copositive Programming

We study decision rule approximations for multi-stage robust linear optimization problems. We examine linear decision rules for the generic problem instances and quadratic decision rules for the case when only the problem right-hand sides are uncertain. The decision rule problems are amenable to exact copositive programming reformulations that yield tight, tractable semidefinite programming solution schemes. We prove that these new approximations are tighter than the state-of-the-art schemes and demonstrate their superiority through numerical experiments.
A Generalized Cutting Plane Algorithm for Robust Optimization with Chrysanthos Gounaris, Nikolaos Lappas, Anirudh Subramanyam, Argonne National Laboratory (joint work with Karthikey Sharma)

We propose a primal branch-and-bound algorithm that generalizes the well-known cutting plane method of Mutapcic and Boyd to the case of decision-dependent uncertainty sets. A comprehensive computational study showcases the advantages of the proposed algorithm over that of existing methods that rely on classical duality-based reformulations.

Mathieu Besançon, INRIA Lille Nord-Europe (joint work with Miguel Anjos, Luce Brotcorne)

Near-optimal robust bilevel optimization

Bilevel optimization corresponds to integrating the optimal response to a lower-level problem in a problem. We introduce near-optimal robustness for bilevel problems, building on existing concepts from the literature. This model generalizes the pessimistic approach, protecting the decision-maker from limited deviations of the lower level. This models finds intuitive interpretations in various optimization settings modelled as bilevel problems. We develop a duality-based solution method for cases where the lower-level is convex, leveraging the methodology from robust and bilevel optimization.

Omid Nohadani, Northwestern University (joint work with Karthikey Sharma)

Optimization Under Decision-dependent Uncertainty

The efficacy of robust optimization spans a variety of settings with predetermined uncertainty sets. In many applications, uncertainties are affected by decisions and cannot be modeled with current frameworks. This talk takes a step towards generalizing robust optimization to problems with decision-dependent uncertainties, which we show are NP-complete. We introduce a class of uncertainty sets whose size depends on decisions, and proposed reformulations that improve upon alternative techniques. In addition, the proactive uncertainty control mitigates over conservatism of current approaches.

Controller Design for Large-Scale Systems with Karthikey Sharma

The alternating minimization algorithm has been proposed by Paul Tseng to solve convex programming problems with two-block separable linear constraints and objectives, whereby (at least) one of the components of the latter is assumed to be strongly convex. The fact that one of the subproblems to be solved within the iteration process of this method does not usually correspond to the calculation of a proximal operator through a closed formula affects the implementability of the algorithm. In this talk, we allow in each block of the objective a further smooth convex function and propose a proximal version of the algorithm, which is achieved by equipping the algorithm with proximal terms induced by variable metrics. For suitable choices of the latter, the solving of the two subproblems in the iterative scheme can be reduced to the computation of proximal operators. We investigate the convergence of the proposed algorithm in a real Hilbert space setting and illustrate its numerical performances on two applications in image processing and machine learning.

Kimon Antonakopoulos, University Grenoble Alpes/Inria (joint work with Panayotis Mertikopoulos)

Primal-Dual Methods for Stochastic Variational Inequalities with Unbounded Operators

Motivated by applications in machine learning and imaging, we study a class of variational inequality problems with possibly unbounded operators. In contrast to their classical counterparts, these problems could exhibit singularities near the boundary of the problem domain, thus precluding the use of standard first-order methods. To circumvent this difficulty, we introduce a family of local norms adapted to the problem’s singularity landscape, and we derive a class of Bregman proximal methods that exploit this structure and provide optimal convergence rates in this setting.
Stochastic Optimization and Its Applications (Part II)
Organizer: Fengmin Xu
Chair: Fengmin Xu

Sunho Jang, Seoul National University (joint work with Insoon Yang)
Stochastic Subgradient Methods for Dynamic Programming in Continuous State and Action Spaces
To solve dynamic programs with continuous state and action spaces, we first approximate the output of the Bellman operator as a convex program with uniform convergence. This convex program is then solved using stochastic subgradient descent. To avoid the full projection onto the high-dimensional feasible set, we develop an algorithm that samples, in a coordinated fashion, a mini-batch for a subgradient and another for projection. We show several properties of this algorithm, including convergence, and a reduction in the feasibility error and in the variance of the stochastic subgradient.

Jussi Lindgren, Aalto University School of Science (joint work with Jukka Liukkonen)
Stochastic optimization, Quantum Dynamics and Information Theory
We present a new approach to foundations of quantum mechanics via stochastic optimization. It is shown that the Schrödinger equation can be interpreted as an optimal dynamic for the value function for a coordinate-invariant linear-quadratic stochastic control problem. The optimal path for the quantum particle obeys a stochastic gradient descent scheme, which minimizes relative entropy or the free energy. This in turn allows for a new interpretation for quantum mechanics through the tools of non-equilibrium statistical mechanics and information theory vis-a-vis the path integral formulation.

Luis Espath, King Abdullah University of science and technology (KAUST) (joint work with Andre Carlon, Ben Dia, Rafael Lopez, Raul Tempone)
Nesterov-aided Stochastic Gradient Methods using Laplace Approximation for Bayesian Design Optimization
We focus on the Optimal Experimental Design OED problem of finding the setup that maximizes the expected information gain. We augment the stochastic gradient descent with the Nesterov’s method and the restart technique, as O’Donoghue and Candes originally proposed for deterministic optimization. We couple the stochastic optimization with three estimators for OED: the double-loop Monte Carlo estimator DLMC, the Monte Carlo estimator using the Laplace approximation for the posterior distribution MCLA and the double-loop Monte Carlo estimator with Laplace-based importance sampling DLMCIS.
Applications in Finance and Real Options
Chair: Luis Zuluaga

Daniel Ralph, University of Cambridge (joint work with Rutger-Jan Lange, Kristian Støre)
“POST”, a robust method for Real-Option Valuation in Multiple Dimensions Using Poisson Optional Stopping Times

We provide a new framework for valuing multidimensional real options where opportunities to exercise the option are generated by an exogenous Poisson process; this can be viewed as a liquidity constraint on decision times. This approach, which we call the Poisson optional stopping times (POST) method, finds the value function as a monotone and linearly convergent sequence of lower bounds. In a case study, we demonstrate the effectiveness of POST by comparing it to the frequently used quasi-analytic method, showing some difficulties that arise when using the latter. POST has a clear convergence analysis, is straightforward to implement and robust in analysing multidimensional option-valuation problems of modest dimension.

Peter Schütz, Norwegian University of Science and Technology NTNU (joint work with Sjur Westgaard)
Optimal hedging strategies for salmon producers

We use a multistage stochastic programming model to study optimal hedging decisions for risk-averse salmon producers. The objective is to maximize the weighted sum of expected revenues from selling salmon either in the spot market or in futures contracts and Conditional Value-at-Risk (CVaR) of the revenues over the planning horizon. The scenario tree for the multistage model is generated based on a procedure that combines Principal Component Analysis and state space modelling. Results indicate that salmon producers should hedge price risk already at fairly low degrees of risk aversion.

Luis Zuluaga, Lehigh University (joint work with Onur Babat, Juan Vera)
Computing near-optimal Value-at-Risk portfolios using integer programming techniques

Value-at-Risk (VaR) is one of the main regulatory tools used for risk management purposes. However, it is difficult to compute optimal VaR portfolios; that is, an optimal risk-reward portfolio allocation using VaR as the risk measure. This is due to VaR being non-convex and of combinatorial nature. Here, we present an algorithm to compute near-optimal VaR portfolios that takes advantage of a MILP formulation of the problem and provides a guarantee of the solution’s near-optimality.
**Recent Advances in Convex and Non-Convex Optimization and Their Applications in Machine Learning (Part II)**

**Organizers:** Qihang Lin, Tianbao Yang  
**Chair:** Tianbao Yang

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**Yuejie Chi,** Carnegie Mellon University  
**Implicit Regularization in Nonconvex Low-Rank Matrix Completion**

We show that factored gradient descent with spectral initialization converges linearly for noisy and 1-bit low-rank matrix completion in terms of both Frobenius and infinity norms, without the need of explicitly promoting incoherence via regularizations, at near-optimal sample and computational complexities. This is achieved by establishing an “implicit regularization” phenomenon of the algorithm via a leave-one-out perturbation argument.

**Praneeth Netrapalli,** Microsoft Corporation (joint work with Chi Jin, Michael Jordan)  
**Nonconvex-Nonconcave Minmax Optimization: Stable Limit Points of Gradient Descent Ascent are Locally Optimal**

Minimax optimization, especially in its general nonconvex-nonconcave formulation, has found extensive applications in modern machine learning frameworks. While gradient descent ascent (GDA) is widely used in practice to solve these problems its theoretical behavior has been considered highly undesirable due to the possibility of convergence to non local-Nash equilibria. In this talk, we introduce the notion of local minimax as a more suitable alternative to the notion of local Nash equilibrium and show that up to some degenerate points, stable limit points of GDA are exactly local minimax.

**Raef Bassily,** The Ohio State University (joint work with Mikhail Belkin)  
**On the Effectiveness of SGD in Modern Over-parameterized Machine Learning**

I will talk about recent advances in understanding Stochastic Gradient Descent and its effectiveness in modern machine learning. I will discuss linear convergence of SGD for a broad class of convex as well as non-convex problems in the interpolated (over-parameterized) regime. I will also discuss some practical and theoretical implications pertaining to training neural networks.

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**Recent Advances in Distributed Optimization**

**Organizers:** Pavel Dvurechensky, Cesar A Uribe  
**Chair:** Cesar A Uribe

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**Alexander Gasnikov,** Moscow Institute of Physics and Technology (joint work with Darina Dvinskikh, Pavel Dvurechensky, Alexey Kroshnin, Nazarii Tupitsa, Cesar A Uribe)  
**On the Complexity of Approximating Wasserstein Barycenters**

We study two distributed algorithms for approximating Wasserstein barycenter of a set of discrete measures. The first approach is based on the Iterative Bregman Projections (IBP) algorithm for which our novel analysis gives a complexity bound proportional to $mn^2/e^2$ to approximate the original non-regularized barycenter. Using an alternative accelerated-gradient-descent-based approach, we obtain a complexity proportional to $mn^{2.5}/e$.

**Jingzhao Zhang,** (joint work with Ali Jadbabaie, Aryan Mokhtari, Suvrit Sra, Cesar A Uribe)  
**Direct Runge-Kutta discretization achieves acceleration**

We study gradient-based optimization methods obtained by directly discretizing a second-order heavy-ball ordinary differential equation (ODE). When the function is smooth enough and convex, we show that acceleration can be achieved by a stable discretization using standard Runge-Kutta integrators. Furthermore, we introduce a new local flatness condition under which rates even faster than Nesterov’s method can be achieved with low-order integrators. Similar techniques can be applied to strongly convex first order optimization problems and distributed optimization problems.
Complementarity: Extending Modeling and Solution Techniques (Part I)
Organizer: Michael Ferris
Chair: Michael Ferris
Olivier Huber, Humboldt-Universität zu Berlin
On Solving Models with Optimal Value Function
We look at solving mathematical programs that contain other optimization problems, specifically containing Optimal Value Functions (OVF). In general, problems with OVF are feature non-smoothness, that is both hard to model and solve. Rather than designing specific algorithms for this kind of problem, we propose an approach based on reformulations. In this talk we first focus the conditions for such reformulations to be applicable. Secondly, we present ReSHOP, an implementation of those procedures, as well as its Julia interface.

Youngdae Kim, Argonne National Laboratory
SELKIE: a model transformation and distributed solver for structured equilibrium problems
We introduce SELKIE, a general-purpose solver for equilibrium problems described by a set of agents. It exploits problem structures, such as block structure and cascading dependencies of interacting agents, in a flexible and adaptable way to achieve a more robust and faster solution path. Various decomposition schemes can be instantiated in a convenient and computationally efficient manner. SELKIE has been implemented and is available within GAMS/EMP. Examples illustrating the flexibility and effectiveness of SELKIE are given, including a Dantzig Wolfe method for Variational Inequalities.

Michael Ferris, University of Wisconsin-Madison (joint work with Andy Philpott)
Capacity expansion and operations tradeoffs in renewable electricity
Various countries have announced target dates for a 100% renewable electricity system. Such targets require long-term investment planning, medium-term storage management (including batteries and pumped storage), as well as a short-term analysis of demand-response, involuntary load curtailment and transmission congestion. We consider using complementarity models of dynamic risked equilibria to formulate these problems, the implications of stochasticity, and demonstrate the application of additional modeling constructs and distributed algorithms for their solution.
Praveesh Kothari, Carnegie Mellon University

**Average-Case Algorithm Design Using Sum-of-Squares**

I will explain how a primal-dual viewpoint on Sum-of-Squares method and its proof-complexity interpretation provides a general blueprint for parameter estimation problems arising in machine learning/average-case complexity. As a consequence, we will be able to obtain state-of-the-art algorithms for basic problems in theoretical machine learning/statistics including estimating components of Gaussian mixtures, robust estimation of moments of distributions, robust independent component analysis and regression, tensor decomposition, tensor completion and dictionary learning.

Amir Ali Ahmadi, Princeton University (joint work with Bachir El Khadir)

**Learning Dynamical Systems with Side Information**

We present a mathematical framework for learning a dynamical system from a limited number of trajectory observations but subject to contextual information. We show that sum of squares optimization is a particularly powerful tool for this task.
Algorithms for Large-Scale Convex and Nonsmooth Optimization (Part II)
Chair: Daniel Robinson
Masoud Ahookhosh, KU Leuven (joint work with Panagiotis Patrinos, Andreas Themelis)
A superlinearly convergent Bregman forward-backward method for nonsmooth nonconvex optimization
A superlinearly convergent Bregman forward-backward method for solving sum of two nonconvex functions is proposed, where the first function is relatively smooth and the second one is (nonsmooth) nonconvex. We first introduce the Bregman forward-backward envelope (BFBE), verify its first- and second-order properties under some mild assumptions, and develop a newton-type forward-backward method using BFBE that only needs first-order black-box oracle. After giving the global and local superlinear convergence of the method, we will present encouraging numerical results from several applications.

Avinash Dixit, Indian Institute of Technology (BHU) Varanasi (joint work with Tanmoy Som)
A new accelerated algorithm to solve convex optimization problems
We consider the convex minimization problems of the sum of two convex functions, in which one is differentiable. In the present research work, we used the iterative technique to solve the minimization problem. The recent trend is to introduce techniques having greater convergence speed. Firstly, we introduce an accelerated algorithm to find minimization of a nonexpansive mapping and corresponding proximal gradient algorithm to solve convex optimization problems. Later on, the proposed algorithm is compared with already existing algorithms on the basis of convergence speed and accuracy.

Ewa Bednarczuk, Warsaw University of Technology (joint work with Krzysztof Rutkowski)
[moved] On Lipschitzness of projections onto convex sets given by systems of nonlinear inequalities and equations under relaxed constant rank condition
When approaching convex optimization problems from continuous perspective the properties of related dynamical systems often depend on behavior of projections. In particular, when investigating continuous variants of primal-dual best approximation methods, projections onto moving convex sets appear. We investigate lipschitzness of projection onto moving convex sets. To this aim we use the relaxed constant rank condition, introduced by Minchenko and Stakhovski.
**Wed.3 H 3008**  
Generalized Distances and Envelope Functions  
Organizer: Ting Kei Pong  
Chair: Ting Kei Pong  
Scott B. Lindstrom, The Hong Kong Polytechnic University (joint work with Regina S. Burachik, Minh N. Dao)  
The Fitzpatrick Distance  
Recently, Burachik and Martinez-Legaz introduced a distance constructed from a representative function for a maximally monotone operator. This distance generalizes the Bregman distance, and we name it the Fitzpatrick distance. We explore the properties of its variants.

