MOPTA 2016

Modeling and Optimization: Theory and Applications

http://coral.ie.lehigh.edu/~mopta

17-19 August '16

Lehigh University
Bethlehem, PA, USA

Program and Abstracts

■ A very warm Welcome to MOPTA 2016

The Modeling and Optimization: Theory and Applications (MOPTA) conference is an annual event aiming to bring together a diverse group of people from both discrete and continuous optimization, working on both theoretical and applied aspects. The format consists of invited talks from distinguished speakers and selected contributed talks, spread over three days. The goal is to present a diverse set of exciting new developments from different optimization areas while at the same time providing a setting that will allow increased interaction among the participants. We aim to bring together researchers from both the theoretical and applied communities who do not usually have the chance to interact in the framework of a medium- scale event. MOPTA 2016 is hosted by the Department of Industrial and Systems Engineering at Lehigh University.

■ Directions

Conference Location

The **conference** will take place at:
Lehigh University
Rauch Business Center
621 Taylor Street
Bethlehem, PA 18015
US

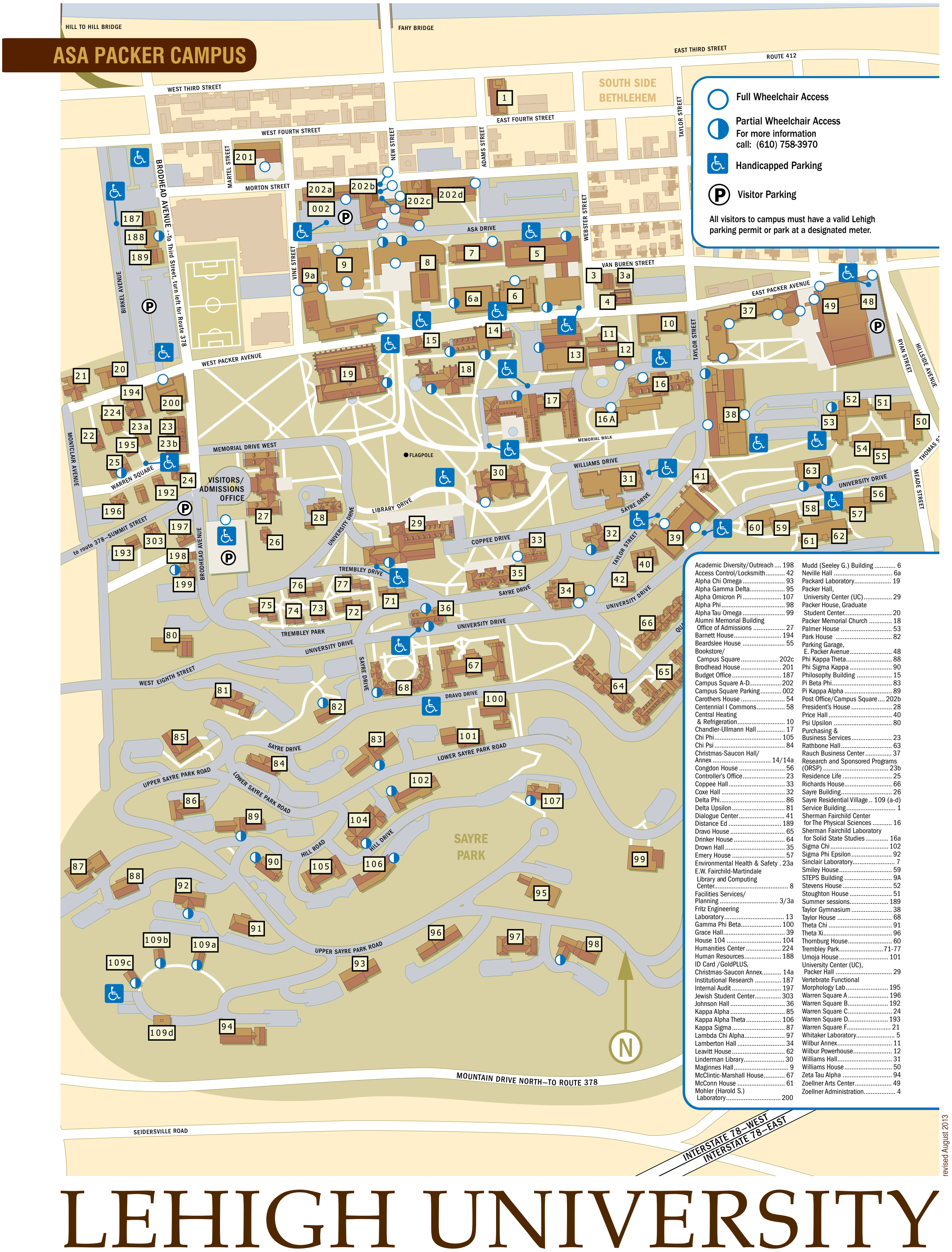
Conference Dinner Location

The **conference dinner** will take place at:
Lehigh University
Iacocca Hall, 111 Research Drive
Mountaintop Campus
Bethlehem, PA 18015
US

Graduate Student Social Location

Graduate students attending the Graduate Student Social – Please know that Packer House (see ASA Packer Campus map - Building 20), where the social is located, is within walking distance of Comfort Suites.
If you need to leave during the conference, please see the registration desk for information about taxis and car services.