Andreas Themelis, KU Leuven (joint work with Panagiotis Patrinos)  
A universal majorization-minimization framework for the convergence analysis of nonconvex proximal algorithms  
We provide a novel unified interpretation of nonconvex splitting algorithms as compositions of Lipschitz and set-valued majorization-minimization mappings. A convergence analysis is established based on proximal envelopes, a generalization of the Moreau envelope. This framework also enables the integration with fast local methods applied to the nonlinear inclusion encoding optimality conditions. Possibly under assumptions to compensate the lack of convexity, this setting is general enough to cover ADMM as well as forward-backward, Douglas-Rachford and Davis-Yin splittings.

Ting Kei Pong, The Hong Kong Polytechnic University (joint work with Michael Friedlander, Ives Macedo)  
Polar envelope and polar proximal map  
Polar envelope is a convolution operation specialized to gauges, and is analogous to Moreau envelope. In this talk, we discuss important properties of polar envelope and the corresponding polar proximal map. These include smoothness of the envelope function, and uniqueness and continuity of the proximal map. We also highlight the important roles the polar envelope plays in gauge duality and the construction of algorithms for gauge optimization.

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**Wed.3 H 0105**  
Geometry and Optimization  
Organizer: Coralia Cartis  
Chair: Coralia Cartis  
Florentin Goyens, University of Oxford  
Nonlinear matrix recovery  
We investigate the recovery of a partially observed high-rank matrix whose columns obey a nonlinear structure. The structures covered are unions of clusters and algebraic varieties, which include unions of subspaces. Using a nonlinear lifting to a space of features, as proposed by Ongie et al. in 2017, we reduce the problem to a constrained nonconvex optimization formulation, which we solve using Riemannian optimization methods. We give theoretical convergence and complexity guarantees and provide encouraging numerical results for low dimensional varieties and clusters.

Erlend Skaldehaug Riis, University of Cambridge  
A geometric integration approach to nonsmooth, nonconvex optimisation  
Discrete gradient methods are popular numerical methods from geometric integration for solving systems of ODEs. They are known for preserving structures of the continuous system, e.g. energy dissipation, making them interesting for optimisation problems. We consider a derivative-free discrete gradient applied to dissipative ODEs such as gradient flow, thereby obtaining optimisation schemes that are implementable in a black-box setting and retain favourable properties of gradient flow. We give a theoretical analysis in the nonsmooth, nonconvex setting, and conclude with numerical results.

Mario Lezcano Casado, University of Oxford  
Optimization in compact matrix Lie groups, with applications to machine learning  
We present and analyze a novel approach to perform first-order optimization with orthogonal and unitary constraints. This approach is based on a parametrization stemming from Lie group theory through the exponential map. The parametrization transforms the constrained optimization problem into an unconstrained one over a Euclidean space, for which common first-order optimization methods can be used. The theoretical results presented are general enough to cover the special orthogonal group, the unitary group and, in general, any connected compact Lie group.
Developments in Structured Nonconvex Optimization (Part II)
Organizers: Jun-ya Gotoh, Yuji Nakatsukasa, Akiko Takeda
Chair: Jun-ya Gotoh
Nikitas Rontsis, University of Oxford (joint work with Paul Goulart, Yuji Nakatsukasa)
An eigenvalue based active-set solver for norm-constrained quadratic problems, with applications to extended trust region subproblems and sparse PCA

We present an active-set algorithm for the minimisation of a non-convex quadratic function subject to linear constraints and a single norm constraint. The suggested algorithm works by solving a series of Trust Region Subproblems (TRS) the global solution of which has been studied extensively in the literature. We extend these results by showing that non-global minima of the TRS, or a certificate of their absence, can be also calculated efficiently by solving a single eigenproblem. We demonstrate the usefulness of the algorithm in solving Sparse PCA and extended Trust Region Subproblems.

Andrέ Uschmajew, Max Planck Institute for Mathematics in the Sciences (joint work with Felix Krahmer, Max Pfeffer)
A Riemannian optimization approach to sparse low-rank recovery

The problem of recovering a row or column sparse low-rank matrix from linear measurements arises for instance in sparse blind deconvolution. We consider non-convex optimization algorithms for such problems that combine the idea of an ADMM method for sparse recovery with Riemannian optimization on the low-rank manifold and thresholding.

Tianxiang Liu, RIKEN Center for Advanced Intelligence Project (AIP) (joint work with Ivan Markovsky, Ting Kei Pong, Akiko Takeda)
A successive difference-of-convex approximation method with applications to control problems

In this talk, we consider a class of nonconvex nonsmooth optimization problems whose objective is the sum of a smooth function and several nonsmooth functions, some of which are composed with linear maps. This includes the problems arising from system identification with multiple rank-constraints, each of which involves Hankel structure. To solve it, we propose a successive DC approximation method, which makes use of the DC structure of the Moreau envelope. We prove the convergence of the method under suitable assumptions and discuss how it can be applied to concrete applications.

Advances in Nonlinear Optimization Algorithms (Part II)
Chair: Mehiddin Al-Baali
Erik Berglund, KTH Royal University of Technology (joint work with Mikael Johansson)
An Eigenvalue Based Limited Memory BFGS Method

Many matrix update formulas in quasi-Newton methods can be derived as solutions to nearest-matrix problems. In this talk, a similar idea is proposed for developing limited memory quasi-Newton methods. We characterize a class of symmetric matrices that can be stored with limited memory. We then derive an efficient way to find the closest member of this class to any symmetric matrix and propose a trust region method that makes use of it. Numerical experiments show that our algorithm has superior performance on large logistic regression problems, compared to a regular L-BFGS trust region method.

Wenwen Zhou, SAS Institute Inc. (joint work with Joshuа Griffin, Riadh Omeni)
A modified projected gradient method for bound constrained optimization problems

This talk will focus on solving bound constrained nonconvex optimization problems with expensive-to-evaluate functions. The motivation for this research was from collaborations with members from the statistics community seeking better handling of their optimization problems. The method first solves a QP using the projected gradient method to improve the active set estimate. The method next uses a modified conjugate gradient method applied to the corresponding trust region subproblem to leverage second order information. The numerical results will be provided.

Hao Wang, ShanghaiTech University
An inexact first-order method for constrained nonlinear optimization

We propose inexact first-order methods for solving constrained nonlinear optimization problems. By controlling the inexactness of the subproblem solution, we can significantly reduce the computational cost needed for each iteration. A penalty parameter updating strategy during the subproblem solve enables the algorithm to automatically detect infeasibility. Global convergence for both feasible and infeasible cases are proved. Complexity analysis for the KKT residual is also derived under loose assumptions. Performance of proposed methods is demonstrated by numerical experiments.
New Trends in Optimization Methods and Machine Learning (Part III)
Chair: El houcine Bergou
Saeed Ghadimi, Princeton University (joint work with Krishnakumar Balasubramanian)
Zeroth-order Nonconvex Stochastic Optimization: Handling Constraints, High-Dimensionality, and Saddle-Points

We analyze zeroth-order stochastic approximation algorithms for nonconvex optimization with a focus on addressing constrained optimization, high-dimensional setting, and saddle-point avoiding. In particular, we generalize the conditional stochastic gradient method under zeroth-order setting and also highlight an implicit regularization phenomenon where the stochastic gradient method adapts to the sparsity of the problem by just varying the step-size. Furthermore, we provide a zeroth-order variant of the cubic regularized Newton method and discuss its rate of convergence to local minima.

Hien Le, University of Mons (joint work with Nicolas Gillis, Panagiotis Patrinos)
Inertial Block Mirror Descent Method for Non-convex Non-smooth Optimization

We propose inertial versions of block coordinate descent methods for solving nonconvex nonsmooth composite optimization problems. Our methods do not require a restarting step, allow using two different extrapolation points, and take advantage of randomly shuffled. To prove the convergence of the whole generated sequence to a critical point, we modify the well-known proof recipe of Bolte, Sabach and Teboulle, and incorporate it with using auxiliary functions. Applied to solve nonnegative matrix factorization problems, our methods compete favourably with the state-of-the-art NMF algorithms.

Michal Kočvara, University of Birmingham (joint work with Chin Pang Ho, Panos Parpas)
On Newton-type multilevel optimization methods

Building upon multigrid methods, a framework of multilevel optimization methods was developed to solve structured optimization problems, including problems in optimal control, image processing, etc. In this talk, we give a broader view of the multilevel framework and establish some connections between multilevel algorithms and the other approaches. By studying a case study of the so-called Newton-type multilevel model, we take the first step to show how the structure of optimization problems could improve the convergence of multilevel algorithms.

Man Shun Ang, UMONS (joint work with Nicolas Gillis)
Accelerating Nonnegative-X by extrapolation, where X ∈ Least Square, Matrix Factorization, Tensor Factorization

Non-negativity constraint is ubiquitous. A family of non-negativity constrained problems (NCP) are the non-negative least squares (NNLS), the non-negative matrix factorization (NMF) and the non-negative tensor factorization (NTF). The goal of these NCP problems in general is to fit an given object (vector, matrix, or tensor) by solving an optimization problem with non-negativity constraints. Various algorithms are proposed to solve the NCP. In this talk, we introduce an general extrapolation-based acceleration scheme that that can significantly accelerate the algorithm for NNLS, NMF and NTF.
Optimal Control of Nonsmooth Systems (Part III)
Organizers: Constantin Christof, Christian Clason
Chair: Christian Clason

Gerd Wachsmuth, BTU Cottbus-Senftenberg (joint work with Constantin Christof)
Second-order conditions for optimal control of the obstacle problem

In this talk, we consider second-order optimality conditions for the optimal control of the obstacle problem. In particular, we are interested in sufficient conditions which guarantee the local/global optimality of the point of interest. Our analysis extends and refines existing results from the literature. We present three counter-examples which illustrate that rather peculiar effects can occur in the analysis of second-order optimality conditions for optimal control problems governed by the obstacle problem.

Anne-Therese Rauls, TU Darmstadt (joint work with Stefan Ulbrich)
Subgradient Calculus for the Obstacle Problem

In this talk, we discuss differentiability properties of a general class of obstacle problems and characterize generalized derivatives from the Bouligand subdifferential of the solution operator for the obstacle problem in all points of its domain. The subgradients we obtain are determined by solution operators of Dirichlet problems on quasi-open domains. To use the derived subgradients in practice within nonsmooth optimization methods, a discretization of the obstacle problem is necessary. We investigate how the respective subgradients can be approximated in this case.

Georg Müller, Universität Konstanz (joint work with Constantin Christof)
Multiobjective Optimal Control of a Non-Smooth Semi-Linear Elliptic PDE

The understanding of and the techniques for dealing with nonsmoothness in scalar optimization with PDEs have increased drastically over the last years. In multiobjective non-smooth optimization, however, few results are known.

This talk addresses the multiobjective optimal control of a non-smooth semi-linear elliptic PDE with max-type nonlinearity. First results are focused on first order optimality condition based on multiple adjoint equations. Additionally, we discuss the numeric characterization of the Pareto front for few objectives using scalarization techniques and regularization.

Optimal Control and Dynamical Systems (Part VII)
Organizers: Cristopher Hermosilla, Michele Palladino
Chair: Michele Palladino

Emilio Vilches, Universidad de O’Higgins
Some results on the optimal control of implicit sweeping processes

In this talk, we present some results on the optimal control of implicit sweeping processes such as characterization of nonsmooth Lyapunov pairs and parametric stability. Some applications to implicit evolution variational inequalities are given.

Cristopher Hermosilla, Universidad Tecnica Federico Santa Maria
Hamilton-Jacobi-Bellman approach for optimal control problems of sweeping processes

This talk is concerned with a state constrained optimal control problem governed by a perturbed Moreau’s sweeping process. The focus of the talk is on the Bellman approach for an infinite horizon problem. In particular, we focus on the regularity of the value function and on the Hamilton-Jacobi-Bellman equation it satisfies. We discuss a uniqueness result and we make a comparison with standard state constrained optimal control problem to highlight a regularizing effect that the sweeping process induces on the value function.

Fernando Lobo Pereira, Universidade do Porto Faculdade de Engenharia (joint work with Ismael Pena, Geraldo Nunes Silva)
A Predictive Control Framework for the Sustainable Management of Resources

This article concerns a predictive control framework to support decision-making in the context of resources management in which sustainability is achieved by deconflicting short-term – usually profit-seeking – goals of multiple agents, and the goal of seeking the the collective equilibrium in the sense of preserving the required production efficiency level.

This class of problems arise in a very large spectrum of contexts such as agriculture, oceanic biomass exploitation, manufacturing, and services systems. In each one of these contexts, the competition among the multiple decision-makers often entails that each one adopts control strategies maximizing his/her profit in the short term, and, as a consequence, a long term depletion of the ingredients required to sustain the production efficiency of the overall system.

Given the usual complexity of any realistic scenario, we consider an abstract context clarifying the core mathematical issues of a bi-level control architecture that, under some reasonable general assumptions, generates control strategies ensuring the asymptotic convergence to a sustainable global equilibrium while ensuring the economic (and, thus, social) short term sustainability.
Decomposition-Based Methods for Optimization of Time-Dependent Problems (Part II)

Organizers: Matthias Heinkenschloss, Carl Laird
Chair: Matthias Heinkenschloss

Nicolas Gauger, TU Kaiserslautern (joint work with Eric Cyr, Stefanie Günther, Lars Ruthotto, Jacob B. Schroder)

Layer-parallel training of deep residual neural networks

Residual neural networks (ResNets) are a promising class of deep neural networks that have shown excellent performance for a number of learning tasks, e.g., image classification and recognition. Mathematically, ResNet architectures can be interpreted as forward Euler discretizations of a nonlinear initial value problem whose time-dependent control variables represent the weights of the neural network. Hence, training a ResNet can be cast as an optimal control problem of the associated dynamical system. For similar time-dependent optimal control problems arising in engineering applications, parallel-in-time methods have shown notable improvements in scalability. In this talk, we demonstrate the use of those techniques for efficient and effective training of ResNets. The proposed algorithms replace the classical (sequential) forward and backward propagation through the network layers by a parallel nonlinear multigrid iteration applied to the layer domain. This adds a new dimension of parallelism across layers that is attractive when training very deep networks. From this basic idea, we derive multiple layer-parallel methods. The most efficient version employs a simultaneous optimization approach where updates to the network parameters are based on inexact gradient information in order to speed up the training process. Using numerical examples from supervised classification, we demonstrate that the new approach achieves similar training performance to traditional methods, but enables layer-parallelism and thus provides speedup over layer-serial methods through greater concurrency.

Alexander Engelmann, Karlsruhe Institute of Technology (joint work with Timm Faulwasser)

Decomposition of optimal control problems using bi-level distributed ALADIN

We explore the decomposition of optimal control problems using a recently proposed decentralized variant of the Augmented Lagrangian Alternating Direction Inexact Newton (ALADIN) method. Specifically, we consider a bi-level distributed variant of ALADIN, wherein the outer ALADIN structure is combined with a second inner level of distribution handling the coupling QP by means of decentralized ADMM or similar algorithms. We draw upon case studies from energy systems and from predictive control to illustrate the efficacy of the proposed framework.

Carl Laird, Sandia National Laboratories (joint work with Michael Bynum, Bethany Nicholson, Jose Santiago Rodriguez, John Sirola, Victor Zavala)

Schur-complement and ADMM approaches for Time-Domain Decomposition in Optimization with PyNumero

PyNumero is a Python package based on Pyomo that supports development of numerical optimization algorithms. Using MPI, PyNumero has been used to develop decomposition algorithms for structured nonlinear programming problems, including problem-level decomposition approaches (e.g., ADMM) and approaches that decompose the linear algebra in the inner SQP step. In this presentation, we will show computational performance of Schur-complement based approaches and ADMM approaches on with time-domain decomposition for dynamic optimization problems.

Robust Nonlinear Optimization

Organizer: Frans de Ruiter
Chair: Frans de Ruiter

Oleg Kelis, Technion -Israel Institute of Tecnology (joint work with Valery Glizer)

Finite-horizon singular $H_\infty$ control problem: a regularization method

We consider an finite horizon singular $H_\infty$ control problem. A regularization of this problem is proposed leading to a new $H_\infty$ problem with a partial cheap control. The latter is solved by adapting a perturbation technique. Then, it is shown on how accurately the controller, solving this $H_\infty$ partial cheap control problem, solves the original singular $H_\infty$ control problem.

Jianzhe (Trevor) Zhen, EPFL (joint work with Daniel Kuhn, Wolfram Wiesemann)

Distributionally Robust Nonlinear Optimization

Leveraging a generalized ‘primal-worst equals dual-best’ duality scheme for robust optimization, we derive from first principles a strong duality result that relates distributionally robust to classical robust optimization problems and that obviates the need to mobilize the machinery of abstract semi-infinite duality theory. In order to illustrate the modeling power of the proposed approach, we present convex reformulations for data-driven distributionally robust optimization problems whose ambiguity sets constitute type-$p$ Wasserstein balls for any $p \in [1, \infty]$.

Frans de Ruiter, Tilburg University, The Netherlands (joint work with Aharon Ben-Tal, Ernst Roos, Jianzhe (Trevor) Zhen, Dick den Hertog)

Effective approach for hard uncertain convex inequalities

In many problems the uncertain parameters appear in a convex way, which is problematic as no general techniques exist for such problems. In this talk, we provide a systematic way to construct safe approximations to such constraints when the uncertainty set is polyhedral. We reformulate the original problem as a linear adjustable robust optimization problem in which the nonlinearity of the original problem is captured by the new uncertainty set. We demonstrate the quality of the approximations with a study of geometric programming problems and numerical examples from radiotherapy optimization.
Algorithms and Applications of Robust Optimization
Organizer: William Haskell
Chair: William Haskell

Napat Rujeerapaiboon, National University of Singapore (joint work with Cagil Kocyigit, Daniel Kuhn)
Robust Multidimensional Pricing: Separation without Regret

We study a robust monopoly pricing problem with a minimax regret objective, where a seller endeavors to sell multiple goods to a single buyer, only knowing that the buyer’s values for the goods range over a rectangular uncertainty set. We interpret this problem as a zero-sum game between the seller, who chooses a selling mechanism, and a fictitious adversary, who chooses the buyer’s values. We prove that this game admits a Nash equilibrium that can be computed in closed form. We further show that the deterministic restriction of the problem is solved by a deterministic posted price mechanism.

Wolfram Wiesemann, Imperial College Business School (joint work with Zhi Chen, Daniel Kuhn)
Data-Driven Chance Constrained Programs over Wasserstein Balls

We provide an exact deterministic reformulation for data-driven chance constrained programs over Wasserstein balls. For individual chance constraints as well as joint chance constraints with right-hand side uncertainty, our reformulation amounts to a mixed-integer conic program. In the special case of a Wasserstein ball with the $1$-norm or the $\infty$-norm, the cone is the nonnegative orthant, and the chance constrained program can be reformulated as a mixed-integer linear program.

William Haskell, Purdue University (joint work with Hien Le Thi Khanh, Renbo Zhao)
An Inexact Primal-Dual Smoothing Framework with Applications to Robust Optimization

We propose an inexact primal-dual smoothing framework to solve a strongly-convex- generally-concave saddle point problem with non-bilinear structure, with potentially a large number of component functions. We develop a probabilistic version of our smoothing framework, which allows each sub-problem to be solved by randomized algorithms inexactness in expectation. In addition, we extend both our deterministic and probabilistic frameworks to solve generally convex-concave saddle point problems. We comment on the application of this method to robust data-driven optimization.
Stochastic Optimization and Its Applications (Part III)
Organizer: Fengmin Xu
Chair: Fengmin Xu

Christian Bayer, WIAS (joint work with Raul Tempone, Sören Wolfers)

**Pricing American options by exercise rate optimization**

We consider the pricing American basket options in a multivariate setting, including the Heston and the rough Bergomi models. In high dimensions, nonlinear PDEs methods for solving the problem become prohibitively costly due to the curse of dimensionality. Our novel method uses Monte Carlo simulation and the optimization of exercise strategies parametrized as randomized exercise strategies. Integrating analytically over the random exercise decision yields an objective function that is differentiable with respect to perturbations of the exercise rate, even for finitely many sampled paths.

Xiaobo Li, National University of Singapore (joint work with Saif Benjaafar, Daniel Jiang, Xiang Li)

**Inventory Repositioning in On-Demand Product Rental Networks**

We consider a product rental network with a fixed number of rental units distributed across multiple locations. Because of the randomness in demand and in the length of the rental periods and in unit returns, there is a need to periodically reposition inventory. We formulate the problem as a Markov Decision Process and offer a characterization of the optimal policy. In addition, we propose a new cutting-plane-based approximate dynamic programming algorithm that leverages the structural properties. A novel convergence analysis, together with promising numerical experiments, is provided.
Thu.1 09:00–10:15

Thu.1 H 3004

Applications in Logistics and Supply Chain Management
Chair: Ali Ekici

Okan Özener, Ozyegin University (joint work with Basak Altan)
A Game Theoretical Approach for Improving the Operational Efficiencies of Less-than-truckload Carriers Through Load Exchanges

Less-than-truckload (LTL) transportation offers fast, flexible and relatively low cost transportation services to shippers. In order to cope with the effects of economic recessions, LTL industry implemented ideas such as reducing excess capacity and increasing revenues through better yield management. In this paper, we extend these initiatives beyond the reach of individual carriers and propose a collaborative framework that facilitates load exchanges to reduce the operational costs of the collaborating LTL carriers.

Mingyu Li, Department of Industrial Economics and Technology Management, NTNU (joint work with Peter Schütz)
Decision support for ship routing in dynamic and stochastic ice conditions

We discuss the problem of finding the optimal route for a ship sailing in non-stationary ice conditions, with uncertainty resulted from poor quality of ice conditions forecasts. We formulate the problem as a shortest path problem with uncertain and time-dependent travel times but alternative objective can be risk or cost. We consider a 15-day planning horizon, with new ice information updated regularly and reconsider decisions accordingly. We present the look-ahead model formulation, a stochastic dynamic programming based solution method and preliminary results.

Ali Ekici, Ozyegin University (joint work with Serhan Duran, Okan Özener)
Ordering from Capacitated Suppliers under Cycle Time Limitation

We study the ordering policy of a retailer which procures a single item from multiple capacitated suppliers and satisfies an exogenous demand. Retailer’s objective is to minimize total fixed, variable and inventory holding cost. We develop cyclic ordering policies for the retailer with limited cycle time. We propose a novel iterative-natured heuristic framework which looks for the best cycle time while selecting suppliers and allocating orders. Computational experiments show that the proposed heuristic framework provides better results compared to other methods in the literature.

Thu.1 H 0105

Distributed and Decentralized Optimization: Learning, Lower-Complexity Bounds, and Communication-Efficiency
Organizers: Andy Sun, Wotao Yin
Chair: Kaizhao Sun

Qing Ling, Sun Yat-Sen University
RSA: Byzantine-Robust Stochastic Aggregation Methods for Distributed Learning from Heterogeneous Datasets

We propose a class of robust stochastic methods for distributed learning from heterogeneous datasets at presence of an unknown number of Byzantine workers. The key is a regularization term incorporated with the cost function to robustify the learning task. In contrast to most of the existing algorithms, the resultant Byzantine-Robust Stochastic Aggregation (RSA) methods do not rely on the assumption that the data are i.i.d. on the workers. We show that the RSA methods converge to a near-optimal solution with the learning error dependent on the number of Byzantine workers.

Mingyi Hong, University of Minnesota (joint work with Haoran Sun)
Distributed Non-Convex First-Order Optimization and Information Processing: Lower Complexity Bounds and Rate Optimal Algorithms

We consider a distributed non-convex optimization problems, in which a number of agents collectively optimize a sum of smooth local objective functions. We address the question: What is the fastest rate that any distributed algorithms can achieve, and how to achieve those rates. We develop a lower bound analysis, and show that in the worst-case it takes any first-order algorithm $O(1/(\epsilon^2 k^{1/4}))$ iterations to achieve some $\epsilon$-solution, where $k$ is the network spectrum gap. We also develop a rate-optimal distributed method whose rate matches the lower bound. The algorithm combines ideas from distributed consensus, as well as classical fast solvers for linear systems.

Wotao Yin, University of California, Los Angeles
LAG: Lazily Aggregated Gradient is Communication-Efficient in Distributed and Decentralized Optimization

In Lazily Aggregated Gradient (LAG), the nodes in a distributed or decentralized algorithm can choose to use outdated gradient information, therefore, reduce communication. This is also called gradient censoring. Surprisingly, the original convergence rates remain the same in the strongly-convex, convex, and nonconvex cases while communication is reduced. When local Lipschitz constants are heterogeneous, communication is reduced significantly. Numerical experiments with synthetic and real data will demonstrate this significant communication reduction. This talk combines different recent works.
**Thu.1 H 3006**

**Large-Scale Optimization for Statistical Learning**  
Organizer: Paul Grigas  
Chair: Paul Grigas

Rahul Mazumder, Massachusetts Institute of Technology  
Algorithmic approaches for Nonparametric Function estimation with Shape Constraints [canceled]

Nonparametric function estimation is a quintessential problem in statistical data-analysis with widespread applications in online advertising, econometrics, operations research, etc. We consider the problem of estimating functions are (a) smooth and have (b) shape constraints (monotonicity, convexity, etc.). This leads to an infinite-dimensional convex quadratic optimization problem posing computational challenges. We propose a framework to jointly achieve goals (a), (b). Time permitting, we will discuss the problem of fitting a multivariate convex function to data.

Hussein Hazimeh, MIT (joint work with Rahul Mazumder)  
Learning Hierarchical Interactions at Scale [canceled]

In many learning settings, it is beneficial to augment the main features with pairwise interactions. Such interaction models can be enhanced by performing variable selection under the so-called “strong hierarchy” constraint. Existing convex optimization based algorithms face difficulties in handling problems where the number of main features is beyond a thousand. We propose convex first order algorithms to exactly solve the problem with up to a billion variables on a single machine. We also discuss how to solve the original nonconvex problem via a tailored branch-and-bound algorithm.

**Thu.1 H 3007**

**Big Data and Machine Learning - Contributed Session I**  
Chair: Guozhi Dong

Scindhiya Laxmi, Indian institute of Technology Roorkee (joint work with S. K. Gupta)  
Human Activity Recognition using Intuitionistic Fuzzy Proximal Support Vector Machines

Human activity recognition is an active area of research in Computer Vision. One of the difficulties of an activity recognition system is the presence of noises in the training data. We addressed this problem by assigning membership and hesitation degrees to the training instances according to its contribution to the classification problem. In this way, the impact of noises and outliers has been reduced to some extent. The methodology intuitionistic fuzzy proximal support vector machine for human activity is proposed to speed up the training phase and to increase the classification accuracy.

Robert Ravier, Duke University (joint work with Vahid Tarokh)  
Online Optimization for Time Series of Parametrizable Objective Functions

The time-varying component of many objective functions of practical interest in online optimization is fully contained in a finite number of parameters. This allows us to use methods from standard time series analysis in order to predictively optimize. We investigate the theoretical and computational effects of using these methods. In particular, we focus on both the potential improvements of regret upper bounds when utilizing these techniques as well as algorithms for simultaneously modeling and optimizing.

Guozhi Dong, Humboldt-Universität zu Berlin (joint work with Michael Hintermüller, Kostas Papafitsoros)  
A data-driven model-based method for quantitative MRI

Recently, an integrated physics-based model has been introduced for quantitative magnetic resonance imaging. It incorporates the physical model by Bloch equations into the data acquisition, and leads to high accuracy estimation of the tissue parameters. However, in general, the physical model might be not explicitly known. In this talk, we introduce a novel data-driven model-based method which combines the advances of integrated physics-based method with deep neural networks.
Complementarity: Extending Modeling and Solution Techniques (Part II)
Organizer: Michael Ferris
Chair: Michael Ferris
Francesco Caruso, University of Naples “Federico II” (joint work with Maria Carmela Ceparano, Jacqueline Morgan)
Approximation of Nash equilibria via continuous optimization

We propose an algorithm based on a non-standard (non-convex) relaxation of the classical best response approach which guarantees the convergence to a Nash equilibrium in two-player non zero-sum games when the best response functions are not linear, both their compositions are not contractions and the strategy sets are Hilbert spaces. First, we prove a uniqueness result for Nash equilibria. Then, we define an iterative method and a numerical approximation scheme, relying on a continuous optimization technique, which converge to the unique Nash equilibrium. Finally, we provide error bounds.

David Stewart, University of Iowa (joint work with Mario Barela)
Simulating electrical circuits with diodes and transistors

Electrical circuits with dynamical elements (inductors and capacitors) are implicit differential algebraic equations, and when ideal diodes are included they are differential complementarity problems. The matrices that arise in these problems are symmetric positive definite, which means solutions exist and are unique. These systems can be efficiently solved numerically by high order Diagonally Implicit Runge-Kutta methods in a way that exploits the network structure.

Methods and Applications in Mixed Integer Semidefinite Programming
Organizer: Christoph Helmberg
Chair: Christoph Helmberg
Angelika Wiegele, Alpen-Adria-Universität Klagenfurt (joint work with Nicolo Gusmeroli, Franz Rendl)
An Exact Penalty Method over Discrete Sets

We are interested in solving linearly constrained binary quadratic problems (BQP) by transforming the problems into unconstrained ones and using a max-cut solver. This is in the spirit of “exact penalty methods”, but optimizing the penalized function over the discrete set. We improve on a method investigated by Lasserre (2016) who computed a sufficiently large penalty parameter by solving two semidefinite programs. Our new parameters lead to a better performance when solving the transformed problem. We present preliminary computational results demonstrating the strength of this method.

Julie Sliwak, RTE, Polytechnique Montréal, LIPN (joint work with Miguel Anjos, Lucas Létocart, Jean Maeght, Emiliano Traversi)
A conic-bundle approach to solve semidefinite relaxations of Alternating Current Optimal Power Flow problems

The Alternating Current Optimal Power Flow (ACOPF) problem is a challenging problem due to its significant nonconvexity. To prove global optimality, Semidefinite Relaxations (SDRs) are a powerful tool: the rank-one SDR is often exact and when it is not, the Lasserre hierarchy SDRs achieve global optimality. However, solving large-scale semidefinite programs is still a computational challenge. We propose a conic-bundle algorithm to solve SDRs of ACOPF based on a clique decomposition arising from an ad-hoc chordal extension of the power network.

Felix Lieder, Heinrich-Heine-Universität Düsseldorf
Exploiting Completely Positive Projection Heuristics

In this talk we revisit completely positive cone programs. A simple reformulation as a fixed point problem leads us to a family of (globally convergent) outer algorithms. NP-hardness of the original problem is shifted to the completely positive projection operator. Its sequential (approximate) evaluations are then tackled by exploiting the underlying structure in combination with powerful local optimization tools. Finally some promising numerical results on small dimensional maximum stable set problems are presented, indicating that the resulting heuristics often perform well in practice.
Nonnegative matrix factorization over polynomial signals via a sum-of-squares approach

Nonnegative matrix factorization (NMF) is a linear dimensionality reduction technique successfully used for analysis of discrete data, such as images. It is a discrete process by nature while the analyzed signals may be continuous. The aim of this work is to extend NMF to deal with continuous signals, avoiding a priori discretization. In other words, we seek a small basis of nonnegative signals capable of additively reconstructing a large dataset. We propose a new method to compute NMF for polynomials or splines using an alternating minimization scheme relying on sum-of-squares representation.

Noisy Euclidean Distance Matrix Completion with A Single Missing Node

We present several solution techniques for the noisy single source localization problem, i.e., the Euclidean distance matrix completion problem with a single missing node to locate under noisy data. For the case that the sensor locations are fixed, we show that this problem is implicitly convex, and we provide a purification algorithm along with the SDP relaxation to solve it efficiently and accurately. For the case that the sensor locations are relaxed, we study a model based on facial reduction. We present several approaches to solve this problem efficiently and compare their performance.