■ Maps


ASA PACKER CAMPUS
HILL TO HILL BRIDGE
FAHY BRIDGE
EAST THIRD STREET
ROUTE 412
WEST THIRD STREET
SOUTH SIDE BETHLEHEM
EAST FOURTH STREET
WEST FOURTH STREET
MORTON STREET
ASA DRIVE
VAN BUREN STREET
EAST PACKER AVENUE
WEST PACKER AVENUE
MEMORIAL DRIVE WEST
FLAGPOLE
VISITORS/ ADMISSIONS OFFICE
WARREN SQUARE
to route 378—SUMMIT STREET
LIBRARY DRIVE
COPPEE DRIVE
TREMBLEY DRIVE
TREMBLEY PARK
SAYRE DRIVE
UNIVERSITY DRIVE
WILLIAMS DRIVE
MEMORIAL WALK
WEST EIGHTH STREET
DRAVO DRIVE
LOWER SAYRE PARK ROAD
UPPER SAYRE PARK ROAD
HILL ROAD
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All visitors to campus must have a valid Lehigh parking permit or park at a designated meter.
Academic Diversity/Outreach 198
Access Control/Locksmith 42
Alpha Chi Omega 93
Alpha Gamma Delta 95
Alpha Omicron Pi 107
Alpha Phi 98
Alpha Tau Omega 99
Alumni Memorial Building Office of Admissions 27
Barnett House 194
Beardslee House 55
Bookstore/ Campus Square 202c
Brodhead House 201
Budget Office 187
Campus Square A-D 202
Campus Square Parking 002
Carothers House 54
Centennial I Commons 58
Central Heating & Refrigeration 10
Chandler-Ullmann Hall 17
Chi Phi 105
Chi Psi 84
Christmas-Saucon Hall/ Annex 14/14a
Congdon House 56
Controller's Office 23
Coppee Hall 33
Coxe Hall 32
Delta Phi 86
Delta Upsilon 81
Dialogue Center 41
Distance Ed 189
Dravo House 65
Drinker House 64
Drown Hall 35
Emery House 57
Environmental Health & Safety . 23a
E.W. Fairchild-Martindale Library and Computing Center 8
Facilities Services/ Planning 3/3a
Fritz Engineering Laboratory 13
Gamma Phi Beta 100
Grace Hall 39
House 104 104
Humanities Center 224
Human Resources 188
ID Card /GoldPLUS, Christmas-Saucon Annex 14a
Institutional Research 187
Internal Audit 197
Jewish Student Center 303
Johnson Hall 36
Kappa Alpha 85
Kappa Alpha Theta 106
Kappa Sigma 87
Lambda Chi Alpha 97
Lamberton Hall 34
Leavitt House 62
Linderman Library 30
Maginnes Hall 9
McClintic-Marshall House 67
McConn House 61
Mohler (Harold S.) Laboratory 200
Mudd (Seeley G.) Building 6
Neville Hall 6a
Packard Laboratory 19
Packer Hall, University Center (UC) 29
Packer House, Graduate Student Center 20
Packer Memorial Church 18
Palmer House 53
Park House 82
Parking Garage, E. Packer Avenue 48
Phi Kappa Theta 88
Phi Sigma Kappa 90
Philosophy Building 15
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Pi Kappa Alpha 89
Post Office/Campus Square 202b
President's House 28
Price Hall 40
Psi Upsilon 80
Purchasing & Business Services 23
Rathbone Hall 63
Rauch Business Center 37
Research and Sponsored Programs (ORSP) 23b
Residence Life 25
Richards House 66
Sayre Building 26
Sayre Residential Village .. 109 (a-d)
Service Building 1
Sherman Fairchild Center for The Physical Sciences 16
Sherman Fairchild Laboratory for Solid State Studies 16a
Sigma Chi 102
Sigma Phi Epsilon 92
Sinclair Laboratory 7
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Taylor Gymnasium 38
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University Center (UC), Packer Hall 29
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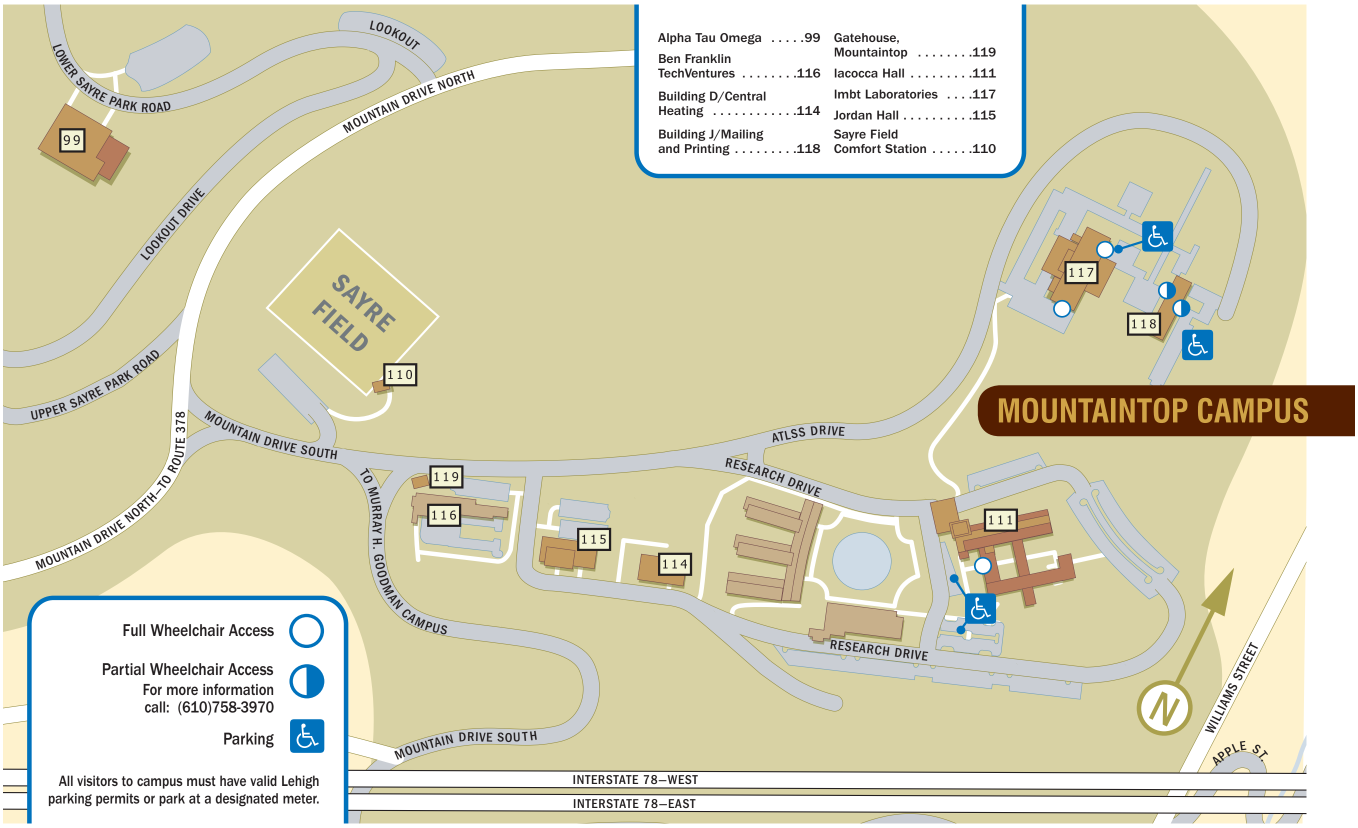
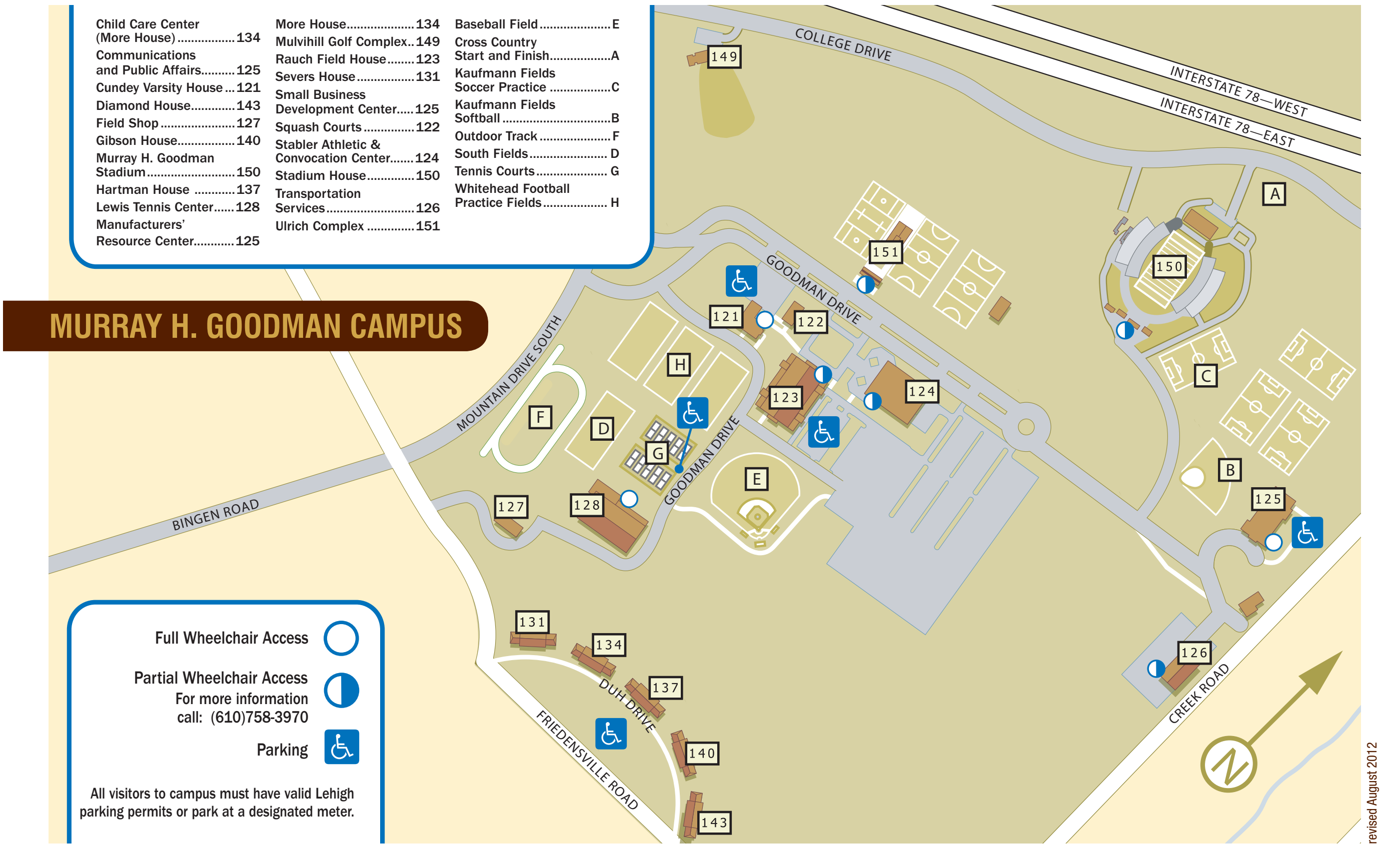
Warren Square C 24
Warren Square D 193
Warren Square F 21
Whitaker Laboratory 5
Wilbur Annex 11
Wilbur Powerhouse 12
Williams Hall 31
Williams House 50
Zeta Tau Alpha 94
Zoellner Arts Center 49
Zoellner Administration 4
revised August 2013
LEHIGH UNIVERSITY

LEHIGH UNIVERSITY CAMPUS MAPS





■ Plenary Talks

Wednesday 08:30–09:30. David Simchi-Levi

Applying Machine Learning & Optimization in Online Revenue Management

MIT

dslevi@mit.edu

In a dynamic pricing problem where the demand function is unknown a priori, price experimentation or product bundling can be used for demand learning. In practice, however, online sellers are faced with a few business constraints, including the inability to conduct extensive experimentation, limited inventory and high demand uncertainty. In this talk we show how data-driven research fosters the development of new engineering and scientific methods that explain, predict, and change behavior. Collaborating with Groupon, we developed a dynamic pricing model where the demand function is unknown but belongs to a known finite set. The data suggested that we can approximate the true demand function by a collection of linear demand functions. Groupon allows for a limited number of price changes during the selling season and the objective is to minimize the regret, i.e. the expected total revenue loss compared to a clairvoyant who knows the demand distribution in advance. We demonstrate a pricing policy that incurs the smallest possible regret, up to a constant factor. Implementation of our algorithm at Groupon shows significant impact on revenue and market share. In the second part of the presentation we extend the model to a network revenue management problem where an online retailer aims to maximize revenue from multiple products with limited inventory. This model is motivated by collaboration with retailer Rue La La where the retailer does not know the expected demand at each price point and must learn the demand information from sales data. We propose an efficient and effective dynamic pricing algorithm, which builds upon the Thompson sampling algorithm used for multi-armed bandit problems by incorporating inventory constraints into the pricing decisions. The algorithm proves to have both strong theoretical performance guarantees as well as promising numerical performance results when compared to other algorithms developed for the same setting. In the last part, we report on implementation of our methods and algorithms at B2W Digital, a large Latin America retailer. An important opportunity at B2W is product bundling. We show that bundling can be used as a form of price experimentation, that is, a mixed bundling scheme allows the firm to quickly learn the customer valuation distributions without having to change any prices. We then introduce a simple price bundling scheme that takes into account customer valuations and product cost. Throughout the presentation, I will spend time characterizing exactly what I mean by data driven research, why it is relevant today more than ever before, and why it provides new opportunities for more creativity and a bigger and sometimes surprising impact on the organization. As you will see, this line of research can be quite different from what some in our profession refer to as empirical research.

Speaker Biography. David Simchi-Levi is a Professor of Engineering Systems at MIT and Chairman of OPS Rules, an operations analytics consulting company and Opalytics, a cloud analytics platform. He is considered one of the premier thought leaders in supply chain management and business analytics. His research focuses on developing and implementing robust and efficient techniques for operations management. He has published widely in professional journals on both practical and theoretical aspects of supply chain and revenue management. His Ph.D. students have accepted faculty positions in leading academic institutes including U. of California Berkeley, Columbia U., Cornell U., Duke U., Georgia Tech, Harvard U., U. of Illinois Urbana-Champaign, U. of Michigan, Purdue U. and Virginia Tech. Professor Simchi-Levi co-authored the books Managing the Supply Chain (McGraw-Hill, 2004), the award winning Designing and Managing the Supply Chain (McGraw-Hill, 2007) and The Logic of Logistics (3rd edition, Springer 2013). He also published Operations Rules: Delivering Customer Value through Flexible Operations (MIT Press, 2011). He served as the Editor-in-Chief for Operations Research (2006-2012), the flagship journal of INFORMS and for Naval Research Logistics (2003-2005). He is an INFORMS Fellow, MSOM Distinguished Fellow and the recipient of the 2014 INFORMS Daniel H. Wagner Prize for Excellence in Operations Research Practice; 2014 INFORMS Revenue Management and Pricing Section Practice Award; 2009 INFORMS Revenue Management and Pricing Section Prize and Ford 2015 Engineering Excellence Award.Professor Simchi-Levi has consulted and collaborated extensively with private and public organizations. He was the founder of LogicTools which provided software solutions and professional services for supply chain optimization. LogicTools became part of IBM in 2009.

Wednesday 11:30–12:30. Robert Shorten

Cars and Smarter Cities: New Services and New Applications for Control and Optimization

University College Dublin and IBM Research

Robert.Shorten@nuim.ie

The automotive industry is probably experiencing its most disruptive period since the invention of the diesel engine. Driven by new technologies, advances in mathematics, increasingly stringent regulation, new and disruptive business models, changing consumer demands, as well as a desire to make our cities smarter, more efficient, and cleaner, automotive OEM's are searching for new ways to re-imagine and monitize their products. At the forefront of this innovation is the search for new Smart Mobility and Smart City services that can be delivered to and from vehicles, and the resulting partnerships between traditional automotive OEM's and other non-traditional automotive industries. Research questions arising in this context driving exciting new activities in a number of disciplines. Among these, Control and Optimization has much to offer, and much to gain as a discipline, by embracing some of the questions that are of concern as planners and municipalities re- imagine our cities. In this talk, I will discuss several such applications, and discuss (relatively) new academic problems that they give rise to. Topics to be covered may include: eco-driving in an IoT context; the design of car parks in the context of collaborative consumption (shared economy) models; and car enabled infrastructure concepts. A new optimization strategy for IoT will be presented based on an old friend, and time permitting, several open challenges will be enunciated and the suitability of classical controllers discussed for smart city applications.

Speaker Biography. Professor Shorten graduated from UCD, with a B.E. degree in Electronic Engineering in 1990, and a Ph.D. degree in 1996. From 1993 to 1996 Professor Shorten worked at Daimler-Benz research labs in Berlin where completed his Ph.D. work, and was also the holder of a Marie Curie Fellowship. In 1996 he was invited to work as a visiting fellow at the Center for Systems Science, Yale University, commencing a long-standing research collaboration with Professor K. S. Narendra on the study of switched systems. Since returning to Ireland in 1997 as the recipient of a European Presidential Felowship, Professor Shorten has been active in a number of theoretical and applied research areas including: computer networking; classical automotive research; collaborative mobility (including smart transportation and electric vehicles); as well as basic control theory and linear algebra. Professor Shorten is a co-founder of the Hamilton Institute, National University of Ireland, Maynooth, where he was a Full Professor until March 2013, and was also the holder of a Visiting Professship at TU Berlin in 2011-12. From 2013 to 2015 he led the Control and Optimization activities at IBM Research Ireland in the area of Smart Cities. He is currently Professor of Control Engineering and Decision Science at University College Dublin (UCD) and retains a part-time appointment at IBM Research. Professor Shorten is an Associate Editor of a number of journals and a co-author of the recently published book: AIMD dyanamics and distributed resource allocation (SIAM 2016).

Wednesday 15:15–16:15. Michael Friedlander

Level-set methods for convex optimization

University of British Columbia

mpf@cs.ubc.ca

Convex optimization problems in a variety of applications have favorable objectives but complicating constraints, and first-order methods are not immediately applicable. We propose an approach that exchanges the roles of the objective and constraint functions, and instead approximately solves a sequence of parametric problems. We describe the theoretical and practical properties of this approach for a broad range of problems, including low-rank semidefinite optimization problems. (Joint work with A. Aravkin, J. Burke, D. Drusvyatskiy, S. Roy.)

Speaker Biography. Michael Friedlander is IBM Professor of Computer Science and Professor of Mathematics at the University of British Columbia. He received his PhD in Operations Research from Stanford University in 2002, and his BA in Physics from Cornell University in 1993. From 2002 to 2004 he was the Wilkinson Fellow in Scientific Computing at Argonne National Laboratory. He has held visiting positions at UCLA's Institute for Pure and Applied Mathematics (2010), and at Berkeley's Simons Institute for the Theory of Computing (2013). He serves on the editorial boards of various journals, including the SIAM Journal on Optimization, the SIAM Journal on Matrix Analysis and Applications, Mathematical Programming, and Mathematics of Operations Research. His research is primarily in developing numerical methods for large-scale optimization, their software implementation, and applying these to problems in signal processing and machine learning.

Thursday 08:30–09:30. Michael Pinedo

Stochastic Optimization in Operational Risk Management

Stern Business School, New York University

mpinedo@stern.nyu.edu

Joint work with Yuqian Xu (Stern Business School, New York University) and Lingjiong Zhu (Department of Mathematics, Florida State University)
In this presentation we consider a jump-diffusion model to analyze the impact of large shocks caused by operational risk events on a financial firm's value process. We study capital investments in the infrastructure of a financial firm that aims at mitigating the impact of operational risk events by changing the stochastic nature of the large shocks. We analyze and compare investment strategies in two settings: one to maximize the firm's expected utility function over a fixed investment horizon, and the other one to minimize the probability of ruin over an infinite horizon. We characterize the analytical solutions of optimal investment strategies as a function of the firm's growth rate, the jumping process parameters, and a loss reduction efficiency factor. We then proceed to discuss the impact of insurance contracts, and determine the regime in which a financial firm, while having insurance, still has an incentive to invest in infrastructure and the regime in which it has not. Our modeling framework, combining jump-diffusions with stochastic control, suggests a direction for future research in operational risk management.

Speaker Biography. Michael Pinedo is the Julius Schlesinger Professor of Operations Management in the Department of Information, Operations and Management Sciences at New York University's Leonard N. Stern School of Business. Professor Pinedo's research focuses on the modeling of production and service systems, and, more specifically, on the planning and scheduling of these systems. Recently, his research also has focused on operational risk in financial services. He has authored and co-authored numerous technical papers on these topics. He is the author of the books, Scheduling: Theory, Algorithms and Systems (Prentice-Hall), and, Planning and Scheduling in Manufacturing and Services (Springer), and the coauthor of, Queueing Networks: Customers, Signals and Product Form Solutions (Wiley). He is co-editor of, Creating Value in Financial Services: Strategies, Operations, and Technologies (Kluwer), and editor of Operational Control in Asset Management - Processes and Costs (Palgrave/McMillan). Over the last three decades Professor Pinedo has been involved in industrial systems development. He supervised the design, development and implementation of two planning and scheduling systems for the International Paper Company. He also actively participated in the development of systems at Goldman Sachs, Philips Electronics, Siemens, and at Merck. Professor Pinedo is currently editor of the Journal of Scheduling (Wiley). He is associate editor of Naval Research Logistics, department editor of Production and Operations Management, and Associate Editor of Annals of Operations Research. Professor Pinedo received an Ir. degree in Mechanical Engineering from the Delft University of Technology, the Netherlands in 1973 and a M.Sc. and a Ph.D. in Operations Research from the University of California at Berkeley in 1978.

Thursday 15:15–16:15. Jacek Gondzio

Continuation in Optimization: From interior point methods for large-scale optimization to Big Data optimization

The University of Edinburgh

J.Gondzio@ed.ac.uk

In this talk we will discuss similarities between two homotopy-based approaches: - (inexact) primal-dual interior point method for LP/QP, and - preconditioned Newton conjugate gradient method for big data optimization. Both approaches rely on clever exploitation of the curvature of optimized functions and deliver efficient techniques for solving optimization problems of unprecedented sizes. We will address both theoretical and practical aspects of these methods.

Speaker Biography. Jacek Gondzio obtained his PhD in Automatic Control and Robotics from Warsaw University of Technology in 1989. He held a research position at the Systems Research Institute of the Polish Academy of Sciences and two visiting positions: at the University of Paris IX Dauphine in 1990-1991 and at the University of Geneva in 1993-1998. Since 1998, he has been at the School of Mathematics at the University of Edinburgh. His research interests include the theory and implementation of algorithms for very large-scale optimization. He is best known for his contributions in the area of interior point methods. He is a member of the editorial board of Computational Optimization and Applications, European Journal of Operational Research, Mathematical Programming Computation and Optimization Methods and Software,

Friday 08:30–09:30. Gerard Cornuejols

Ideal 0,1 matrices that do not pack

Carnegie Mellon University

gc0v@andrew.cmu.edu

This talk presents recent results of Ahmad Abdi, Kanstantsin Pashkovich, and myself. The set covering problem is at the heart of combinatorial optimization. A 0,1 matrix A is said to be ideal when all the extreme points of the formulation Ax >= 1, x >=0 are integral. Total dual integrality of this linear system is a stronger property. A conjecture of Conforti and myself states that, in fact, this property is equivalent to the so-called packing property. In this talk, we present properties of ideal 0,1 matrices that do not pack. In particular, we demonstrate the centrality of 0,1 matrices A with covering number 2 (i.e., the matrix A contains 2 columns whose 1s cover all the rows).

Speaker Biography. Gerard Cornuejols is a professor at Carnegie Mellon University. He holds the IBM chair in Operations Research and is a University Professor. He received the von Neumann Theory Prize (2011) offered by INFORMS, the Dantzig prize (2009) offered jointly by the Math Optimization Society and SIAM, the SIAM Outstanding Paper Prize (2004), the Fulkerson Prize (2000) offered jointly by the American Math Society and the Math Optimization Society, and the Lanchester Prize twice (1977 and 2015) offered by INFORMS. He is a member of the National Academy of Engineering.

Friday 11:30–12:30. Sem Borst

Optimal Load Distribution in Large-Scale Service Systems

Nokia Bell Labs / Eindhoven University of Technology

s.c.borst@tue.nl

Load balancing algorithms play a crucial role in optimizing resource utilization and user performance in parallel-server systems, such as cloud networks and data centers. The classical Join-the-Shortest-Queue (JSQ) policy always assigns incoming tasks to the server with the shortest queue, and has strong optimality properties in symmetric Markovian scenarios, but suffers from prohibitive messaging overhead in large-scale systems. This has motivated a deep interest in so-called power-of-d strategies, where incoming tasks are assigned to the server with the shortest queue among d servers randomly selected from the total available pool of N servers. Mean-field limits indicate that a value as small as d = 2 yields significant performance improvements over a purely random assignment scheme (d = 1) in a many-server regime, while involving far lower messaging overhead than the JSQ policy. We will examine how the value of d needs to scale with the total number of servers N in order to match the optimal performance of the JSQ policy, and show that the overhead can be substantially reduced while maintaining asymptotic optimality. Time permitting, we will also briefly discuss token-based load balancing algorithms which achieve asymptotically optimal performance with yet lower overhead.
Note: Based on joint work with Debankur Mukherjee (TU/e), Johan van Leeuwaarden (TU/e) and Phil Whiting (Macquarie University)

Speaker Biography. Sem Borst joined the Mathematics of Networks and Systems Research Department, Bell Laboratories, Murray Hill, NJ, in 1995, and has been there since. From 1998 to 2006, he had a part-time affiliation with the Center for Mathematics and Computer Science (CWI) in Amsterdam. Since 1998 Sem has also held a part-time professorship with the Department of Mathematics and Computer Science at Eindhoven University of Technology (TU/e). His main research areas are performance evaluation and resource allocation for stochastic systems, in particular computer-communication networks.
Sem was (co-)recipient of the best-paper awards at Sigmetrics/Performance 1992 and IEEE Infocom 2003, the 2001 Yosef Levy Prize, and the 2005 Van Dantzig Prize. He serves or has served on the editorial boards of several journals, such as ACM Transactions on Modeling and Performance of Computing Systems, IEEE/ACM Transactions on Networking, Operations Research, Queueing Systems, and has been a program committee member of numerous conferences.