An adaptive LP-Newton method for second-order cone optimization

The LP-Newton method solves the linear optimization problem (LP) by repeatedly projecting a current point onto a certain relevant polytope. In this talk, we extend the LP-Newton method to the second-order cone optimization problem (SOCP) via a linear semi-infinite optimization problem (LSIP) reformulation. In the extension, we produce a sequence by projection onto polyhedral cones constructed from LPs obtained by finitely relaxing the LSIP. We show the global convergence of the proposed algorithm under mild assumptions, and investigate its efficiency through numerical experiments.

Exact relaxations of non convex trust region subproblems with an additional quadratic constraint

In this work we study nonconvex trust region problems with an additional quadratic constraint. For this class of problems we propose a family of relaxations, and study some key properties regarding convexity, exactness of the relaxation, sufficient condition for exactness, etc. For the case that the additional quadratic constraint is not convex, we generalize sufficient conditions for exactness of the relaxation proposed originally for trust region problems with an additional conic and discuss some examples for which trivial extensions of the sufficient conditions do not apply.

Higher-Order Cone Programming [canceled]

We introduce a conic embedding condition that gives a hierarchy of cones and cone programs. This condition is satisfied by a large number of convex cones including the cone of copositive matrices, the cone of completely positive matrices, and all symmetric cones. We discuss properties of the intermediate cones and conic programs in the hierarchy. In particular, we demonstrate how this embedding condition gives rise to a family of cone programs that interpolates between LP, SOCP, and SDP.
CNV

Splitting Methods and Applications (Part I)
Organizers: Pontus Giselsson, Ernest Ryu, Adrien Taylor
Chair: Adrien Taylor

Francisco Javier Aragón Artacho, University of Alicante (joint work with Yair Censor, Aviv Gibali)
The cyclic Douglas–Rachford algorithm with r-sets-Douglas–Rachford operators

The Douglas–Rachford (DR) algorithm is an iterative procedure that uses sequential reflections onto convex sets and which has become popular for convex feasibility problems. In this paper we propose a structural generalization that allows to use r-sets-DR operators in a cyclic fashion. We prove convergence and present numerical illustrations of the potential advantage of such operators with $r > 2$ over the classical 2-sets-DR operators in a cyclic algorithm.

Sorin-Mihai Grad, Vienna University (joint work with Oleg Wilfer)
Combining duality and splitting proximal point methods

We approach via conjugate duality some optimization problems with intricate structure that cannot be directly solved by means of the existing proximal point type methods. A splitting scheme is employed on the dual problem and the optimal solutions of the original one are recovered by means of optimality conditions. We use this approach for minmax location and entropy constrained optimization problems, presenting also some computational results where our method is compared with some recent ones from the literature.

Xiaoqun Zhang, Shanghai Jiao Tong University
A Stochastic Primal Dual Fixed Point Method for Composited Convex Optimization

In this work we proposed a stochastic version of primal dual fixed point method (SPDFP) for solving a sum of two proper lower semi-continuous convex function one of which is composited with a linear operator. Under some assumptions we proved the convergence of the proposed algorithm and also provided a variant for the implementation. Convergence analysis shows that the expected error of iterate is of the order $O(k^{-\alpha})$ where $k$ is the iteration number and $\alpha \in (0, 1)$. Finally, two numerical examples are performed to demonstrate the effectiveness of the proposed algorithms.

DER

Emerging Trends in Derivative-Free Optimization (Part III)
Organizers: Ana Luisa Custodio, Sébastien Le Digabel, Margherita Porcelli, Francesco Rinaldi, Stefan Wild
Chair: Ana Luisa Custodio

Susan Hunter, Purdue University (joint work with Kyle Cooper, Kalyani Nagaraj)
Bi-objective simulation optimization on integer lattices using the epsilon-constraint method in a retrospective approximation framework

We propose the Retrospective Partitioned Epsilon-constraint with Relaxed Local Enumeration (R-PERLE) algorithm to solve the bi-objective simulation optimization problem on integer lattices. R-PERLE is designed for simulation efficiency and provably converges to a local efficient set w.p.1 under appropriate regularity conditions. It uses a retrospective approximation (RA) framework and solves each resulting bi-objective sample-path problem only to an error tolerance commensurate with the sampling error. We discuss the design principles that make our algorithm efficient.

Mauro Passacantando, Università di Pisa (joint work with Stefano Lucidi, Francesco Rinaldi)
A global optimization approach for solving non-monotone equilibrium problems

A global optimization approach for solving non-monotone equilibrium problems (EPs) is proposed. The regularized gap functions are used to reformulate any EP as a constrained global optimization program and some bounds on the Lipschitz constant of such functions are provided. The proposed approach combines exact penalty functions with an improved version of the DIRECT algorithm which exploits local bounds of the Lipschitz constant. Unlike most existing methods, no monotonicity condition is assumed. Preliminary numerical results on several classes of EPs show the effectiveness of the approach.

Evgeniya Vorontsova, Université Grenoble Alpes (joint work with Pavel Dvurechensky, Alexander Gasnikov, Eduard Gorbunov)
[moved] Optimal stochastic gradient-free methods with inexact oracle

We propose new accelerated stochastic gradient-free methods for convex and strongly convex optimization problems with small additive noise of unknown nature. We try to make the analysis accurate to obtain the best possible estimates on how this noise accumulates. Note that we don’t assume that we “live” in a bounded set. Since that we have to show that generated sequence of points will be bounded. This requires new technique.
Global Optimization - Contributed Session II
Chair: Özan Evkaya

Majid Darehmiraki, Behbahan Khatam Alanbia University of Technology (joint work with Seyedeh Masoumeh Hosseini Nejad)

The proximal gradient method for the subproblem of trust region method

Trust region algorithms are a class of numerical methods for nonlinear optimization problems, which have been extensively studied for many decades. Finding solution for the subproblem of the trust region method is a fundamental problem in nonlinear optimization. In this paper, using Tikhonov regularization, we first turn the constrained quadratic problem into an unconstrained problem, and then solve it by the proximal gradient (PG) method. The proposed method is effective both for dense and large-sparse problems, including the so-called hard case.

José Fernández, University of Murcia (joint work with Laura Anton-Sanchez, Boglárka G.-Tóth, Juana L. Redondo, Pilar M. Ortigosa)

Firm expansion: how to invest? A MINLP model and B&B and heuristic procedures to deal with it

A chain wants to expand its presence in a given region, where it already owns some existing facilities. The chain can open a new facility and/or modify the qualities of some of its existing facilities and/or close some of them. In order to decide the location and quality of the new facility (in case it is open) as well as the new qualities for the existing facilities, a MINLP is formulated, whose objective is to maximize the profit obtained by the chain. Both an exact interval Branch-and-Bound method and a heuristic evolutionary algorithm are proposed to cope with this problem.

Ozan Evkaya, Atilim University

Parameter estimations of finite mixture models with particular optimization tools

Copulas can be easily incorporated into finite mixtures but as the structure of mixture models the gradient based optimization tools are not practical for the purpose of parameter estimation. This paper mainly investigates the performance of various optimization tools with different properties in terms of finding parameters of finite mixture models. In that respect, traditional gradient based, recently developed heuristic and global optimization algorithms are studied. For testing performance, considered problem with specific optimization routines are compared in terms of accuracy and run time.

Uncertainty in Multi-Objective Optimization
Organizers: Gabriele Eichfelder, Alexandra Schwartz
Chair: Patrick Groetzner

Fabian Chlumsky-Harttmann, TU Kaiserslautern (joint work with Anita Schöbel)

Cutting planes for robust multi-objective optimization

Previously developed concepts for robust multi-objective optimization such as set-based and point-based minmax robust efficiency determine efficient solutions that are good in the worst case. However, finding robust efficient solutions for a given uncertain multi-objective problem remains difficult. We adopt a row generating approach incrementally increasing the set of considered scenarios and investigate what selection rule for the scenario to add is most beneficiary to achieve fast convergence.

Patrick Groetzner, Augsburg University (joint work with Ralf Werner)

Multiobjective Optimization Under Uncertainty: A Robust Regret Approach

Consider a multiobjective decision problem with uncertainty given as a set of scenarios. In the single criteria case, robust optimization methodology helps to identify solutions which remain feasible and of good quality for all possible scenarios. Here one method is to compare the possible decisions under uncertainty against the optimal decision with the benefit of hindsight, i.e. to minimize the regret of not having chosen the optimal decision. In this talk I will extend this regret to the multiobjective setting to introduce a robust strategy for multiobjective optimization under uncertainty.
Recent Advances of First-Order Methods for Nonlinear Problems (Part I)
Organizers: Shiqian Ma, Yangyang Xu
Chair: Shiqian Ma
Haihao Lu, MIT
Q-Stochastic Gradient Descent: a New Stochastic First-Order Method for Ordered Empirical Loss Minimization

We propose a new approach to stochastic first-order method for tackling empirical loss minimization problems such as those that arise in machine learning. We develop a theory and computationally simple way to construct a gradient estimate that is purposely biased. On the theory side, we show that the proposed algorithm is guaranteed to converge at a sublinear rate to the global optimum of the modified objective function. On the computational side, we present numerical experiments that confirm the usefulness of the new method compared with standard SGD in different settings.

Tianbao Yang, University of Iowa (joint work with Rong Jin, Qihang Lin, Qi Qi, Yi Xu)

Stochastic Optimization for DC Functions and Non-smooth Non-convex Regularizers with Non-asymptotic Convergence

We propose new stochastic optimization algorithms and study their first-order convergence theories for solving a broad family of DC functions. We improve the existing algorithms and theories of stochastic optimization for DC functions from both practical and theoretical perspectives. Moreover, we extend the proposed stochastic algorithms for DC functions to solve problems with a general non-convex non-differentiable regularizer, which does not necessarily have a DC decomposition but enjoys an efficient proximal mapping.

N. Serhat Aybat, Penn State University (joint work with Afrooz Jalilzadeh, Uday Shanbhag, Erfan Y. Hamedani)
A Doubly-Randomized Block-Coordinate Primal-Dual Method for Large-scale Convex-Concave Saddle Point Problems: Acceleration via Variance-Reduction

We consider computing a saddle point \((x^*, y^*)\) of convex-concave \(L(x, y) = \sum_{n=1}^{N} \Phi_n(x, y)\). This problem class includes convex optimization with a large number of constraints. To contend with the challenges in computing full gradients, we employ a primal-dual scheme in which randomly selected primal and dual variable blocks, \(x_i\) and \(y_j\), are updated at every iteration. When \(N\) is large, we can utilize an increasing batch-size of the gradients of \(\Phi_n\), to achieve the optimal rate of \(O(1/k)\) in terms of \(L(x^k, y^k) - L(x^*, y^*)\). Preliminary results on QCQPs with many constraints look promising.

Optimality Conditions in Nonlinear Optimization (Part I)
Organizer: Gabriel Haeser
Chair: Paulo J. S. Silva
Alexey Tret’yakov, University of Podlase in Siedlce (joint work with Olga Brezhneva, Yuri Evtushenko)
Elementary proofs of a Karush-Kuhn-Tucker Theorem

We present elementary proofs of a Karush-Kuhn-Tucker (KKT) theorem for an optimization problem with inequality constraints. We call the proofs “elementary” because they do not use advanced results of analysis. Our proofs of the KKT theorem use only basic results from Linear Algebra and a definition of differentiability. The simplicity of the proofs makes them particularly suitable for use in a first undergraduate course in optimization.

Bruno Figueira Lourenço, University of Tokyo
Amenable cones, error bounds and algorithms

We will talk about a new family of cones called “amenable cones”. We will show that feasibility problems over amenable cones admit error bounds even when constraint qualifications fail to hold. Therefore, amenable cones provide a natural framework for extending the so-called “Sturm’s Error Bound”. We will present many example of amenable cones and discuss the connection between the amenability condition and other properties such as niceness and facial exposedness. At the end, we will also discuss algorithmic implications of our results.

Paulo J. S. Silva, University of Campinas - UNICAMP (joint work with Roberto Andreani, Gabriel Haeser, Leonardo D. Secchin)
Sequential optimality conditions for mathematical problems with complementarity constraints

Recently, the convergence of methods for nonlinear optimization problems has been analyzed using sequential optimality conditions. However, such conditions are not well suited for Mathematical Problems with Complementarity Constraints (MPCCs). Here we propose new sequential conditions for usual stationarity concepts in MPCC, namely weak, C- and M-stationarity, together with the associated weakest MPCC constraint qualifications. We also show that some algorithms reach AC-stationary points, extending their convergence results. The new results include the linear case, not previously covered.
**Methods of Optimization in Riemannian Manifolds (Part I)**
Organizer: Orizon Pereira Ferreira
Chair: Orizon Pereira Ferreira

João Xavier da Cruz Neto, Federal University of Piauí (joint work with Lucas Meireles, Gladyston de Carvalho Bento)

**An Inexact Proximal Point Method for Multiobjective Optimization on Riemannian Manifolds**

In this talk, a definition of approximate Pareto efficient solution as well as a necessary condition for such solutions in the multiobjective setting on Riemannian manifolds is proposed. An inexact proximal point method for nonsmooth multiobjective optimization by using the notion of approximate solution is also proposed. The main convergence result ensures that each cluster point (if any) of any sequence generated by the method is a Pareto critical point. Furthermore, when the problem is convex on a Hadamard manifold, full convergence of the method for a weak Pareto optimal is obtained.

João Carlos Souza, Federal University of Piauí (joint work with Yldenilson Almeida, Paulo Oliveira, João Xavier da Cruz Neto)

**Accelerated proximal-type method for DC functions in Hadamard manifolds**

In this work, a proximal-type method for solving minimization problems involving smooth DC (difference of convex) functions in Hadamard manifolds is presented. The method accelerates the convergence of the classical proximal point method for DC functions and, in particular, convex functions. We prove that the point which solves the proximal subproblem can be used to define a descent direction of the objective function. Our method uses such a direction together with a line search for finding critical points of the objective function. We illustrate our results with some numerical experiments.

Maurício Louzeiro, UFG (joint work with Orizon Pereira Ferreira, Leandro Prudente)

**Gradient Method for Optimization on Riemannian Manifolds with Lower Bound Curvature**

The gradient method for minimize a differentiable convex function on Riemannian manifolds with lower bounded sectional curvature is analyzed in this talk. The analysis of the method is presented with three different finite procedures for determining the step size, namely, Lipschitz stepsize, adaptive stepsize and Armijo’s stepsize. Convergence of the whole sequence to a minimizer, without any level set boundedness assumption, is proved. Iteration-complexity bound is also presented. As well as, some examples of functions that satisfy the assumptions of our results.

**Mixed-Integer Optimal Control and PDE Constrained Optimization (Part III)**
Organizers: Falk Hante, Christian Kirches, Sven Leyffer
Chair: Christian Kirches

Clemens Zeile, Otto-von-Guericke University Magdeburg (joint work with Francesco Braghin, Nicolò Robuschi, Sebastian Sager)

**Multiphase Mixed-Integer Nonlinear Optimal Control of Hybrid Electric Vehicles**

This talk considers the problem of computing the minimum-fuel energy management strategy of a hybrid electric vehicle on a given driving cycle. A tailored algorithm is devised by extending the combinatorial integral approximation technique that breaks down the original mixed-integer nonlinear program into a sequence of nonlinear programs and mixed-integer linear programs. Specifically, we address the multiphase context and propose combinatorial constraints for the optimal gear choice, torque split and engine on/off controls in order to account for technical requirements.

Bart van Bloemen Waanders, Sandia National Laboratory

**Mixed Integer PDE-constrained optimization with scalable software**

We present algorithms to solve mixed integer problems constrained by partial differential equations (PDEs). A branch and bound methodology is used to address the discrete nature of the problem and at each bound computation the relaxation requires the solution of a PDE-constrained optimization problem. A hierarchical modeling approach (with multiple starts) efficiently supports the bounding process. Low-fidelity models allow exploration for the most promising branching options. We discuss our C++ software design which features scalable parallelism. A numerical prototype demonstrates our approach.

Sven Leyffer, Argonne National Laboratory (joint work with Todd Munson, Ryan Vogt)

**Mixed-Integer PDE Constrained Optimization for Design of Electromagnetic Cloaking**

We formulate a mixed-integer partial-differential equation constrained optimization problems (MIPDECO) for designing an electromagnetic cloak governed by the 2D Helmholtz equation with absorbing boundary conditions. We extend the formulation to include uncertainty with respect to the angle of the incidence wave, and develop a mixed-integer trust-region approach for solving both the nominal and the uncertain instance. Our method alternates between a forward/adjoint PDE solve and a knapsack problem. We present numerical results of our new approach that demonstrate its effectiveness.
**Thu.1 H 0112  PDE**

**Geometric Methods in Optimization of Variational Problems (Part I)**
Organizers: Roland Herzog, Anton Schiela
Chair: Roland Herzog
Ronny Bergmann, TU Chemnitz (joint work with Roland Herzog, Daniel Tenbrinck, Jose Vidal-Nunez)

**A primal-dual algorithm for convex nonsmooth optimization on Riemannian manifolds**

Based on a Fenchel dual notion on Riemannian manifolds we investigate the saddle point problem related to a nonsmooth convex optimization problem. We derive a primal-dual hybrid gradient algorithm to compute the saddle point using either an exact or a linearized approach for the involved nonlinear operator. We investigate a sufficient condition for convergence of the linearized algorithm on Hadamard manifolds. Numerical examples illustrate, that on Hadamard manifolds we are on par with state of the art algorithms and on general manifolds we outperform existing approaches.

Robin Richter, Georg-August Universität Göttingen (joint work with Duy Hoang Thai, Stephan Huckemann)

**Bilevel optimization in imaging with application to fingerprint analysis**

Removing texture from an image while preserving sharp edges, to obtain a so-called cartoon, is a challenging task in image processing, especially since the term texture is mathematically not well defined. We propose a generalized family of algorithms, guided by two optimization problems simultaneously, profiting from the advantages of both variational calculus and harmonic analysis. In particular, we aim at avoiding introduction of artefacts and staircasing, while keeping the contrast of the image.

Dominik Stöger, TU München, Fakultät für Mathematik (joint work with Felix Krahmer)

**The convex geometry of matrix completion**

Matrix completion refers to the problem of reconstructing a low-rank matrix from only a random subset of its entries. It has been studied intensively in recent years due to various applications in learning and data science. A benchmark algorithm for this problem is nuclear norm minimization, a natural convex proxy for the rank. We will discuss the stability of this approach under the assumption that the observations are perturbed by adversarial noise.

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**Thu.1 H 2013  PDE**

**PDE-constrained Optimization Under Uncertainty (Part I)**
Organizers: Harbir Antil, Drew Philip Kouri, Thomas Michael Surowiec, Michael Ulbrich, Stefan Ulbrich
Chair: Thomas Michael Surowiec
René Henrion, Weierstrass Institute for Applied Analysis and Stochastics (WIAS) (joint work with Mohamad Hassan Farshbaf Shaker, Martin Gugat, Holger Heitsch)

**Optimal Neumann boundary control of the vibrating string with uncertain initial data**

The talk addresses a PDE-constrained optimization problem, namely the optimal control of vibrating string under probabilistic constraints. The initial position of the string is supposed to be random (multiplicative noise on Fourier coefficients). The objective is to find a cost optimal control driving the final energy of the string to an amount smaller then epsilon with probability larger than p. The numerical solution of the resulting convex optimization problem relies on the ‘spheric-radial decomposition’ of Gaussian random vectors.

Harbir Antil, George Mason University

**Risk-Averse Control of Fractional Diffusion**

In this talk, we introduce and analyze a new class of optimal control problems constrained by elliptic equations with uncertain fractional exponents. We utilize risk measures to formulate the resulting optimization problem. We develop a functional analytic framework, study the existence of solution and rigorously derive the first-order optimality conditions. Additionally, we employ a sample-based approximation for the uncertain exponent and the finite element method to discretize in space.

Philipp Guth, University of Mannheim (joint work with Vesa Kaarnioja, Frances Kuo, Claudia Schillings, Ian Sloan)

**PDE-constrained optimization under uncertainty using a quasi-Monte Carlo method**

In this work we apply a quasi-Monte Carlo (QMC) method to an optimal control problem constrained by an elliptic PDE equipped with an uncertain diffusion coefficient. In particular the optimization problem is to minimize the expected value of a tracking type cost functional with an additional penalty on the control. It is shown that the discretization error of the solution is bounded by the discretization error of the adjoint state. For the convergence analysis the latter is decomposed into truncation error, finite element error and QMC error, which are then analysed separately.

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**Thu.1 09:00–10:15  151**
Robust Optimization: New Advances in Methodology and Applications
Organizer: Nikos Trichakis
Chair: Nikos Trichakis

Lukáš Adam, Southern University of Science and Technology
Distributionally robust multi-objective optimization [canceled]

Recently, there were multiple papers concerning distributionally robust optimization. They usually consider a single objective. In this talk, we generalize the concept into optimization problems with multiple objectives. We present several approaches based on scalarization, Pareto front and set comparison. We show the advantages and disadvantages of all approaches both from a theoretical point and computational complexity. We conclude the talk by a numerical comparison.

Phoebe Vayanos, University of Southern California (joint work with John P. Dickerson, Duncan McElfresh, Eric Rice)
Robust Active Preference Learning

We consider the problem faced by a recommender system that seeks to offer a user their favorite item. Before making a recommendation, the system has the opportunity to elicit the user’s preferences by making a moderate number of queries. We propose an exact robust optimization formulation of the problem which integrates the learning (preference elicitation) and recommendation phases and an equivalent reformulation as a mixed-binary linear program. We evaluate the performance of our approach on synthetic and real data from the US homeless youth where we learn the preferences of policy-makers.

Nikos Trichakis, MIT (joint work with David Simchi-Levi, Peter Yun Zhang)
Robust Optimization for Response Supply Chain Design Against Bioattacks

We study end-to-end design of a supply chain for antibiotics to defend against bioattacks. We model the defender’s inventory prepositioning and dispensing capacity installation decisions, attacker’s move, and defender’s adjustable shipment decisions, so as to minimize inventory and life loss costs, subject to population survivability targets. We provide theoretical backing to the performance of the Affinely Adjustable Robust Counterpart by proving its optimality under certain conditions. We conduct a high-fidelity case study with millions of nodes to guard against anthrax attacks in the US.

Sparse Optimization and Information Processing - Contributed Session II
Organizer: Shoham Sabach
Chair: Mustafa C. Pinar

Radu-Alexandru Dragomir, Université Toulouse Capitole & D.I. Ecole Normale Supérieure
Fast Gradient Methods for Symmetric Nonnegative Matrix Factorization

We describe fast gradient methods for solving the symmetric nonnegative matrix factorization problem (SymNMF). We use recent results on non-Euclidean gradient methods and show that the SymNMF problem is smooth relatively to a well-chosen Bregman divergence. This approach provides a simple hyper-parameter-free method which comes with theoretical convergence guarantees. We also discuss accelerated variants. Numerical experiments on clustering problems show that our algorithm scales well and reaches both state of the art convergence speed and clustering accuracy for SymNMF methods.

Yue Xie, University of Wisconsin-Madison (joint work with Uday Shanbhag)
A Tractable ADMM Scheme for Computing KKT Points and Local Minimizers for l0 Minimization Problems

We consider an equivalent formulation of $l^0$-minimization problem over a polyhedral set as MPCC. It is known that $l^0$-norm penalty implicitly emphasizes sparsity of the solution. We show that under suitable assumptions, an equivalence is derived between KKT points and local minimizers of this formulation. A perturbed variant of proximal ADMM is proposed for which each subproblem is tractable and convergence can be claimed under mild assumptions. Preliminary numerics suggest that this scheme may significantly outperform their standard nonconvex ADMM counterparts.

Mustafa C. Pinar, Bilkent University (joint work with Deniz Akkaya)
Minimizers in Robust Regression Adjusted for Sparsity

Robust regression analysis using Huber’s linear-quadratic loss function has been studied in the context of numerical optimization since the 1980s. Its statistical properties under deviations from normality are well-known. We couple the Huber loss function with a $L^1$-norm term to induce sparsity, and study the local and global minimizers of the resulting non-convex function inspired from results of Nikolova on the least squares regression adjusted for sparsity.
Yassine Laguel, Université Grenoble Alpes (joint work with Wellington De Oliveira, Jerome Malick, Guilherme Ramalho, Wim Van Ackooij)

On the interplay between generalized concavity and chance constraints

Probabilistic constraints (or chance constraints) aim at providing safety regions for optimization problems exposed to uncertainty. Understanding when these regions are convex is important for numerical resolution of the optimization problem. In this work we show that “eventual convexity” often occurs: for structured but general models of chance constraints, convexity of levels sets is guaranteed when the probability level is greater than a computable threshold. We illustrate our results on examples uncovered by previous theory.

Pedro Pérez-Aros, Universidad de O’Higgins (joint work with René Henrion, Wim Van Ackooij)

Generalized gradients for probabilistic/robust (probust) constraints

Ideas from robust optimization lead to probust functions, i.e. probability functions acting on generalized semi-infinite inequality systems. In this work, we employ powerful tools from variational analysis to study generalized differentiation of such probust functions. We also provide explicit outer estimates of the generalized subdifferentials in terms of nominal data.
APP Thu.2 H 3004

Applications in Economics
Chair: Po-An Chen

Benteng Zou, University of Luxembourg (joint work with Luisito Bertinelli, Stephane Poncin)
The Dynamics Competition of Key Elements of Sustainable Technology – the Rare Earth Elements

Rare earth elements are widely used in i-phones, computers, hybrid cars, wind and solar energy and are essentially important for the worldwide sustainable development. Few has been done related to rare earth elements competition in economic research. This current study tries to fill in this gap. A monopoly to duopoly competition is constructed and studied. We provide necessary and sufficient conditions when should enter the competition and what would be the consequences and response of China. We also provide the analysis if cooperation between China and USA is possible.

Asiye Aydilek, Gulf University for Science and Technology (joint work with Harun Aydilek)
Do we really need heterogenous agent models under recursive utility?

We investigate the existence of representative agent under various heterogeneities in a recursive utility framework. We provide the analytical solution of household allocations. We numerically explore whether we can find a representative agent whose income is the aggregate income of the society and whose allocations are the aggregate allocations of the society under heterogeneity in the parameter of risk aversion and/or parameter of intertemporal substitution, or discount rate or survival probability. We find that there is no representative agent.

Po-An Chen, National Chiao Tung University (joint work with Chi-Jen Lu, Yu-Sin Lu)
An Alternating Algorithm for Finding Linear Arrow-Debreu Market Equilibrium

Jain reduced equilibrium computation in Arrow-Debreu (AD) markets to that in bijective markets. Motivated by the convergence of mirror-descent algorithms to market equilibria in linear Fisher markets, we simply design algorithms to solve a rational convex program for linear bijective markets in this paper. Our algorithm for computing linear AD market equilibrium is based on solving the rational convex program formulated by Devanur et al., repeatedly alternating between a step of gradient-descent-like updates and a follow-up step of optimization. Convergence can be achieved by a new analysis.

APP Thu.2 H 3012

Applications in Engineering
Chair: Manuel Radons

Dimitrios Nerantzis, Imperial College London (joint work with Filippo Pecci, Ivan Stoianov)
Pressure and energy optimization of water distribution systems without storage capacity.

We consider the problem of optimal pressure and energy control of water distribution systems without storage capacity. We formulate the problem as a nonlinear, nonconvex program and employ an interior point algorithm (IPOPT) for its efficient solution. We present our results from a case study using a large scale, real network from UK.

Manuel Radons, TU Berlin (joint work with Timo Burggraf, Michael Joswig, Marc Pfetsch, Stefan Ulbrich)
Semi-automatically optimized calibration of internal combustion engines

Modern combustion engines incorporate a number of actuators and sensors that can be used to control and optimize the performance and emissions. We describe a semi-automatic method to simultaneously measure and calibrate the actuator settings and the resulting behavior of the engine. The method includes an adaptive process for refining the measurements, a data cleaning step, and an optimization procedure. The combination of these techniques significantly reduces the number of measurements required to achieve a given set of calibration goals. We demonstrate our method on practical examples.
**Thu.2 H 0105**  
**BIG**  
**Nonconvex Optimization in Machine Learning (Part I)**  
Organizer: Ethan Fang  
Chair: Ethan Fang  
Yuxin Chen, Princeton University  
**Noisy Matrix Completion: Bridging Convex and Nonconvex Optimization**  
This talk is about noisy matrix completion. Arguably one of the most popular paradigms is convex relaxation, which achieves remarkable efficacy in practice. However, the theoretical support of this approach is still far from optimal. We make progress towards demystifying the practical efficacy of convex relaxation vis-à-vis random noise. When the rank of the matrix is $O(1)$, we demonstrate that convex programming achieves near-optimal estimation errors. All of this is enabled by bridging convex relaxation with nonconvex optimization, a seemingly distinct algorithm that is robust against noise.  
Zhuoran Yang, Princeton University  
**Variational Transport: A Convergent Particle-Based Algorithm for Distributional Optimization**  
We consider the problem of minimizing a functional defined over a family of probability distributions, where the functional is assumed to have a variational form. For this problem, we propose the variational transport algorithm, which approximately performs functional gradient descent over the manifold of probability distributions via iteratively pushing a set of particles. By characterizing both the statistical error of estimating the functional gradient and the progress of optimization algorithm, we show that the proposed algorithm enjoys global convergence with high probability.  
Alfonso Lobos, University of California, Berkeley (joint work with Paul Grigas, Nathan Vermeersch)  
**Stochastic In-Face Frank-Wolfe Methods for Non-Convex Optimization and Sparse Neural Network Training**  
The Frank-Wolfe (FW) method and its extensions are well-suited for delivering solutions with desirable structural properties, such as sparsity or low-rank structure. We adapt the methodology of in-face directions within the FW method to the setting of non-convex optimization. We are particularly motivated by the application of stochastic versions of FW and the extensions mentioned above to the training of neural networks with sparse and/or low-rank properties. We develop theoretical computational guarantees, and we complement these results with extensive numerical experiments.
**BIG**

**Thu.2 H 3007**

**Big Data and Machine Learning - Contributed Session II**  
Chair: Rachael Tappenden

Lei Zhao, Shanghai Jiao Tong University (joint work with Daoli Zhu)

**Linear Convergence of Variable Bregman Stochastic Coordinate Descent Method for Nonsmooth Nonconvex Optimization by Level-set Variational Analysis**

In this paper, we develop a new variational approach on level sets aiming towards linear convergence of a variable Bregman stochastic coordinate descent (VBSCD) method for a broad class of nonsmooth and nonconvex optimization problem. Along this way, we not only derive the convergence of VBSCD, that is any accumulation of the sequence generated by VBSCD is a critical point, but also provide $\{E_{\xi_k} F(x_k)\}$ $Q-$linear and almost surely $\{E_{\xi_k} x_k\}$ $R-$linear convergence rate.

Sarit Khirirat, Division of Decision and Control (joint work with Mikael Johansson, Sindri Magnússon)

**Compressed Gradient Methods with Memory-Based Error Compensation**

The veritable scale of modern data necessitates information compression in distributed optimization for machine learning. Gradient compression schemes using memory-based error compensation have displayed superior performance in practice. We illustrate how these approaches can be improved by using Hessian information in the compression. Explicit expressions for the accuracy gains on strongly convex and non-convex optimization problems are derived. The superiority of our approach in terms of convergence speed and solution accuracy is illustrated in numerical examples with 1-bit compression.