■ AIMMS/MOPTA Optimization Modeling Competition 2016

The eighth AIMMS/MOPTA Optimization Modeling Competition is a result of cooperation between AIMMS and the organizers of the MOPTA conference. Teams of three graduate students participated and solved a multi-objective network disruption problem. The teams were asked to reduce the capacity of links of a shared transportation network used by competing agents who are making a profit by transporting resources from production centers to demand centers, in such a way that (i) the total profit of one group of agents is reduced as much as possible, but (ii) the total profit of another group of agents is protected as much as possible.
The teams had to form a mathematical model of the problem, implement it in AIMMS, solve it, create a graphical user interface, and write a 15-page report on the project. We are happy that 15 teams from 9 countries registered to the competition. The panel of judges (Boris Defourny and Frank Curtis from Lehigh University and Peter Nieuwesteeg from AIMMS) selected the following three teams for the final:

Team "4101", Industrial Engineering, Universidad de los Andes
Felipe Solano, Santiago Cabrera, Diego Cely
advised by Andrés Medaglia

Team "IIT Madras", Chemical Engineering, Indian Institute of Technology — Madras
Varghese Kurian, Srinesh Chandrakesa, Venkata Reddy
advised by Sridharkumar Narasimhan,

Team "ORTEC",
Lianne van Sweeden (Applied Mathematics, Delft University of Technology),
Tim Bijl (Industrial Engineering and Management, University of Twente),
Sander Vlot (Delft Center for Systems and Control, Delft University of Technology,
advised by Jawad Elomari (ORTEC Consulting).

The finalist teams will each give 20-minute presentations (15 minutes for the talk + 5 minutes for questions) on their work on Thursday, August 18th, starting at 11:30am. The winning team will be announced at the conference banquet on Thursday evening.
We thank all the teams for their participation. We believe that it has been a very positive experience for all parties involved in the process.

■ Instructions

For Speakers

- We ask all speakers to be familiar with the time and the location of their stream and talk, as specified in the conference booklet.
- Speakers should arrive at the location of their stream and talk 10 minutes prior to the scheduled start time of the session.
- Upon arrival you will be met by the chair of the session. Please introduce yourself and, if applicable, provide the chair with a copy of your presentation to upload onto the seminar room computer.
- Talks are strictly 25 minutes long plus 5 minutes for questions and answers. Anyone going over this time will be asked to stop by the chair.
- To aid you with the timing of your presentation, the chair will show the 'time remaining' cards when you have 5 minutes and then 1 minute remaining for your presentation.

For Chairs

- Please arrive at the appropriate seminar room 10 minutes before the start of the stream you will be chairing. You should familiarise yourself with the equipment and ensure there are no obvious problems which would prevent the stream from running to schedule.
- In the event of a problem you should immediately seek the help of a local conference organiser.
- Delegates presenting in the stream should also be present in the seminar room 10 minutes before the start of the stream. You should introduce yourself to the speakers. They will provide you with electronic copies of their presentations to be loaded onto the seminar room computer.
- Uploading presentations: When you arrive at the seminar room you should login to the seminar room computer using the username and password issued to you at registration. You should then upload each speaker's presentation onto the desk top ready for the stream to begin.
- Your main role will be to ensure that the stream runs to time. The speaker has 25 minutes for presentation followed by 5 minutes of questions and answers. Each talk is followed by a 5 minute break for the comfort of the audience and to allow for movement between streams.
- If a speaker fails to show for their talk, advise the audience to attend a talk in an alternative seminar room. Please, do not move the next talk forward.
- Before each speaker presents, you should introduce them and remind the audience that all interruptions and questions are to be reserved until the scheduled 5 minute question and answer session following each presentation.
- Should a speaker overrun, you must politely but firmly stop their presentation and move on to the question and answer section of the time slot.
- After each talk, thank the speaker, encourage applause, and open the floor to questions.

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Aurélie C. Thiele

Luis F. Zuluaga

Janos Pinter

PROGRAM

	Room 085	Room 091	Room 184	Room 271
	Wednesday, 17th August 2016			
07:30 – 08:15	Registration and Breakfast			
08:15 – 08:30	Welcome (Room 184)			
08:30 – 09:30	Plenary talk: David Simchi-Levi (Room 184)			
09:30 – 09:45	Coffee Break			
09:45 – 11:15	Nonsmooth Optimization and Applications I	Optimization in Machine Learning	Integer Programming	Optimization in Energy I
11:15 – 11:30	Coffee Break			
11:30 – 12:30	Plenary talk: Robert Shorten (Room 184)			
12:30 – 13:30	Lunch			
13:30 – 15:00	Nonsmooth Optimization and Applications II	Advances in convexification approaches for nonconvex polynomial optimization problems	Meta-heuristic	Dynamic Optimization
15:00 – 15:15	Coffee Break			
15:15 – 16:15	Plenary talk: Michael Friedlander (Room 184)			
16:15 – 16:30	Coffee Break			
16:30 – 18:30	Optimization Algorithms	Optimization in Machine Learning / Large-Scale Optimization	Management Decision Models	Convex and Conic Relaxations for Intractable Optimization Problems
19:00 – 21:00	Graduate Student Social – Packer House, 217 West Packer Avenue, Bethlehem			
	Thursday, 18th August 2016			
08:00 – 08:30	Registration and breakfast			
08:30 – 09:30	Plenary talk: Michael Pinedo (Room 184)			
09:30 – 09:45	Coffee Break			
09:45 – 11:15	Recent Advances in First-Order Methods and Applications in Network Estimation	Machine Learning	Convexification Techniques in Mixed-Integer Programming	Optimization in Energy II
11:15 – 11:30	Coffee Break			
11:30 – 12:30	Modeling Competition (Room 184)			
12:30 – 13:30	Lunch			
13:30 – 15:00	Nonlinear Optimization: Algorithms, Theory, and Applications	Robust and Bi-Level Optimization	Meta-heuristic	Applications of Optimization in Networked Control Systems – Part I
15:00 – 15:15	Coffee Break			
15:15 – 16:15	Plenary talk: Jacek Gondzio (Room 184)			
16:15 – 16:30	Coffee Break			
16:30 – 18:00	Nonlinear Optimization	Optimization and Machine Learning	Conic Optimization	The Application of Optimization in Structural Design Problems
18:00 – 19:00	Cocktail Reception (Wood Dining Room Foyer)			
19:00 – 21:00	Banquet (Wood Dining Room)			
	Friday, 19th August 2016			
08:00 – 08:30	Registration and Breakfast			
08:30 – 09:30	Plenary talk: Gerard Cornuejols (Room 184)			
09:30 – 09:45	Coffee Break			
09:45 – 11:15	Stochastic models in resource allocation	Parallel Optimization and Machine Learning	Conic Optimization	Power Flow and Renewable Energy
11:15 – 11:30	Coffee Break			
11:30 – 12:30	Plenary talk: Sem Borst (Room 184)			
12:30 – 13:30	Lunch			
13:30 – 15:00	Polynomial optimization and interior point methods	Applications of Optimization in Networked Control Systems – Part II		Resource Allocation
15:00 – 15:15	Coffee Break			

07:30–08:15 **Registration and breakfast**

08:15–08:30 **Welcome** (Room 184)

08:30–09:30 **Plenary talk** (Room 184) *Chair: Frank E. Curtis*

- **Applying Machine Learning & Optimization in Online Revenue Management** *David Simchi-Levi*

09:30–09:45 **Coffee Break**

09:45–11:15 **Nonsmooth Optimization and Applications I** (Room 085) *Chair: B. Jadamba,M. Nguyen,H. Phan*

1. **First- and second-order adjoint method for parameter identification** *Baasansuren Jadamba*
2. **Parameter Identification in Variational and Quasi-Inequalities** *Akhtar Khan*
3. **Algorithms for minimizing differences of convex functions and applications** *Mau Nam Nguyen*

09:45–11:15 **Optimization in Machine Learning** (Room 091) *Chair: Chenxin Ma, Martin Takac*

1. **Covariance of the decision vector in stochastic complementarity problem using first-order approximation** *Sriram Sankaranarayanan*
2. **Gradient sliding for smooth and nonsmooth optimization** *Yuyuan Ouyang*
3. **Acceleration of a Communication-Efficient Distributed Dual Block Descent Algorithm** *Chenxin Ma*

09:45–11:15 **Integer Programming** (Room 184) *Chair: Sangho Shim*

1. **An extended formulation of the convex recoloring problem on a tree** *Sangho Shim*
2. **Using derivative-free optimization algorithms to tune the global optimization solver BARON** *Nikolaos Ploskas*
3. **Concise Decision Diagrams for Branching and Storing Near-Optimal Solutions** *Thiago Serra*

09:45–11:15 **Optimization in Energy I** (Room 271) *Chair: Boris Defourny*

1. **Convexification of Power Flow Equations for Power Systems in Presence of Noisy Measurements and Bad Data** *Ramtin Madani*
2. **Net Metering Policies for Rooftop Solar Generation** *Siddharth Prakash Singh*
3. **Energy Management Systems (EMS) for Microgrids** *Claudio Canizares*

11:15–11:30 **Coffee Break**

11:30–12:30 **Plenary talk** (Room 184) *Chair: Robert H. Storer*

- **Cars and Smarter Cities: New Services and New Applications for Control and Optimization** *Robert Shorten*

12:30–13:30 **Lunch**

13:30–15:00 **Nonsmooth Optimization and Applications II** (Room 085) *Chair: B. Jadamba,M. Nguyen,H. Phan*

1. **Optimization in Road Designs** *Hung Phan*
2. **Steklov representations of electrostatics approximations of vector fields and applications** *Manki Cho*
3. **A geometric approach to subdifferential calculus and Fenchel conjugates** *R. Blake Rector*