Rachael Tappenden, University of Canterbury (joint work with Naga Venkata C. Gudapati, Majid Jahani, Chenxin Ma, Martin Takáč)

**Underestimate Sequences and Quadratic Averaging**

This talk discusses several first order methods for minimizing strongly convex functions in both the smooth and composite cases. The algorithms, based on efficiently updating lower bounds on the objective functions, have natural stopping conditions that provide the user with a certificate of optimality. Convergence of all algorithms is guaranteed via a new Underestimate Sequence framework, and the algorithms converge linearly, with the accelerated variants converging at the optimal linear rate.

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**VIS**

**Thu.2 H 3013**

**Numerical Methods for Bilevel Optimization and Applications (Part I)**  
Organizer: Alain Zemkoho  
Chair: Alain Zemkoho

Anthony Dunn, University of Southampton

**Foam prediction to improve biogas production using anaerobic digestion**

Anaerobic digestion is used in renewable energy plants to produce biogas from recycled biological waste. Within the reaction digester, a phenomenon known as foaming can occur at irregular time intervals which results in a reduced yield of biogas and requires an extensive repair period. We show that machine learning based techniques (relying on single and two-level optimization) allow for the development of a predictive maintenance model that recognises periods of high foam risk. This enables the plant operators to apply suitable changes in the operations system to reduce the risk.

Andrey Tin, University of Southampton

**Gauss-Newton-type method for bilevel optimization**

This article examines the application of Newton-type methods for overdetermined systems to find solutions of bilevel programming problems. Since the Jacobian of the system is non-square, we discuss Gauss-Newton method and Newton method with Moore-Penrose pseudo inverse to solve the system. To our knowledge, this is the first time these methods are discussed in literature to solve bilevel programs. We prove that the methods can be well-defined for the introduced optimality conditions. In numerical part we compare the results of the methods with known solutions and performance of 124 examples.

Alain Zemkoho, University of Southampton (joint work with Yekini Shehu, Phan Tu Vuong)

**An inertial extrapolation method for convex simple bilevel optimization**

We consider a scalar objective minimization problem over the solution set of another optimization problem. This problem is known as simple bilevel optimization problem and has drawn a significant attention in the last few years. We propose and establish the convergence of a fixed-point iterative method with inertial extrapolation to solve the problem. Our numerical experiments show that the proposed method outperforms the currently known best algorithm to solve the class of problem considered.
**Advances in Algorithms for Conic Optimization**

**Organizer:** Julio C. Goez  
**Chair:** Joachim Dahl

Joachim Dahl, Joachim Dahl  
**A primal-dual algorithm for exponential-cone optimization**

We discuss a primal-dual algorithm for exponential-cone optimization. The algorithm is based on primal-dual scaling proposed by Tuncel, with similar properties as Nesterov-Todd scalings for symmetric cones. We also discuss a new corrector for nonsymmetric cones, which considerably reduces the number of iterations required to solve a number of test problems. This algorithm has recently been developed for version 9 of the MOSEK software.

Alex Wang, Carnegie Mellon University (joint work with Fatma Kilinc-Karzan)

**A Linear-Time Algorithm for Generalized Trust Region Subproblem based on a Convex Quadratic Reformulation**

We consider the generalized trust region subproblem (GTRS) of minimizing a nonconvex quadratic objective over a nonconvex quadratic constraint. An obvious lifting of this problem recasts the GTRS as minimizing a linear objective subject to two nonconvex quadratic constraints. In this talk, we give an explicit characterization of the convex hull of this nonconvex region and show how it leads to a linear time (in the input size) algorithm for approximating the GTRS.

Julio C. Goez, NHH Norwegian School of Economics  
**Disjunctive conic cuts: the good, the bad, and implementation [canceled]**

We discuss a generalization of Balas disjunctive cuts which introduces the concept of disjunctive conic cuts (DCCs) and disjunctive cylindrical cuts (DCyCs). The first part of this talk will summarize the main results about DCCs and DCyCs including some results about valid conic inequalities for hyperboloids and non-convex quadratic cones. In the second part, we will discuss some of the limitation of this approach to derive useful valid inequalities in the context of MISOCO. In the last part we explore the potential for implementation of DCCs and DCyCs.

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**Polynomial Optimization Algorithms, Software, and Applications**

**Organizer:** Etienne de Klerk  
**Chair:** Anders Eltved

Brais González Rodríguez, Universidade de Santiago de Compostela (joint work with Julio González Díaz, Ángel M. González Rueda, Joaquín Ossorio Castillo, Diego Rodríguez Martínez, David Rodríguez Penas)

**RAPOSA, a freely available solver for polynomial optimization problems**

We will present a new implementation of the reformulation linearization techniques, RLT, in the context of polynomial programming problems, originally introduced in Sherali and Tuncbilek (1991). The implementation incorporates most of the features of the RLT algorithm discussed in past literature. Moreover, additional enhancements have been introduced, such as parallelization and warm start features at various levels of the branching process. The current version of the algorithm has proven to be very efficient, and comparisons with other global optimization solvers will be presented.

Yi-Shuai Niu, Shanghai Jiao Tong University (joint work with Ya-Juan Wang)

**Higher-order moment portfolio optimization via DC programming and sums-of-squares**

We are interested in solving higher-order moment portfolio optimization via DC (Difference of Convex) programming approach. The problem can be rewritten as a polynomial optimization which is equivalent to a DC program based on the Difference-of-Convex-Sums-of-Squares (DCSOS) decomposition. The later problem can be solved by DCA. We also propose an improved DC algorithm called Boosted DCA (BDCA). The main idea of BDCA is to introduce a line search based on Armijo typo rule to accelerate the convergence of DCA. Numerical simulation results show good performance of our methods.

Anders Eltved, Technical University of Denmark (joint work with Martin S. Andersen)

**Exact Relaxation of Homogeneous Quadratically Constrained Quadratic Programs with Tree Structure**

We study the semidefinite relaxation of homogeneous non-convex quadratically constrained quadratic programs where the matrices have a specific sparsity pattern. In particular, we consider problems where the graph of the aggregate nonzero structure of the matrices is a tree. We present a priori sufficient conditions for the semidefinite relaxation to be exact, which implies that the original problem is solvable in polynomial time. Checking these conditions requires solving a number of second order cone programs based on the data in the matrices, which can be done in polynomial time.
Algorithms for Conic Programming
Organizer: Etienne de Klerk
Chair: Konrad Schrempf
Chee Khian Sim, University of Portsmouth
Polynomial complexity and local convergence of an interior point algorithm on semi-definite linear complementarity problems
We consider an infeasible predictor-corrector primal-dual path following interior point algorithm to solve semi-definite linear complementarity problems (SDLCPs). The well-known Nesterov-Todd (NT) search direction is used in the algorithm. We provide the best known polynomial complexity when the algorithm is used to solve SDLCPs, and also give two sufficient conditions for when local superlinear convergence of iterates generated by the algorithm occurs.

Kresimir Mihic, University of Edinburgh (joint work with Jacek Gondzio, Spyridon Pougkakiotis)
Randomized multi-block ADMM based iterative methods for solving large scale coupled convex problems
In this work we propose an ADMM based framework for solving large scale quadratic optimization problems. We focus on non-separable dense and huge-scale sparse problems for which the current interior point methods do not bring satisfactory performance in terms of run time or scalability. We show that by integrating first and second order methods we can achieve a significant boost in performance with a limited loss in solution quality.

Konrad Schrempf, University of Applied Sciences Upper Austria
Primal “non-commutative” interior-point methods for semidefinite programming
Going over from the continuous (analytical) to the discrete (applied) setting one can use an “algebraic barrier” to get a family of (primal) “non-commutative” feasible-interior-point methods which are in particular useful for polynomial optimization (using sum-of-squares). I’m going to summarize the main ideas of my recent preprint arxiv:1812.10278 and show how an algebraic center can be used in different ways to find “good” minimization directions.

Splitting Methods and Applications (Part II)
Organizers: Francisco Javier Aragón Artacho, Matthew K. Tam
Chair: Francisco Javier Aragón Artacho
C.H. Jeffrey Pang, National University of Singapore
Deterministic distributed asynchronous optimization with Dykstra’s splitting
Consider the setting where each vertex of a graph has a function, and communications can only occur between vertices connected by an edge. We wish to minimize the sum of these functions. For the case when each function is the sum of a strongly convex quadratic and a convex function, we propose a distributed version of Dykstra’s algorithm. This algorithm is distributed, decentralized, asynchronous, has deterministic convergence. We show how to extend to directed graphs with unreliable communications and some results on convergence rates.

Pontus Giselsson, Lund University
Separate and Project: Nonlinear Forward-Backward Splitting with Projection Correction
We propose nonlinear forward-backward splitting with projection correction. The algorithm performs a forward-backward step that creates a separating hyperplane between the current point and the solution set. This is followed (if needed) by a correction step that projects onto the separating hyperplane. The metric in the backward step is an arbitrary strictly monotone single-valued mapping. This gives a very general method with known special cases such as, AFBA, Bregman PDHG, NoLips, FB(H)F, etc. Another special case is a novel four-operator splitting method for monotone inclusions.

Adrien Taylor, Inria/ENS Paris (joint work with Carolina Bergeling, Pontus Giselsson, Ernest Ryu)
Computer-aided proofs for operator splitting
We propose a methodology for automatically studying the performance of common splitting methods. The methodology enjoys comfortable tightness guarantees and relies on appropriate uses of semidefinite programming and/or symbolic computations. We illustrate the use of the framework for generating tight contraction factors for Douglas–Rachford splitting that are likely too complicated for a human to find bare-handed. We show that the methodology can also be used for performing optimal parameter selection.
Convex and Nonsmooth Optimization - Contributed Session II
Chair: Jose Vidal-Nunez

Nima Rabiei, American University of Iraq
AAR-Based Decomposition Method For Limit Analysis
The analysis of the bearing capacity of structures with a rigid-plastic behaviour can be achieved resorting to computational limit analysis. Recent techniques have allowed scientists and engineers to determine upper and lower bounds of the load factor under which the structure will collapse. Despite the attractiveness of these results, their application to practical examples is still hampered by the size of the resulting optimisation process.

Maryam Yashtini, Georgetown University (joint work with Sung Ha Kang)
High Quality Reconstruction with Euler’s elastica-based methods
In this talk, I present numerical methods for solving Euler’s elastica-regularized model for image processing. The minimizing functional is non-smooth and non-convex, due to the presence of a curvature term, which makes this model more powerful than the total variation-based models. Theoretical analysis as well as various numerical results in image processing and medical image reconstruction will be presented.

Jose Vidal-Nunez, TU Chemnitz (joint work with Ronny Bergmann, Roland Herzog, Daniel Tenbrinck)
Fenchel duality for convex optimization on Riemannian manifolds
This talk introduces a new duality theory that generalizes the classical Fenchel-Legendre conjugation to functions defined on Riemannian manifolds. We present that results from convex analysis also hold for this novel duality theory on manifolds. Especially the Fenchel–Moreau theorem and properties involving the Riemannian subdifferential can be stated in this setting. A main application of this theory is that a specific class of optimization problems can be rewritten into a primal-dual saddle-point formulation. This is a first step towards efficient algorithms.
**Recent Advances of First-Order Methods for Nonlinear Problems (Part II)**
Organizers: Shiqian Ma, Ion Necoara, Quoc Tran-Dinh, Yangyang Xu
Chair: Yangyang Xu

Hao Yu, Alibaba Group (U.S.) Inc (joint work with Michael Neely)

**A primal-dual parallel method with \( MCALO(1/\epsilon) \) convergence for constrained composite convex programs**

This work considers large scale constrained (composite) convex programs, which are difficult to solve by interior point methods or other Newton-type methods due to the non-smoothness or the prohibitive computation and storage complexity for Hessians and matrix inversions. The conventional Arrow-Hurwicz-Uzawa subgradient method is a parallel algorithm with \( O(1/\epsilon^2) \) convergence for constrained convex programs that are possibly non-smooth or non-separable. This work proposes a new primal-dual parallel algorithm with faster \( MCALO(1/\epsilon) \) convergence for such challenging constrained convex programs.

Runchao Ma, University of Iowa (joint work with Qihang Lin)

**Iteration Complexity for Constrained Optimization Problem under Local Error Bound and Weak Convexity**

This paper considers the constrained optimization problem with functional constraints. We first consider the case when problem is convex and has local error bound condition. Algorithms are proposed when condition number in local error bound is either known or unknown. Iteration complexity is derived to show the benefit coming from local error property. We then consider the case that constrained optimization problem is a weakly convex problem where both objective function and constraint are weakly convex. Algorithm is proposed and corresponding complexity is analyzed.

Yuyuan Ouyang, Clemson University

**Lower complexity bounds of first-order methods for some machine learning models**

We consider a class of large-scale optimization problems that arise from machine learning applications. In particular, the objective function has rotational invariance with respective decision variables. We show that, given the machine learning model, there exists worst-case datasets that yield lower complexity bounds of first-order methods for the specified model.

**Optimality Conditions in Nonlinear Optimization (Part II)**
Chair: Paulo J. S. Silva

Olga Brezhneva, Miami University (joint work with Ewa Szczepanik, Alexey Tret’yakov)

**Necessary and sufficient optimality conditions for p-regular inequality constrained optimization problems**

The focus of this talk is on nonregular optimization problems with inequality constraints. We are interested in the case when classical regularity assumptions (constraint qualifications) are not satisfied at a solution. We propose new necessary and sufficient optimality conditions for optimization problems with inequality constraints in the finite dimensional spaces. We present generalized KKT-type optimality conditions for nonregular optimization problems using the construction of a \( p \)-factor operator. The results are illustrated by some examples.

Maria Daniela Sanchez, Centro de Matemática de La Plata, Universidad Nacional de La Plata (joint work with Nadia Soledad Fazzio, Maria Laura Schuverdt, Raul Pedro Vignau)

**Optimization Problems with Additional Abstract Set Constraints**

We consider optimization problems with equality, inequality and additional abstract set constraints. We extend the notion of Quasinormality Constraint Qualification for problems with additional abstract set constraints. Also, we analyse the global convergence of the Augmented Lagrangian method when the algorithm is applied to problems with abstract set constraints. Motivated by the results obtained, we also studied the possibility to extend the definitions of others constraint qualifications well known in the literature for the case in which abstract set constraints is considered.

S. K. Gupta, IIT Roorkee

**Optimality conditions for a class of multiobjective interval valued fractional programming problem**

The article aims to study the Karush-Kuhn-Tucker optimality condition for a class of a fractional interval multivalued programming problem. For the solution concept, LU and LS-Pareto optimality are discussed, and some nontrivial examples are illustrated. The concepts of LU-V-invex and LS-V-invex for a fractional interval problem are introduced and using these assumptions, the Karush-Kuhn-Tucker optimality conditions for the problem have been established. Non-trivial examples are discussed throughout to make a clear understanding of the results established.
**Methods of Optimization in Riemannian Manifolds (Part II)**

Organizer: Orizon Pereira Ferreira  
Chair: Orizon Pereira Ferreira  
Josua Sassen, University of Bonn (joint work with Behrend Heeren, Klaus Hildebrandt, Martin Rumpf)

**Geometric optimization using nonlinear rotation-invariant coordinates**

We consider Nonlinear Rotation-Invariant Coordinates (NRIC) representing triangle meshes with fixed combinatorics as a vector stacking all edge lengths and dihedral angles. Previously, conditions for the existence of vertex positions matching given NRIC have been established. We develop the machinery needed to use NRIC for solving geometric optimization problems and introduce a fast and robust algorithm that reconstructs vertex positions from close-to integrable NRIC. Comparisons to alternatives indicate that NRIC-based optimization is particularly effective for near-isometric problems.

Orizon Pereira Ferreira, Federal University of Goias (UFG)  
(Joint work with Maurício Louzeiro, Leandro Prudente)

**Iteration-complexity and asymptotic analysis of steepest descent method for multiobjective optimization on Riemannian manifolds**

The steepest descent method for multiobjective optimization on Riemannian manifolds with lower bounded sectional curvature is analyzed in this paper. The aim of the paper is twofold. Firstly, an asymptotic analysis of the method is presented. The second aim is to present iteration-complexity bounds for the method with these three stepsizes. In addition, some examples are presented to emphasize the importance of working in this new context. Numerical experiments are provided to illustrate the effectiveness of the method in this new setting and certify the obtained theoretical results.

Andreas Weinmann, Hochschule Darmstadt

**Reconstructing manifold-valued images using total variation regularization and related methods**

In various problems in image processing, the data take values in a nonlinear manifold. Examples are circle-valued data in SAR imaging, special orthogonal group-valued data expressing vehicle headings, aircraft orientations or camera positions, motion group data as well as shape-space data. A further example is the space of positive matrices representing the diffusibility of water molecules in DTI imaging. In this talk we consider various variational approaches for such data including TV and higher order methods.

Thomas Vogt, University of Lübeck

**Measure-valued Variational Models for Non-Convex Imaging Problems**

Many non-convex variational models from image processing can be solved globally using convex relaxation frameworks. A popular framework comes from the context of calibration methods. We show that this framework can be interpreted as a measure-valued variational problem. This perspective can be applied to scalar, vectorial and manifold-valued problems with first- and second-order regularization.

Gladyston de Carvalho Bento, TU Chemnitz

**Generalized optimality conditions for weak Pareto-optimal solutions on Riemannian manifolds**

It is known that optimality criteria form the foundations of mathematical programming both theoretically and computationally. In this talk we will be approach generalized optimality conditions for weak Pareto-optimal solutions on Riemannian manifolds which allowed to consider the proximal point method for nondifferentiable multiobjective programs without any assumption of convexity over the constraint sets that determine the vectorial improvement steps throughout the iterative process.
A primal-dual algorithm for PDE-constrained optimization under uncertainty

We propose a primal-dual algorithm for solving nonsmooth risk-averse optimization problems in Banach spaces motivated by PDE-constrained optimization under uncertainty. The overall algorithm is based on the well-known method of multipliers, whereas the subproblem solves are based on inexact Newton solvers for smooth PDE-constrained problems. The analysis exploits a number of recent results on the epigraphical regularization of risk measures. We prove convergence of the algorithm for solutions and stationary points and we conclude with several illustrative numerical examples.

Robustness aspects in model validation for dynamic processes

Development and quantitative validation of complex nonlinear dynamic models is a difficult task that requires the support by numerical methods for parameter estimation, and the optimal design of experiments. In this talk special emphasis is placed on issues of robustness, i.e. how to take into account uncertainties – such as outliers in the measurements for parameter estimation, and the dependence of optimal experiments on unknown values of model parameters. New numerical methods will be presented, and applications will be discussed that indicate a wide scope of applicability of the methods.

Multilevel Quasi-Monte Carlo for stochastic PDE constrained optimization

This talk explores the use of multilevel quasi-Monte Carlo methods to generate estimations of gradients and Hessian-vector products for the optimization of PDEs with random coefficients. In ideal circumstances, the computational effort may scale linearly with the required accuracy, instead of quadratically, as is the case for Monte Carlo based methods. The performance is tested for a tracking type robust optimization problem constrained by an elliptic diffusion PDE with lognormal diffusion coefficient.

Data Analytics with B(R)agging Prediction Models.

We discuss prescribing optimal decisions in a framework where their cost depends on uncertain problem parameters that need to be learned from supervised data. Any naive use of training data may, however, lead to gullible decisions over-calibrated to one particular data set. In this presentation, we describe an intriguing relationship between distributional robust decision making and a bagging learning method by Breiman.
Continuous Systems in Information Processing (Part II)
Organizer: Martin Benning
Chair: Daniel Tenbrinck
Jan Lellmann, University of Lübeck

Measure-Valued Variational Image Processing

Many interesting image processing problems can be solved by finding suitable minimizers of a variational model. In this talk, we consider models where the unknowns reside in a space of measures. We will consider theoretical results and discuss some applications, in particular in diffusion-weighted imaging, manifold-valued optimization and approximation of non-convex problems.

Noémie Debroux, University of Cambridge (joint work with Angelica Aviles-Rivero, Veronica Corona, Martin Graves, Carole Le Guyader, Carola-Bibiane Schönlieb, Guy Williams)
A unified variational joint reconstruction and registration model for motion-compensated MRI

This work addresses a central topic in Magnetic Resonance Imaging (MRI) which is the motion-correction problem in a joint reconstruction and registration framework. From a set of multiple MR acquisitions corrupted by motion, we aim at jointly reconstructing a single high quality motion-free corrected image and retrieving the physiological dynamics through the deformation maps. To this purpose, we propose a novel variational model relying on hyperelasticity and compressed sensing principles.

Daniel Tenbrinck, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) (joint work with Martin Burger, Fjedor Gaede)
Variational Graph Methods for Efficient Point Cloud Spar-sification

In this talk we present an efficient coarse-to-fine optimization strategy for sparsification of large point clouds modeled via finite weighted graphs. Our method is derived from the recently proposed Cut Pursuit strategy and leads to a significant speed up (up to factor 120) in computing optimizers for a family of related variational problems. We demonstrate results on both unperturbed as well as noisy 3D point cloud data.
Sugandima Mihirani Vidanagamachchi, University of Ruhuna (joint work with Shirly Devapriya Dewasurendra)
A Reconfigurable Architecture for Commentz-Walter Algorithm

This work describes the hardware implementation of Commentz-Walter algorithm to match multiple patterns in protein sequences. Multiple pattern matching for different applications with the most widely used Aho-Corasick algorithm has been carried out over the years by PCs as well as GPUs and FPGAs. However, due to the complexity of Commentz-Walter algorithm, it has not been implemented in any hardware platform except in PCs. In this work, a specific architecture for this task using Commentz-Walter algorithm has been developed, tested and implemented on an FPGA to efficiently match proteins.

Yidiat Omolade Aderinto, University of Ilorin (joint work with Issa Temitope Issa)
On Mathematical Model of Biological Pest Control of Sorghum Production

In this paper, mathematical model of Sorghum production from seed/planting to harvesting stage was presented with respect to its pests/prey and the corresponding natural prey enemy (predators) at every stage. The model was characterized, the existence and uniqueness of the model solution was established. And finally numerical applications was carried out using Differential Transform method, and it was found that pests at different stages of sorghum production can be minimized below injury level using biological control which in turn leads to maximization of the sorghum production.

Jean-Paul Arnaout, Gulf University for Science & Technology
Worm Optimization Algorithm for the Euclidean Location-Allocation Problem

Facility location is a critical aspect of strategic planning for a broad spectrum of public and private firms. This study addresses the Euclidean location-allocation problem with an unknown number of facilities, and an objective of minimizing the fixed and transportation costs. This is a NP-hard problem and in this paper, a worm optimization (WO) algorithm is introduced and its performance is evaluated by comparing it to Genetic Algorithms (GA) and Ant Colony Optimization (ACO). The results show that WO outperformed ACO and GA and reached better solutions in a faster computational time.
The problem of locating repetitive unknown motifs in signals appears ubiquitously in neuroscience, computational imaging, microscopy data analytics, and more. We cast this problem as a short-and-sparse blind deconvolution problem, and formulate it as a nonconvex optimization problem over the sphere. By studying the geometric structure of the nonconvex landscape, we show how to develop practical optimization methods, that solves the problem to the target solution up to a shift ambiguity. The new geometric insights lead to new optimization strategies that even works in very challenging regimes.

Cheolmin Kim, Northwestern University (joint work with Youngseok Kim, Diego Klabjan)

Scale Invariant Power Iteration

Several machine learning models can be formulated as maximization of a scale invariant function under a Euclidian ball constraint, for example, PCA, GMM, NMF. We generalize power iteration to this setting and analyze convergence properties of the algorithm. Our main result states that if initialized close to a local maximum, then the algorithm converge to this local maximum. Also, the convergence rate is linear and thus equal to the rate of power iteration. Numerically, we benchmark the algorithm against state-of-the-art methods to find out that the algorithm outperforms benchmark algorithms.

Dimosthenis Pasadakis, Università della Svizzera italiana (USI) (joint work with Drosos Kourounis, Olaf Schenk)

Spectral Graph Partition Refinement using the Graph p-Laplacian

A continuous reformulation of the traditional spectral method for the bi-partitioning of graphs is presented, that exploits the tendency of the p-norm to promote sparsity, thus leading to partitions with smaller edgecuts. The resulting non-linear and non convex graph p-Laplacian quotient minimization is handled with an accelerated gradient descent, while a continuation approach reduces the p-norm from a 2-norm towards a 1-norm. The benefits of our scheme are demonstrated in a plethora of complex graphs emerging from power networks and social interactions.
**Thu.3 H 2033**

**Miscellaneous Topics in Conic Programming**  
Organizer: Etienne de Klerk  
Chair: Sandra S. Y. Tan

Antonios Varvitsiotis, National University of Singapore (NUS)  
**Robust self-testing of quantum systems via noncontextuality inequalities**

Self-testing unknown quantum systems is a fundamental problem in quantum information processing. We study self-testing using non-contextuality inequalities and show that the celebrated Klyachko-Can-Binicio˘glu-Shumovsky non-contextuality tests admit robust self-testing. Our results rely crucially on the graph-theoretic framework for contextuality introduced by Cabello, Severini, and Winter, combined with well-known uniqueness and robustness properties for solutions to semidefinite programs.

Lucas Slot, CWI (joint work with Monique Laurent)  
**Convergence analysis of measure-based bounds for polynomial optimization on compact sets**

We investigate a hierarchy of upper bounds introduced by Lasserre (2011) for the minimization of a polynomial $f$ over a set $K$, obtained by searching for a degree $2r$ sos density function minimizing the expected value of $f$ over $K$ with respect to a given measure. For the hypercube, de Klerk and Laurent (2018) show that the convergence rate of these bounds to the global minimum is $O(1/r^2)$. We extend this result to a large subclass of convex bodies. For general compact $K$, we show a convergence rate in $O((\log r/r)^2)$ when $K$ is a convex body.

Sandra S. Y. Tan, NUS (joint work with Vincent Y. F. Tan, Antonios Varvitsiotis)  
**A Unified Framework for the Convergence Analysis of Optimization Algorithms via Sum-of-Squares**

Given the popularity of machine learning, understanding the convergence properties of the optimization algorithms is of theoretical importance. However, existing convergence proofs consist mostly of ad-hoc arguments. We introduce a novel framework for bounding the convergence rates of various algorithms by means of sum-of-squares certificates, thereby unifying their convergence analyses. Using our approach, we recover known convergence bounds for three widely-used first-order algorithms, putting forth a promising framework for unifying the convergence analyses of other optimization algorithms.

**Thu.3 H 2038**

**Conic Optimization Approaches to Discrete Optimization Problems**  
Organizer: Etienne de Klerk  
Chair: Enrico Bettiol

Fatima Ezzahra Khalloufi, Faculty of science of Agadir, Ibn Zohr University (joint work with Rachida Abounacer, Mohamed Hachimi)  
**The novel Improvement of Clarke and Wright algorithm for solving Capacitated Vehicle Routing problem**

We propose an algorithm that has been improved from the classical Clarke and Wright algorithm to solve the Capacitated vehicle routing problem. The main concept of our proposed algorithm is to combine the Clarke and Wright heuristic with Sweep heuristic inspired of transition of probability used in Ant Colony algorithm to construct a solution. The objective is to seek a set minimum total cost routes for a fleet of $k$ identical vehicle with capacity $D$ to serve $n$ customers form a depot. Our results shows that our approach provides shorter distances in the majority of well-know instances.

Timotej Hrga, University of Ljubljana (joint work with Borut Lužar, Janez Povh)  
**Parallel Branch and Bound algorithm for Stable Set problem**

We present a method for solving stable set problem to optimality that combines techniques from semidefinite optimization and efficient implementation using high-performance computing. We use parallel branch & bound algorithm that applies Lovász theta function and its strengthenings as upper bound to approximate original problem using semidefinite relaxation. Depending on the sparsity of the graph combination of two SDP solvers is used to compute solutions of the obtained relaxations. We will present numerical experience with the proposed algorithm and show scalability and efficiency of it.

Enrico Bettiol, Université Paris 13 (joint work with Immanuel Bomze, Lucas Létocart, Francesco Rinaldi, Emiliano Traversi)  
**A CP relaxation for block-decomposable Binary QCQPs via Column Generation**

We propose an algorithm for binary non-convex quadratically constrained quadratic problems. In the extended formulation with the matrix $X$, product of the original variables, we propose a Dantzig-Wolfe-reformulation-based method with a linear master and a pricing of Max-Cut-type. The domain of this relaxation lies in the cone of Completely Positive matrices. For block-decomposable problems, we present an adaptation of our algorithm which exploits the block structure. We give conditions under which we obtain the same bound as the previous relaxation. We also provide computational results.
Parallel Sessions Abstracts Thu.3 13:30–14:45

Thu.3 H 1028
Splitting Methods and Applications (Part III)
Organizers: Pontus Giselsson, Ernest Ryu, Adrien Taylor
Chair: Ernest Ryu

Puya Latafat, KU Leuven (joint work with Panagiotis Patrinos, Andreas Themelis)
Block-coordinate and incremental aggregated proximal gradient methods: A unified view
We establish a link between the block-coordinate proximal gradient for minimizing the sum of two nonconvex functions (none of which is necessarily separable) and incremental aggregated proximal gradient methods for finite sum problems. The main tool for establishing this connection is the forward-backward envelope (FBE), which serves as a Lyapunov function. This result greatly simplifies the rate-of-convergence analysis and opens up the possibility to develop accelerated variants of incremental aggregated proximal gradient methods.

Matthew K. Tam, University of Göttingen (joint work with Yura Malitsky)
Splitting Algorithms with Forward Steps
The forward-backward splitting algorithm is a method for finding a zero in the sum of two monotone operators when one assumed single-valued and cocoercive. Unfortunately, the latter property, which is equivalent to strong monotonicity of the inverse, is too strong to hold in many monotone inclusions of interest. In this talk, I will report on recently discovered modifications of the forward-backward splitting algorithm which converge without requiring the cocoercivity assumption. Based on joint work with Yura Malitsky (University of Göttingen)

Ernest Ryu, UCLA (joint work with Robert Hannah, Wotao Yin)
Scaled Relative Graph: Nonexpansive operators via 2D Euclidean Geometry
Many iterative methods in applied mathematics can be thought of as fixed-point iterations, and such algorithms are usually analyzed analytically, with inequalities. In this paper, we present a geometric approach to analyzing contractive and nonexpansive fixed point iterations with a new tool called the scaled relative graph (SRG). The SRG provides a rigorous correspondence between nonlinear operators and subsets of the 2D plane. Under this framework, a geometric argument in the 2D plane becomes a rigorous proof of contractiveness of the corresponding operator.

Thu.3 H 1029
Convex and Nonsmooth Optimization - Contributed Session III
Chair: Andrew Eberhard

Ching-pei Lee, National University of Singapore / University of Wisconsin-Madison (joint work with Stephen Wright)
(Non-accelerated) First-Order Algorithms Converge Faster than $O(1/k)$ on Convex Problems
It has been known for many years that both gradient descent and stochastic coordinate descent achieve a global convergence rate of $O(1/k)$ in the objective value, when applied to a scheme for minimizing a Lipschitz-continuously differentiable, unconstrained convex function. In this work, we improve this rate to $o(1/k)$. We extend the result to proximal gradient and proximal stochastic coordinate descent with arbitrary samplings for the coordinates on regularized problems to show similar $o(1/k)$ convergence rates.

Yan Gu, Kyoto University (joint work with Nobuo Yamashita)
An Alternating Direction Method of Multipliers with the BFGS Update for Structured Convex Quadratic Optimization
We consider a special proximal alternating direction method of multipliers (ADMM) for the structured convex quadratic optimization problem. In this work, we propose a proximal ADMM whose regularized matrix in the proximal term is generated by the BFGS update (or limited memory BFGS) at every iteration. These types of matrices use second-order information of the objective function. The convergence of the proposed method is proved under certain assumptions. Numerical results are presented to show the effectiveness.