13:30–15:00 **Advances in convexification approaches for nonconvex polynomial optimization problems** (Room 091) *Chair: Fatma Kilinc-Karzan*

1. **Cuts for Polynomial Optimization** *Chen Chen*
2. **Approximation guarantees for monomial convexification in polynomial optimization** *Akshay Gupte*
3. **A Second-Order Cone Based Approach for Solving the Trust Region Subproblem and Its Variants** *Fatma Kilinc-Karzan*

13:30–15:00 **Meta-heuristic** (Room 184) *Chair: Francis Vasko and Yun Lu*

1. **An Empirical Study of Population-Based Metaheuristics for the Multiple-Choice Multidimensional Knapsack Problem** *Yun Lu*
2. **An Evolutionary-Penalty Approach for Constrained Optimization: Development and Applications** *Rituparna Datta*
3. **Multi-objective design and analysis of robot gripper configurations using an evolutionary-classical approach** *Rituparna Datta*

13:30–15:00 **Dynamic Optimization** (Room 271) *Chair: Ali Mohammad Nezhad*

1. **The Use of Sequential Quadratic Programming for Identification of Design Flaws in Dynamical Systems** *Jan Kuratko*
2. **Robust to Dynamics Optimization** *Amir Ali Ahmadi*
3. **Certifying Lyapunov inequalities using linear and second order cone programming relaxations** *Georgina Hall*

15:00–15:15 **Coffee Break**

15:15–16:15 **Plenary talk** (Room 184) *Chair: Boris Defourny*

- **Level-set methods for convex optimization** *Michael Friedlander*

16:15–16:30 **Coffee Break**

16:30–18:30 **Optimization Algorithms** (Room 085) *Chair: Feifeng Zheng*

1. **Online Scheduling of Ordered Flowshops** *Feifeng Zheng*
2. **An Attractor-Based Multi-Start Local Search System for Multimodal Traveling Salesman Problem** *Weiqi Li*
3. **The Multi-parameterized Cluster Editing Problem: Theory and Practice** *Faisal Abu-Khzam*
4. **A hybrid quasi-Newton projected-gradient method with application to lasso and basis-pursuit denoise** *Ewout van den Berg*

16:30–18:30 **Optimization in Machine Learning / Large-Scale Optimization** (Room 091) *Chair: Hiva Ghanbari and Xi He*

1. **Projection algorithms for nonconvex minimization with application to sparse principal component analysis** *Dzung Phan*
2. **Large Scale Distributed Hessian-Free Optimization for Deep Neural Network** *Xi He*
3. **Improved Diagonalizable Conjugate Gradient Methods for Large-Scale Optimization** *Mehiddin Al-Baali*
4. **A Multi-Batch L-BFGS Method for Machine Learning** *Martin Takac*

16:30–18:30 **Management Decision Models** (Room 184) *Chair: Walter Gomez*

1. **Modeling internal prices for organizations under collective rights systems** *Walter Gomez*
2. **Formulations and approximation algorithms for multi-level facility location problems** *Camilo Ortiz Astorquiza*
3. **The Expansion Decisions of Cassava Manufacturer Purchasing Locations** *Pavee Siriruk*
4. **Remarks on the Stackelberg-Nash risk-averse control problems** *Getachew Befekadu*

16:30–18:30 **Convex and Conic Relaxations for Intractable Optimization Problems** (Room 271) *Chair: Ali Mohammad Nezhad*

1. **Iterative LP and SOCP-based approximations to semidefinite programs** *Georgina Hall*
2. **Linear, Conic, and Non-Convex Formulations of the High Contrast Imaging Problem** *Robert Vanderbei*
3. **On Disjunctive Conic Cuts: When they exist, when they cut?** *Mohammad Shahabsafa*
4. **Semidefinite Programming for Nash Equilibria in Bimatrix Games** *Jeff Zhang*

19:00–21:00 **Graduate Student Social - Packer House, 217 West Packer Avenue, Bethlehem**

08:00–08:30 **Registration and breakfast**

08:30–09:30 **Plenary talk** (Room 184) *Chair: Tamas Terlaky*

- **Stochastic Optimization in Operational Risk Management** *Michael Pinedo*

09:30–09:45 **Coffee Break**

09:45–11:15 **Recent Advances in First-Order Methods and Applications in Network Estimation** (Room 085) *Chair: Niao He*

1. **Large Gaps Between Cyclic and Randomized Algorithms** *Ruoyu Sun*
2. **Network topology inference from spectral templates** *Gonzalo Mateos Buckstein*
3. **Fast and Simple Optimization for Poisson Likelihood Models** *Niao He*

09:45–11:15 **Machine Learning** (Room 091) *Chair: Afshin oroojlooy*

1. **Deep Learning for Newsvendors** *Afshin oroojlooy*
2. **A Deep Learning Model to Predict Stockouts in Multi-Echelon Inventory Systems** *Afshin oroojlooy*
3. **Machine Learning For Predicting Heart Failure Readmission** *Wei Jiang*

09:45–11:15 **Convexification Techniques in Mixed-Integer Programming** (Room 184) *Chair: Sercan Yildiz*

1. **Centerpoints: A link between optimization and convex geometry** *Amitabh Basu*
2. **On Some Polytopes Contained in the 0,1 Hypercube that Have a Small Chvátal Rank** *Dabeen Lee*
3. **Low-Complexity Relaxations and Convex Hulls of Disjunctions on the Positive Semidefinite Cone and General Regular Cones** *Sercan Yildiz*

09:45–11:15 **Optimization in Energy II** (Room 271) *Chair: Boris Defourny*

1. **Using Market Information to Imply Link Failure Probabilities** *Xiameng Hua*
2. **Stochastic Optimal Power Flow with Forecast Errors and Failures in Communication** *Basel Alnajjab*
3. **Self-enforcing Pricing Scheme for Load Aggregators** *Alberto J. Lamadrid*

11:15–11:30 **Coffee Break**

11:30–12:30 **Plenary talk** (Room 184) *Chair: Luis F. Zuluaga*

- **Mopta Modeling Competition** *Peter Nieuwesteeg*

12:30–13:30 **Lunch**

13:30–15:00 **Nonlinear Optimization: Algorithms, Theory, and Applications** (Room 085) *Chair: Mohammadreza Samadi*

1. **A Polyhedral Study on Chance Constrained Program with Random Right-Hand Side** *Bo Zeng*
2. **A Geometry Driven Active-Set Method For Elastic-Net Minimization** *Daniel P. Robinson*
3. **A Sequential Algorithm for Chance-Constrained Nonlinear Optimization** *Frank E. Curtis*

13:30–15:00 **Robust and Bi-Level Optimization** (Room 091) *Chair: Juan S. Borrero*

1. **Improving the Affine Policy in Two-Stage Adjustable Robust Linear Programming with Uncertain Right-Hand Side** *Guanglin Xu*
2. **Robust (Network) Optimization and Statistical Learning** *Dimitri Papadimitriou*
3. **Sequential Max-Min Bilevel Linear Programming with Incomplete Information and Learning** *Juan S. Borrero*

13:30–15:00 **Meta-heuristic** (Room 184) *Chair: Francis Vasko and Yun Lu*

1. **Application of Metaheuristic Algorithms to Structural Mechanics Problems** *Y. Cengiz Toklu*
2. **The Euclidean Steiner Cable-Trench Problem** *Dylan Gaspar and Eric Landquist*
3. **What is the Best Continuous Metaheuristic to Solve the Set covering Problem?** *Francis Vasko*

13:30–15:00 **Applications of Optimization in Networked Control Systems – Part I** (Room 271) *Chair: Milad Siami*

1. **Price-Based Control of Flow Networks** *Shuo Han*
2. **Distributed Newton Method for Global Consensus Problem** *Rasul Tutunov*
3. **Resource Management for Wireless Sensor-Actuator Systems** *Konstantinos Gatsis*

15:00–15:15 **Coffee Break**

15:15–16:15 **Plenary talk** (Room 184) *Chair: Martin Takac*

- **Continuation in Optimization: From interior point methods for large-scale optimization to Big Data optimization** *Jacek Gondzio*

16:15–16:30 **Coffee Break**

16:30–18:00 **Nonlinear Optimization** (Room 085) *Chair: Janos D. Pinter*

1. **How Difficult is Nonlinear Optimization? A Practical Solver Tuning Approach, with Illustrative Results** *Janos D. Pinter*
2. **A Bayesian Optimization Algorithm for Multi Information Source Optimization** *Matthias Poloczek*
3. **Optimized Ellipse Packings in Regular Polygons using Embedded Lagrange Multipliers** *Ignacio Castillo*

16:30–18:00 **Optimization and Machine Learning** (Room 091) *Chair: Hao Wang*

1. **Matrix support functionals for inverse problems, regularization, and learning** *Tim Hoheisel*
2. **Feature-distributed sparse regression** *Yuekai Sun*
3. **When are nonconvex optimization problems not scary?** *Ju Sun*

16:30–18:00 **Conic Optimization** (Room 184) *Chair: Ali Mohammad Nezhad*

1. **A Subgradient Method for Solving General Convex Optimization Problems** *James Renegar*
2. **Solving Conic Systems via Projection and Rescaling** *Javier Pena*
3. **Dimension reduction for semidefinite programs via Jordan algebras** *Frank Permenter*

16:30–18:00 **The Application of Optimization in Structural Design Problems** (Room 271) *Chair: Mohammad Shahabsafa*

1. **Composite Structural Optimization with MISOCO** *Sicheng He*
2. **Design of composite systems for wear performance using topology optimization** *Xiu Jia*
3. **Towards optimal elastoplastic design with shakedown bounds** *Mathilde Boissier*

18:00–19:00 **Cocktail Reception**

19:00–21:00 **Banquet**

08:00–08:30 **Registration and breakfast**

08:30–09:30 **Plenary talk** (Room 184) *Chair: Alexander Stolyar*

- **Ideal 0,1 matrices that do not pack** *Gerard Cornuejols*

09:30–09:45 **Coffee Break**

09:45–11:15 **Stochastic models in resource allocation** (Room 085) *Chair: Sasha Stolyar*

1. **Robust control of flexible processing networks** *Yuan Zhong*
2. **A queueing system with on-demand servers: local stability of fluid limits** *Lam Nguyen*
3. **Optimal Control of General Dynamic Matching System** *Mohammadreza Nazari*

09:45–11:15 **Parallel Optimization and Machine Learning** (Room 091) *Chair: Cho Cho-Jui Hsieh*

1. **On Convergence of Model Parallel Proximal Gradient Algorithm for Stale Synchronous Parallel System** *Yaoliang Yu*
2. **Limited-memory Common-directions Algorithm for Parallel/Distributed Optimization and its Application on Regularized Empirical Risk Minimization** *Ching-pei Lee*
3. **Exploiting Primal and Dual Sparsity for Extreme Classification** *Ian En-Hsu Yen*

09:45–11:15 **Conic Optimization** (Room 184) *Chair: David Papp*

1. **Polynomial optimization with sum-of-squares interpolants** *David Papp*
2. **A rounding procedure for a maximally complementary solution of second-order conic optimization** *Ali Mohammad Nezhad*
3. **Effects of Disjunctive Conic Cuts within a Branch and Conic Cut Algorithm to Solve Asset Allocation Problems** *Sertalp Cay*

09:45–11:15 **Power Flow and Renewable Energy** (Room 271) *Chair: Luis Zuluaga*

1. **A Game-Theoretic Framework for Resilient and Distributed Generation Control of Renewable Energies in Microgrids** *Quanyan Zhu*
2. **Power System State Estimation with Line Measurements** *Yu Zhang*
3. **Electric Vehicles as Grid Resources** *Mushfiqur Sarker*

11:15–11:30 **Coffee Break**

11:30–12:30 **Plenary talk** (Room 184) *Chair: Lawrence V. Snyder*

- **Optimal Load Distribution in Large-Scale Service Systems** *Sem Borst*

12:30–13:30 **Lunch**

13:30–15:30 **Polynomial optimization and interior point methods** (Room 085) *Chair: Ali Mohammad Nezhad*

1. **Non-Symmetric Interior Point Method In Non-Negative Polynomial And Moment Conic Optimization** *Mohammad Mehdi Ranjbar*
2. **Primal-Dual Interior-Point Methods with Domain-Driven Barriers.** *Mehdi Karimi*

13:30–15:30 **Applications of Optimization in Networked Control Systems – Part II** (Room 184) *Chair: Mirsaleh Bahavarnia*

1. **An Optimization-based Approach to Decentralized Controllability** *Alborz Alavian*
2. **On the Convexity of Optimal Decentralized Control Problem and Sparsity Path** *Salar Fattahi*
3. $\mathcal{H}_2/\mathcal{H}_\infty$ **Feedback Controller Sparsification Under Parametric Uncertainties** *MirSaleh Bahavarnia*

13:30–15:30 **Resource Allocation** (Room 271) *Chair: Miao Bai*

1. **Reactive Surgery Rescheduling on the Day of Surgery** *Miao Bai*
2. **A Novel Technique for Scheduling of Pumps in Water Distribution Systems** *Varghese Kurian*

15:30–15:45 **Coffee Break**

ABSTRACTS

■ Nonsmooth Optimization and Applications I

Room: **Room 085** (09:45-11:15) Chair: *B.Jadamba,M.Nguyen,H.Phan*

1. First- and second-order adjoint method for parameter identification

Baasansuren Jadamba[1,*]

[1]Rochester Institute of Technology; *bxjsma@rit.edu;

We develop a computational framework for the elastography inverse problem of detecting cancerous tumors in human body using an output least-squares (OLS) approach. The framework is based on employing second-order methods and one of the main contributions of this work is a derivation of an efficient computation method for the hessian of the functional. This is done in two different ways, firstly, by giving a new hybrid approach, and secondly, by a new second-order adjoint approach. The derivations of the formulas are given in continuous as well as in discrete setting. Detailed numerical results are presented.

2. Parameter Identification in Variational and Quasi-Inequalities

Akhtar Khan[1,*]

[1]Rochester Institute of Technology; *aaksma@rit.edu;

In this talk our objective is to discuss the inverse problem of identifying variable parameters in certain variational and quasi variational inequalities. We develop a trilinear form based optimization framework that has been used quite e ectively for parameter identi cation in variational equations emerging from partial di erential equations. We investigate the inverse problem in an optimization setting using the output-least squares formulation. We give existence and convergence results for the optimization problem. We also penalize the variational inequality and arrive at optimization problem for which the constraint variational inequality is replaced by the penalized equation. For this case, the smoothness of the parameter-to-solution map is studied and convergence analysis and optimality conditions are given. We also discretize the identi cation problem for quasi-variational inequalities and give the convergence analysis for the discrete problems. Examples are given to justify the theoretical framework.

3. Algorithms for minimizing differences of convex functions and applications

Mau Nam Nguyen[1,*]

[1]Portland State University; *mnn3@pdx.edu;

As convex optimization has been studied for a quite long time, going beyond convexity is of great interest in research of mathematical optimization. A progress to go beyond convexity was made by considering the class of functions that can be represented as differences of convex functions. In this talk we present a number of algorithms for minimizing differences of convex functions. Then we introduce some applications of these algorithms to solve problems of facility location and clustering.

■ Optimization in Machine Learning

Room: **Room 091** (09:45 - 11:15) Chair: *Chenxin Ma, Martin Takac*

1. Covariance of the decision vector in stochastic complementarity problem using first-order approximation

Sriram Sankaranarayanan[1,*], *Felipe Feijoo*[1], *Sauleh Siddiqui*[1]

[1]Johns Hopkins University; *ssankar5@jhu.edu;

We provide an efficient method to estimate the covariance between decisions variables in a solution of a general class of stochastic nonlinear complementarity problems. We use first-order Taylor approximation methods to approximate the decision variables due to a perturbation in the random parameters. Then we estimate the covariance between the decision variables due to the random perturbation. Having done this, we extend the deterministic version of the North American Natural Gas Model (NANGAM), to incorporate effects due to uncertainty in the parameters of the demand function, supply function, infrastructure, and investment costs.

2. Gradient sliding for smooth and nonsmooth optimization

Yuyuan Ouyang[1,*], *Guanghui Lan*[2]

[1]Clemson University; *yuyuano@clemson.edu;[2]Georgia Institute of Technology;

We consider a class of smooth and nonsmooth optimization problem that could be solved by the gradient sliding method. In particular, the problem of interest is the sum of a smooth convex function and one other convex function, while the latter is either smooth or having a saddle point structure. We propose a gradient sliding type method that solves the smooth optimization problem with complexity bound $O(\sqrt{1/\varepsilon})$, and solves the saddle point problem with complexity bound $O(1/\varepsilon)$. In order to compute an approximate solution efficiently, the proposed method skips the gradient evaluation of the former smooth component from time to time, so that the number of its gradient evaluations is bounded by $O(\sqrt{1/\varepsilon})$, while the overall performance still followings the aforementioned complexity bound.

3. Acceleration of a Communication-Efficient Distributed Dual Block Descent Algorithm

Chenxin Ma[1,*], *Frank E. Curtis*[1], *Nathan Srebro*[2], *Martin Takac*[1]

[1]Lehigh University; *chm514@lehigh.edu;[2]TTIC;

Distributed optimization algorithms for very large-scale machine learning suffer from communication bottlenecks. Confronting this issue, a communication efficient primal-dual coordinate ascent framework (CoCoA) and its improved variant CoCoA+ have been proposed, achieving a convergence rate of $O(1/t)$ for solving empirical risk minimization problems with Lipschitz losses. In this paper, we propose an accelerated variant of CoCoA+ and show that it has a rate of $O(1/t^2)$ in terms of reducing dual suboptimality. Our analysis is also notable in that our convergence rate bounds involve constants that, except in extreme cases, are significantly reduced compared to those previously proved for CoCoA+.

■ Integer Programming

Room: **Room 184** (09:45 - 11:15) Chair: *Sangho Shim*

1. An extended formulation of the convex recoloring problem on a tree

Sangho Shim[1,*], *Sunil Chopra*[2], *Bartosz Filipecki*[3], *Kangbok Lee*[4], *Minseok Ryu*[5], *Mathieu Van Vyve*[3]

[1]Robert Morris University, PA; *shim@rmu.edu;[2]Northwestern University;[3]Universite catholique de Louvain, Belgium;[4]The City University of New York;[5]University of Michigan, Ann Arbor;

We introduce a strong extended formulation of the convex recoloring problem on a tree, which has an application in analyzing phylogenetic trees. The extended formulation has only a polynomial number of constraints, but dominates the conventional formulation and the exponentially many valid inequalities introduced by Campelo et al. (2015). We show that all valid inequalities introduced by Campelo et al. (2015) can be derived from the extended formulation. We also show that the natural restriction of the extended formulation provides a complete inequality description of the polytope of subtrees of a tree. The solution time using the extended formulation is much smaller. Moreover the extended formulation solves all the problem instances attempted in Campelo et al. (2015) and larger sized instances at the root node of the branch-and-bound tree without branching.

2. Using derivative-free optimization algorithms to tune the global optimization solver BARON

Nikolaos Ploskas[1,*], *Jianfeng Liu*[1], *Nikolaos V. Sahinidis*[1]

[1]Carnegie Mellon University; *nploskas@andrew.cmu.edu;

Optimization solvers provide various options that allow users to control different algorithmic aspects. Tuning solver options is often necessary since it leads to significant performance improvements. All previous proposed methods for tuning optimization solvers options have focused on MILP and local NLP solvers. We investigate the potential of tuning the global optimization solver BARON for NLP and MINLP problems. We perform a computational study over a set of 126 problems from GLOBALLib and MINLPLib collections in order to identify optimal values for each one of the problems and also find a single set of options that can improve the performance of BARON across the entire test collection. A total of 27 derivative-free optimization algorithms are used and compared in the process. Detailed computational results will be presented.

3. Concise Decision Diagrams for Branching and Storing Near-Optimal Solutions

Thiago Serra[1,*], *John Hooker*[1]

[1]Carnegie Mellon University; *tserra@cmu.edu;

In many applications of optimization it is useful to have access to alternate solutions that may even be suboptimal. However, maintaining a large pool of solutions requires more efficient on-the-fly storage than that provided by a search tree. Decision diagrams have recently been used to more compactly encode solutions to discrete optimization problems. Diagrams for near-optimal solutions can be further compressed if relaxed as Sound Decision Diagrams (SndDDs), which store solutions that are within a given tolerance of optimal along with some spurious solutions that are outside the tolerance. We provide a formal characterization of sound relaxations and efficient algorithms to find those with minimum size. Furthermore, we extend such diagram relaxations to also allow spurious solutions that are better than optimal, which we show to be NP-hard to minimize. We present computational results on compressing near-optimal solutions of 0âĂŞ1 problems from the MIPLIB benchmark.