Andrew Eberhard, RMIT University (joint work with Shuai Liu, Yousong Luo)
Partial Smoothness, Tilt Stability and the VU–Decomposition
Under the assumption of prox-regularity and the presence of a tilt stable local minimum we are able to show that a VU like decomposition gives rise to the existence of a smooth manifold on which the function in question coincides locally with a smooth function. We will also consider the inverse problem. If a fast track exists around a strict local minimum does this imply the existence of a tilt stable local minimum? We investigate conditions under which this is so by studying the closely related notions of fast track and of partial smoothness and their equivalence.
**NON**

**Thu.3 H 0104**

**Advances in Nonlinear Optimization With Applications (Part II)**

Organizers: Yu-Hong Dai, Deren Han
Chair: Yu-Hong Dai

Xingju Cai, Nanjing Normal University

**An indefinite proximal point algorithm for maximal monotone operator**

We investigate the possibility of relaxing the positive definiteness requirement of the proximal matrix in PPA. A new indefinite PPA for finding a root of maximal monotone operator is proposed via choosing an indefinite proximal regularization term. The proposed method is more flexible, especially in dealing with cases where the operator has some special structures. We prove the global convergence. We also allow the subproblem to be solved in an approximate manner and propose two exible inexact criteria.

Caihua Chen, Nanjing University

**On the Linear Convergence of the ADMM for Regularized Non-Convex Low-Rank Matrix Recovery**

In this paper, we investigate the convergence behavior of ADMM for solving regularized non-convex low-rank matrix recovery problems. We show that the ADMM will converge globally to a critical point of the problem without making any assumption on the sequence generated by the method. If the objective function of the problem satisfies the Lojasiewicz inequality with exponent at every (globally) optimal solution, then with suitable initialization, the ADMM will converge linearly. We exhibit concrete instances for which the ADMM converges linearly.

Deren Han

**On the convergence rate of a splitting augmented Lagrangian method [canceled]**

In this talk, we present a new ADMM based prediction-correction method (APCM) for solving a three-block convex minimization problem with linear constrains. We solve the subproblem partially parallel in the prediction step and only the third variable and Lagrange multiplier are corrected in the correction step, which results in less time cost in the prediction step and employs different step size in the correction step. We show its global convergence and the $O(1/t)$ convergence rate under mild conditions. We also give the globally linear convergence rate with some additional assumptions.

**Thu.3 H 0106**

**Nonlinear Optimization - Contributed Session III**
Chair: Refail Kasimbeyli

Gulcin Dinc Yalcin, Eskisehir Technical University (joint work with Refail Kasimbeyli)

**Weak Subgradient Based Cutting Plane Method**

In this study, we present a version of the Cutting-Plane Method, developed for minimizing a nonconvex function. We use weak subgradients which is based on the idea of supporting conic surfaces. This supporting approach does not require convexity condition on the function. The suggested method, minimizes the pointwise maximum of superlinear functions, by the weak subgradient. Since the graphs of supporting functions are conical surfaces, the new method is called the “Cutting Conic Surfaces Method”. The subproblem is “linearized” and some illustrative examples are provided.

**Rafael Durbano Lobato, Università di Pisa (joint work with Antonio Frangioni)**

**SMS++: a Structured Modelling System for (Among Others) Multi-Level Stochastic Problems**

The aim of the open-source Structured Modeling System++ (SMS++) is to facilitate the implementation of general and flexible algorithms for optimization problems with several nested layers of structure. We will present the current state of SMS++, focussing on recent developments concerning the representation of uncertainty, which are meant to facilitate the transformation of complex deterministic models into stochastic ones. Specific SMS++ facilities for “general-purpose decomposition techniques” will then allow to efficiently produce multi-level decomposition approaches to these problems.

Refail Kasimbeyli, Eskisehir Technical University (joint work with Gulcin Dinc Yalcin)

**Weak subgradient based solution method using radial epiderivatives**

This work presents a weak subgradient based solution method in nonconvex unconstrained optimization. The weak subgradient notion does not require convexity condition on the function under consideration, and hence allows to investigate a wide class of nonconvex optimization problems. By using relationships between the weak subgradients and the radial epiderivatives, we present a method for approximate estimation of weak subgradients, and use it to update a current solution. The convergence theorems for the presented method, are established and the illustrative examples are provided.

**Acknowledgment**: This study is supported by The Scientific and Technological Research Council of Turkey (TUBITAK) under the Grant No. 217M487.
Variational Inequalities, Minimax Problems and GANs (Part II)
Organizer: Konstantin Mishchenko
Chair: Konstantin Mishchenko
Daoli Zhu, Shanghai Jiao Tong University (joint work with Sien Deng)
A Variational Approach on Level sets and Linear Convergence of Variable Bregman Proximal Gradient Method for Nonconvex Optimization Problems
We provide various level-set based error bounds to study necessary and sufficient conditions on the linear convergence of variable Bregman proximal gradient (VBPG) method for a broad class of nonsmooth and nonconvex optimization problems. We also provide a fresh perspective that allows us to explore the connections among many known sufficient conditions for linear convergence of various first-order methods.

Sarath Pattathil, MIT (joint work with Aryan Mokhtari, Asuman Ozdaglar)
A Unified Analysis of Extra-gradient and Optimistic Gradient Methods for Saddle Point Problems: Proximal Point Approach
In this talk, we consider solving convex-concave saddle point problems. We focus on two variants of gradient decent-ascent (VBPG) methods, and show that they admit a unified analysis as approximations of the classical proximal point method for solving saddle-point problems. This viewpoint enables us to generalize OGDA (in terms of parameters) and obtain new convergence rate results for these algorithms for the bilinear case as well as the strongly convex-concave setting.

Georgios Piliouras, SUTD
Online Optimization in Zero-Sum Games and Beyond: A Dynamical Systems Approach
We study systems where such online algorithms, such as online gradient descent and multiplicative weights, compete against each other in zero-sum games. We prove that these systems exhibit Poincaré recurrence and can be interpreted as Hamiltonian dynamics. We discuss implications of these results for discrete-time dynamics, designing new algorithms with provable guarantees beyond convex-concave games and we present some open questions.
Nonlinear Optimization - Contributed Session I
Chair: Raul Tempone

Truc-Dao Nguyen, Wayne State University (joint work with Tan Cao, Giovanni Colombo, Boris Mordukhovich)
Discrete Approximations of a Controlled sweeping process over polyhedral sets with perturbations

The talk is devoted to a class of optimal control problems governed by a perturbed sweeping (Moreau) process with the moving convex polyhedral set, where the controls are used to determine the best shape of the moving set in order to optimize the given Bolza-type problem. Using the method of discrete approximations together with the advanced tools of variational analysis and generalized differentiation allows us to efficiently derive the necessary optimality conditions for the discretized control problems and the original controlled problem. Some numerical examples are presented.

Adrian Hauswirth, ETH Zürich (joint work with Saverio Bolognani, Florian Dörfler, Gabriela Hug)
Timescale Separation in Autonomous Optimization

Autonomous optimization is an emerging concept in control theory that refers to the design of feedback controllers that steer a physical system to a steady state that solves a predefined nonlinear optimization problem. These controllers are modelled after optimization algorithms, but are implemented in closed loop with the physical system. For this interconnection to be stable, both systems need act on sufficiently different timescales. We quantify the required timescale separation and give prescriptions that can be directly used in the design of such feedback-based optimization schemes.

Raul Tempone, RWTH Aachen (joint work with Christian Bayer, Juho Häppölä)
Pricing American options by Markovian projections

We consider the pricing American basket options in a multi-variate setting, including the Black-Scholes, Heston and the rough Bergomi model. In high dimensions, nonlinear PDEs methods for solving the problem become prohibitively costly due to the curse of dimensionality. We propose a stopping rule depending on a low-dimensional Markovian projection of the given basket of assets. We approximate the optimal early-exercise boundary of the option by solving a Hamilton-Jacobi-Bellman PDE in the projected, low-dimensional space. This is used to produce an exercise strategy for the original option.
Semiglobal exponential stabilization of nonautonomous semilinear parabolic-like systems

It is shown that an explicit oblique projection nonlinear feedback controller is able to stabilize semilinear parabolic equations, with time-dependent dynamics and with a polynomial nonlinearity. The actuators are typically modeled by a finite number of indicator functions of small subdomains. No constraint is imposed on the norm of the initial condition. Simulations are presented, which show the semiglobal stabilizing performance of the nonlinear feedback.

Johannes Milz, Technical University of Munich (joint work with Michael Ulbrich)

An approximation scheme for distributionally robust optimization with PDEs

We consider distributionally robust optimization (DRO) for uncertain discretized PDE-constrained problems. To obtain a tractable and an accurate lower-level problem, we define ambiguity sets by moment constraints and approximate nonlinear functions using quadratic expansions w.r.t. parameters resulting in an approximate DRO problem. Its cost function is given as the sum of the value functions of a trust-region problem and an SDP. We construct smoothing functions and show global convergence of a homotopy method. Numerical results are presented using the adjoint approach to compute derivatives.

Sanjay Mehrotra, Northwestern University (joint work with Jinlin Li, Shanshan Wang)

Distributionally Robust Chance-Constrained Assignment with an Application to Operation Room Assignments

We will present a distributionally robust chance constraint optimization model, where the probability distribution specifying the chance constraint is robustified using a Wasserstein ambiguity set. For this problem, we will present novel techniques for strengthening big-M type formulations, and techniques for generating inequalities for use within a branch-and-cut framework. Results based on experiments using real data from an operating room will be presented, where the problem under consideration is to assign surgeries to the operating room.

Tito Homem-de-Mello, Universidad Adolfo Ibanez (joint work with Guzin Bayraksan, Hamed Rahimian)

Effective scenarios for multi-stage distributionally robust models

Recent research has studied the notion of effective scenarios for static distributionally robust stochastic programs. Roughly speaking, a scenario is deemed effective if its removal changes the optimal value of the problem. In this presentation we discuss the extension of these ideas to the case of multistage stochastic programs. Such extension requires proper ways of defining the meaning of removing a scenario in a dynamic context. Computational and analytical results show that identifying such effective scenarios may provide useful insight on the underlying uncertainties of the problem.

Aurelie Thiele, Southern Methodist University (joint work with Hedieh Ashrafi)

Robust continuous optimization for project portfolio management under uncertainty

We consider the management of projects under uncertainty in a firm’s market entry, competitors’ entry and product adoption dynamics. The company can adjust manpower staffing on a portfolio of projects (new products), which diversifies its portfolio but delays market entry for each product line, making it more likely a rival will launch a competing product first. We present a robust optimization approach to balance those concerns and extend our framework to dynamic policies based on information revealed over time about competitors’ products entering the market.
Dynamic Optimization Under Data Uncertainty
Organizer: Omid Nohadani
Chair: Omid Nohadani
Sebastian Pokutta, Georgia Tech (joint work with Andreas Bärmann, Alexander Martin, O. Schneider)
From Robust Optimization to Online Inverse Optimization

Robust optimization can be solved via online learning requiring only access to the nominal problem for a given uncertainty realization. We show that a similar perspective can be assumed for an online learning approach to online inverse optimization, even for discrete and non-convex decisions. The decision maker observes an expert’s decisions over time and learns an objective function that is equivalent to the expert’s private objective. We present a new framework for inverse optimization through online learning that goes beyond duality approaches and demonstrate its real-world applicability.

Eojin Han, Northwestern University (joint work with Chaithanya Bandi, Omid Nohadani)
Robust Periodic-Affine Policies for Multi-period Dynamic Problems

We introduce a new class of adaptive policies called periodic-affine policies, that allows a decision maker to optimally manage and control large-scale newsvendor networks in the presence of uncertain demand without distributional assumptions. These policies model many features of the demand such as correlation, and can be generalized to multi-product settings and multi-period problems. This is accomplished by modeling the uncertain demand via sets. We provide efficient algorithms and demonstrate their advantages on the sales data from one of India’s largest pharmacy retailers.

Dan Iancu, Stanford University (joint work with Nikos Trichakis, Do-Young Yoon)
Monitoring With Limited Information

We consider a system with an evolving state that can be stopped at any time by a decision maker (DM), yielding a state-dependent reward. The DM observes the state only at limited number of monitoring times, which he must choose, in conjunction with a stopping policy. We propose a robust optimization approach, whereby adaptive uncertainty sets capture the information acquired through monitoring. We consider two versions of the problem, static and dynamic and show that, under certain conditions, the same reward is achievable under either static or dynamic monitoring.

Bolin Pan, UCL (joint work with Simon Arridge, Paul Beard, Marta Betcke, Ben Cox, Nam Huynh, Felix Lucka, Edward Zhang)
Dynamic Photoacoustic Reconstruction using Curvelet Sparsity with Optical Flow Constraint

In photoacoustic tomography, the acoustic propagation time across the specimen is the ultimate limit on sequential sampling frequency. In this talk, we first consider the photoacoustic reconstruction problem from compressed/subsampled measurements by utilizing sparsity in the Curvelet frame. Then we introduce the dynamic photoacoustic reconstruction from subsampled/compressed dynamic data using Curvelet sparsity in the photoacoustic image domain. Additionally, spatio-temporal regularization via optical flow constraint is applied.

Bogdan Toader, Oxford University (joint work with Stephane Chretien, Andrew Thompson)
The dual approach to non-negative super-resolution: impact on primal reconstruction accuracy

We study the problem of super-resolution using TV norm minimisation, where we recover the locations and weights of non-negative point sources from a few samples of their convolution with a Gaussian kernel. A practical approach is to solve the dual problem. In this talk, we study the stability of solutions with respect to the solutions to the dual problem. In particular, we establish a relationship between perturbations in the dual variable and the primal variables around the optimiser. This is achieved by applying a quantitative version of the implicit function theorem in a non-trivial way.
Solution and Analysis of Stochastic Programming and Stochastic Equilibria
Chair: Shu Lu

Pedro Borges, IMPA (joint work with Claudia Sagastizábal, Mikhail Solodov)
New Techniques for Sensitivity Analysis of Solution Mappings with Applications to Possibly Non-Convex Stochastic Programming

We introduce a well-behaved regularization of solution mappings of parametric convex problems that is single-valued and smooth. We do not assume strict complementarity or second order sufficiency. Such regularization gives a cheap upper smoothing for possibly non-convex optimal value functions. Classical first and second order derivatives of the regularized solution mappings can be obtained cheaply solving certain linear systems. For convex two-stage stochastic problems the interest of our techniques is assessed, comparing its numerical performance against a bundle method.

Shu Lu, University of North Carolina at Chapel Hill
Statistical inference for piecewise normal distributions and application to stochastic variational inequalities

Confidence intervals for the mean of a normal distribution with a known covariance matrix can be computed using closed-form formulas. In this talk, we consider a distribution that is the image of a normal distribution under a piecewise linear function, and provide a formula for computing confidence intervals for the mean of that distribution given a sample under certain conditions. We then apply this method to compute confidence intervals for the true solution of a stochastic variational inequality. This method is based on a closed-form formula which makes computation very efficient.
Index of Authors

bold : presenter (with starting time)
italic : co-author
[c] : session chair
[o] : session organiser

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Vieira, Juan Pablo, Massachusetts Institute of Technology
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Viorel, Adrian, Technische University of Cluj-Napoca
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Vollmann, Christian, Trier University
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Vorobyov, Sergiy A., Aalto University
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Vorontsova, Evgeniya, Université Grenoble Alpes
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Vu, Bang Cong, Ecole Polytechnique Fédérale de Lausanne (EPFL)
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Wadbro, Eddie, Umeå University
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Wang, Hao, ShanghaiTech University
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Wang, Liping, Nanjing University of Aeronautics and Astronautics
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Wang, Meihua, Xidian University
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Winckler, Malte, University of Duisburg-Essen
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Yu, Han, University of Southern California
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Yu, Hao, Alibaba Group (U.S.) Inc
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Zhang, Zaikun, Hong Kong Polytechnic University
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Zhao, Renbo [canceled], Massachusetts Institute of Technology
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Zhu, Jia-Jie, Max Planck Institute for Intelligent Systems
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