■ Optimization in Energy I

Room: **Room 271** (09:45 - 11:15) Chair: *Boris Defourny*

1. Convexification of Power Flow Equations for Power Systems in Presence of Noisy Measurements and Bad Data

Ramtin Madani[1,*], *Javad Lavaei*[1], *Ross Baldick*[2]

[1]University of California, Berkeley; *ramtin.madani@berkeley.edu;[2]University of Texas at Austin;

This talk is concerned with the power system state estimation (PSSE) problem, which aims to find the unknown operating point of a power network based on a given set of measurements. The measurements of the PSSE problem are allowed to take any arbitrary combination of nodal active powers, nodal reactive powers, nodal voltage magnitudes and line flows. This problem is non-convex and NP-hard in the worst case. We develop a set of convex programs with the property that they all solve the non-convex PSSE problem in the case of noiseless measurements as long as the voltage angles are relatively small. This result is then extended to a general PSSE problem with noisy measurements, and an upper bound on the estimation error is derived. The objective function of each convex program developed in this work has two terms: one accounting for the non-convexity of the power flow equations and another one for estimating the noise levels. The proposed technique is demonstrated on the 9241-bus European network.

2. Net Metering Policies for Rooftop Solar Generation

Siddharth Prakash Singh[1,*], *Alan Scheller-Wolf*[1]

[1]Tepper School of Business, Carnegie Mellon University; *sps1@andrew.cmu.edu;

During hours of peak sunlight, households with rooftop solar panels often generate more electricity than they can use. Under a service called net-metering, these households can sell this excess generation back to the utility company they are affiliated with. In the USA, it has been standard practice for utility companies to levy a fixed fee for this ‘net-metering’ service and compensate consumers at retail rates for this excess generation, effectively charging customers only for their ‘net’ electricity usage. This payback framework could eat into the margins of the utility company, because it may be forced to actually purchase some amount of electricity back from customers at retail, rather than wholesale rates. Furthermore, this reduction in sales means that investments in transformers, wires, and other hardware can be amortized over fewer kilowatt-hours. Thus the utility company may need to increase retail rates for all customers in order to offset this loss, effectively forcing non-solar customers to subsidize solar customers. This situation has led to regulatory flux related to the rooftop solar industry, notably in the states of Nevada and Arizona.
Market and firm outcomes in this environment depend on the payback framework and retail rates which are proposed by the utility company (U) and regulated by the public utilities commission (PUC), and the price charged by the provider (S) of rooftop solar panels (which is not currently subject to regulatory oversight). We seek to quantify the effect of different types of regulatory actions on market outcomes for customers and firms, taking into account the strategic responses of S and the customers to the decisions agreed upon by U and PUC. We model this environment as a sequential game played by U and S, faced with a continuum of customers who are heterogeneous in their demands and generation potentials. In the first period, U chooses a retail price and payback structure, which is modeled as a profit maximization problem with ‘approval’ constraints imposed by the PUC. In the second period, S chooses a selling price for solar panels by solving a profit maximization problem. In the third period, each atomic customer in the continuum, faced with retail prices, a payback structure, and a price for solar panels decides whether to install solar panels or not, based on their particular characteristics. We characterize the equilibrium solution to this game and study market outcomes under various alternative regulatory policies (constraints) that PUC may impose on U’s optimization problem, like restricting U’s profit, or ensuring a given amount of solar penetration. We then extend our base model to explicitly incorporate day versus night considerations. We handle the resulting problem by optimizing the sum of day and night objectives, using linking constraints to couple day and night decisions. Using data in the public domain, we employ our model to analyze regulatory

changes introduced in the state of Nevada in 2016, and show that these proposed changes are likely to completely annihilate the rooftop solar industry.

3. Energy Management Systems (EMS) for Microgrids

Claudio Canizares[1,*]

[1]University of Waterloo; [*]ccanizar@uwaterloo.ca;

Micrograms are not new to the power systems community, since these local and small grids have been widely deployed and utilized for electricity supply in remote and isolated communities such as islands and remote villages throughout the world. However, there is nowadays a rapid development and deployment of microgrids in the context of smart and resilient power networks, in good part motivated by the need to integrate distributed generation, especially those powered by renewable resources, to reduce operational costs and the environmental impact of these grids, particularly for diesel-depended isolated microgrids.
In this talk, an overview of the main characteristics and challenges of EMS for microgrids will be discussed. An EMS architecture together with deterministic, probabilistic, and robust methodologies developed at Waterloo and being implemented by an industry partner will be described in some detail. Thus, a two-step architecture based on a model predictive control plus receding horizon approach, which allows to divide the Mixed Integer Nonlinear Programing (MINLP) EMS problem into a simplified MILP unit commitment (UC) problem and a very detailed NLP dispatch problem, will be presented. Novel stochastic programing and a robust optimization implementations of the UC problem, to better deal with uncertainty of particularly wind and solar power sources, will be also discussed. The practical feasibility and benefits of the proposed EMS approaches will be demonstrated and compared based on results obtained from tests carried out on a realistic microgrid.

■ Nonsmooth Optimization and Applications II

Room: **Room 085** (13:30-15:00) Chair: *B.Jadamba,M.Nguyen,H.Phan*

1. Optimization in Road Designs

Hung Phan[1,*], *Heinz Bauschke*[2], *Valentin Koch*[3]

[1]University of Massachusetts at Lowell; [*]hung_phan@uml.edu;[2]University of British Columbia;[3]AutoDesk Inc.;

The basic optimization problem of road design is quite challenging due to an objective function that is the sum of nonsmooth functions and the presence of set constraints. In this talk, we present a mathematical model and solution to this problem by employing the Douglas-Rachford splitting algorithm. We compare our algorithm to a state-of-the-art projection algorithm. Our numerical results illustrate the potential of this algorithm to significantly reduce cost in road design.

2. Steklov representations of electrostatics approximations of vector fields and applications

Manki Cho[1,*], *Giles Auchmuty*[2]

[1]Rochester Institute of Technology; [*]mxcsma1@rit.edu;[2]University of Houston;

This talk provides expressions for the boundary potential that provides the best electrostatic potential approximation of a given L^2 vector field on a nice bounded region in R^N. The permittivity of the region is assumed to be known and the potential is required to be zero on the conducting part of the boundary. The boundary potential is found by solving the minimization conditions and using a special basis of the trace space for the space of allowable potentials. The trace space is identified by its representation with respect to a basis of Steklov eigenfunctions. Also numerical experiments as parts of applications of Steklov representations will be supported

3. A geometric approach to subdifferential calculus and Fenchel conjugates

R. Blake Rector[1,*], *Nguyen Mau Nam*[1], *Tuyen Tran*[1]

[1]Portland State University; [*]r.b.rector@pdx.edu;

In this talk we provide an easy path for accessing major calculus rules of subgradients and Fenchel conjugates in finite and infinite dimensions. Our approach is based on geometric notions such as extremal systems, normal cones to convex sets, epigraphs of convex functions, and graphs of convex set-valued mappings. Together with the tools developed by Mordukhovich and others for generalized differential calculus with nonconvex functions and set-valued mappings, this approach allows us to obtain a number of new convex calculus results and major known calculus rules in an accessible way.

■ Advances in convexification approaches for nonconvex polynomial optimization problems

Room: **Room 091** (13:30 - 15:00) Chair: *Fatma Kilinc-Karzan*

1. Cuts for Polynomial Optimization

Chen Chen[1,*], *Daniel Bienstock*[1], *Gonzalo Munoz*[1]

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We explore two strategies to develop cuts for polynomial optimization. First, we adopt a geometric approach based on S-free sets or convex forbidden zones; for polynomial optimization we use the specialized term 'outer-product-free'. We develop an intersection cut for generic problems with closed sets, provided a violation distance oracle. Furthermore, we provide some insight into the nature of maximal outer-product-free sets and present two classes of such sets. The intersection cuts associated with these two classes can be strengthened in the case of intersections at infinity. All our cuts can be produced in polynomial-time for polynomial optimization problems. Second, we present a lift-digitize-and-project method for bounded polynomial optimization problems. The separation problem involves a lifted MILP relaxation where continuous variables are digitized, or represented with discrete variables. The method can exploit sprasity by considering the intersection graph associated with sets of constraints, and applying partial digitization.

2. Approximation guarantees for monomial convexification in polynomial optimization

Akshay Gupte[1,*], *Warren Adams*[1], *Yibo Xu*[1]

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Consider minimizing a polynomial function over a compact convex set. Convexifying each monomial separately yields a lower bound on the global optimum. For any monomial whose domain is a subset of the $[0, 1]^n$ box, we give upper bounds on the approximation

error produced by the closure convex hull of this monomial. The error measure is the maximum absolute deviation between the actual and the approximated product value. Our bounds are functions of the monomial degree. Special structures of the domain for which our bounds are tight are also analyzed. For a multilinear monomial over the $[1, r]^n$ box, where r is a positive real, we give refined error bounds. As a step towards addressing mixed-sign variable domains, we provide error bounds for a multilinear monomial over the $[-1, 1]^n$ box. All the above anaylses together imply an upper bound on the additive error in the global optimum due to monomial convexifications of a polynomial.
Finally, we also analyze errors when each multilinear monomial is approximated with a single linear function. Although the linear function with the smallest error does not relax the monomial, we show that the smallest linear error is theoretically superior to that of the convex hull in each of the $[0, 1]^n$, $[1, r]^n$, and $[-1, 1]^n$ cases.

3. A Second-Order Cone Based Approach for Solving the Trust Region Subproblem and Its Variants

Fatma Kilinc-Karzan[1,*], *Nam Ho-Nguyen*[1]

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We study the trust region subproblem (TRS) of minimizing a nonconvex quadratic function over the unit ball with additional conic constraints. Despite having a nonconvex objective, it is known that the TRS and a number of its variants are polynomial-time solvable. In this talk, we follow a second-order cone based approach to derive an exact convex formulation of the TRS. As a result, our study highlights an explicit connection between the nonconvex TRS and smooth convex quadratic minimization, which allows for the application of cheap iterative methods such as Nesterov's accelerated gradient descent to the TRS. Under slightly stronger conditions, we give a low-complexity characterization of the convex hull of the epigraph of the nonconvex quadratic function intersected with the constraints defining the domain without any additional variables. We also explore the inclusion of additional hollow constraints to the domain of the TRS, and convexification of the associated epigraph.
This is joint work with Nam Ho-Nguyen.

■ Meta-heuristic

Room: **Room 184** (13:30 - 15:00) Chair: *Francis Vasko and Yun Lu*

1. An Empirical Study of Population-Based Metaheuristics for the Multiple-Choice Multidimensional Knapsack Problem

Yun Lu[1,*], *Francis Vasko*[1]

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In this paper, we study the performance of five population-based metaheuristics to solve a large (393) number of comprehensive problem instances from the literature for the important (NP-Hard) multiple-choice multidimensional knapsack problem (MMKP). The five metaheuristics are: teaching-learning-based optimization (TLBO), artificial bee colony (ABC), genetic algorithm (GA), crisscross optimization algorithm (COA), and binary bat algorithm (BBA). All five of these metaheuristics are similar in that they transform a population of solutions in an effort to improve the solutions in the population and they are all implemented in a straightforward manner. Statistically (over all 393 problem instances), we show that COA, GA and TLBO give similar results which are better than other published solution approaches for the MMKP. However, if we incorporate a simple neighborhood search into each of these five metaheuristics, in addition to improved solution quality, there is now no statistically significant difference among the results for these five metaheuristics.

2. An Evolutionary-Penalty Approach for Constrained Optimization: Development and Applications

Rituparna Datta[1,*]

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The holy grail of constrained optimization is the development of an efficient, scale invariant and generic constraint handling procedure in single and multi-objective constrained optimization problems. Most optimization problems in science and engineering consist of one or many constraints, which come into picture mainly due to some physical limitations or functional requirements. Constraints can be divided into inequality type and equality type, but the challenge is to obtain feasible solutions that satisfy all constraints with minimal computational effort. The classical penalty function approach is a widely used constraint handling method, in which the objective function value is penalized in proportion to the constraint violation. Initially Evolutionary Algorithms (EAs) were designed for unconstrained optimization but have now evolved to include various constraint handling mechanisms. We proposed a synergistic combination of bi-objective evolutionary approach with the penalty function methodology, to solve problems with single objective having inequality constraints. This methodology is then extended for equality and inequality+equality mixed constrained problems. Normalization of constraints is crucial for the efficient performance of any constraint handling algorithm. Therefore, our method is extended to normalize all the constraints adaptively during the optimization process. Having developed efficient constraint handling strategies for single-objective optimization problems we then develop constraint handling strategy for bi-objective optimization problems. The working of the procedure on a number of standard numerical test problems and an engineering design problem is demonstrated. In most cases, the proposed hybrid methodology is observed to take one or more orders of magnitude fewer function evaluations to find the constrained minimum solution accurately than some of the best reported existing methodologies. We demonstrate the efficacy of the proposed method by solving real world single and multi-objective constrained optimization problems.

3. Multi-objective design and analysis of robot gripper configurations using an evolutionary-classical approach

Rituparna Datta[1,*]

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This work is concerned with the determination of optimum forces extracted by robot grippers on the surface of a grasped rigid object – a matter which is crucial to guarantee the stability of the grip without causing defect or damage to the grasped object. A multi-criteria optimization of robot gripper design problem is solved with two different configurations involving two conflicting objectives and a number of constraints. The objectives involve minimization of the difference between maximum and minimum gripping forces and simultaneous minimization of the transmission ratio between the applied gripper actuator force and the force experienced at the gripping ends. Two different configurations of the robot gripper are designed by a state-of-the-art algorithm (NSGA-II) and the obtained results are compared with a previous study. Due to presence of geometric constraints, the resulting optimization problem is highly non-linear and multi-modal. Furthermore, the system model has been modified by integrating an actuator model into the robotic gripper problem. A generic actuation system (for e.g. a voice coil actuator) which generates force proportional to the applied voltage is considered. With the incorporation of voltage into the problem, which is related to both the actuator force and the manipulator displacement, the problem becomes more realistic and can be integrated with many real life gripper simulations. The

work has been extended by developing a minimalistic model of Piezoelectric (PZ) actuator, consisting different series and parallel assembly arrangements for both mechanical and electrical parts. To include the effects of connector spring, the relationship of force with actuator displacement is replaced by the relation between force and the displacement of point of actuation at the physical system. Multi-objective evolutionary algorithm (MOEA) is used to solve the bi-objective problem and to optimally find the dimensions of links and the joint angle of a robot gripper. Relationship between force and actuator displacement is obtained using each set of non-dominated solutions. These relationships can provide a better insight to the end user to select the appropriate voltage and gripper design for specific application.

■ Dynamic Optimization

Room: **Room 271** (13:30 - 15:00) Chair: *Ali Mohammad Nezhad*

1. The Use of Sequential Quadratic Programming for Identification of Design Flaws in Dynamical Systems

Jan Kuratko[1,*], *Stefan Ratschan*[2]

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Assume a dynamical system that models a physical device and two sets of states: the set of initial states and the set of unsafe states. Our goal is to investigate whether there is a solution that originates in the set of initial states and reaches the set of unsafe states. Therefore we seek a solution of arbitrary length whose extremities are subjected to in general nonlinear constraints. The result is an underdetermined boundary value problem. Similar problems appear in other areas for example in robot motion planning.
We present a method that uses the specific structure of this boundary value problem: We formulate it as an equality constrained nonlinear optimization problem and solve it using SQP. Our choice of the objective function and constraints results into a sparse and structured saddle-point matrix. In addition the specific structure of the Hessian block allows us to keep its sparse structure even if we use approximation schemes. We show that for linear ODEs we can use analytic formulas for the Hessian computation with almost no additional work to the computation of the Jacobian of constraints. We investigate the properties of the Hessian and show that for linear ODEs it is a singular matrix with large nullity and also with negative eigenvalues.
In the end we will provide numerical results that compare line search and trust region strategies. The problem with the singularity of the Hessian will be addressed and we discuss the effects of using modified Cholesky (Gill-Murray) factorization on the optimality conditions.

2. Robust to Dynamics Optimization

Amir Ali Ahmadi[1,*]

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We introduce a new type of robust optimization problems that we call "robust to dynamics optimization" (RDO). The input to an RDO problem is twofold: (i) a mathematical program (e.g., an LP, SDP, IP), and (ii) a dynamical system (e.g., a linear, nonlinear, discrete, or continuous dynamics). The objective is to maximize over the set of initial conditions that forever remain feasible under the dynamics. We initiate an algorithmic study of RDO and demonstrate tractability of some important cases. Joint work with Oktay Gunluk from IBM Research.

3. Certifying Lyapunov inequalities using linear and second order cone programming relaxations

Georgina Hall[1,*], *Amir Ali Ahmadi*[1]

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We focus on the problem of certifying stability of switched linear systems by upper bounding the Joint Spectral Radius (JSR) of the underlying matrices. Traditionally, upper bounds on the JSR are obtained using sum of squares (sos) optimization which relies on semidefinite programming. In this talk, we present different ways of exploiting the structure of the problem to generate LPs and SOCPs that provide new bounds on the JSR.

■ Optimization Algorithms

Room: **Room 085** (16:30 - 18:30) Chair: *Feifeng Zheng*

1. Online Scheduling of Ordered Flowshops

Feifeng Zheng[1,*], *Kangbok Lee*[2], *Michael L. Pinedo*[3]

[1]Glorious Sun School of Business and Management, Donghua University; Leonard N. Stern School of Business, New York University; *ffzheng@dhu.edu.cn;[2]York College, The City University of New York;[3]Leonard N. Stern School of Business, New York University;

We consider the online scheduling of ordered flowshops with the makespan objective. When a job arrives, its operations have to be scheduled irrevocably without having any information regarding jobs that will be revealed subsequently. The worst case performance of the Greedy Algorithm that schedules jobs without any delay is analyzed. As special cases, the proportionate flowshop with different speeds and the proportionate flowshop with setup times are considered. For some of the cases, lower bounds of the competitive ratio are derived.

2. An Attractor-Based Multi-Start Local Search System for Multimodal Traveling Salesman Problem

Weiqi Li[1,*]

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The Traveling Salesman Problem (TSP) is one of the most popular combinatorial optimization problems and has been studied intensively in many contexts with a variety of different applications. Multimodal Traveling Salesman Problem is a variation of the classic TSP, which contains multiple optimal tours. The objective of a search system dealing with multimodal TSP is to find all optimal tours for the TSP instance. Until now, most of studies on multimodal optimization have focused on multimodal function optimization problems. Widely-used search techniques are niching evolutionary algorithms. To the best of our knowledge, no research in literature has studied multimodal combinatorial optimization problems. This paper introduces an attractor-based search system to solve the multimodal TSP. The proposed search system collects a set of locally optimal tours generated by a multi-start search algorithm, then uses them to construct solutions attractors, and finally find all optimal tours in these solution attractors.

3. The Multi-parameterized Cluster Editing Problem: Theory and Practice

Faisal Abu-Khzam[1,*]

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The Cluster Editing problem seeks a transformation of a given undirected graph into a disjoint union of cliques via a (minimum) number of edge additions or deletions. A multi-parameterized version of the problem is presented, featuring a number of input parameters that bound the amount of both edge-additions and deletions per single vertex, as well as the size of a clique-cluster. We briefly overview previous work on the problem and show that it remains NP-hard even when only one edge can be deleted and at most two edges can be added per vertex. However, the new formulation allows us to solve Cluster Editing (exactly) in polynomial time when the number of edge-edit operations per vertex is smaller than half the minimum cluster size. As a byproduct, we obtain a simple kernelization algorithm that delivers linear-size kernels when the two edge-edit bounds are small constants. We further discuss the practical aspects of the multi-parameterized approach as a better model for correlation clustering. Some open problems and new research directions are also discussed.

4. A hybrid quasi-Newton projected-gradient method with application to lasso and basis-pursuit denoise

Ewout van den Berg[1,*]

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In this talk we present a new algorithm for the optimization of convex functions over simple polyhedral sets. The algorithm is a hybrid of the spectral projected-gradient and quasi-Newton methods in which the type of step is determined dynamically at each iteration. Application and specialization of the framework is illustrated on the Lasso problem. Results include implicit orthogonal bases for the faces of weighted one-norm balls, projection of line segments onto these balls along with a tight upper bound on the number of possible projection segments, and the derivation of an improved duality gap estimate for l2-regularized problems.

■ Optimization in Machine Learning / Large-Scale Optimization

Room: **Room 091** (16:30 - 18:30) Chair: *Hiva Ghanbari and Xi He*

1. Projection algorithms for nonconvex minimization with application to sparse principal component analysis

Dzung Phan[1,*]*, William Hager*[2]*, Jiajie Zhu*[2]

[1]IBM Research; *phandu@us.ibm.com;[2]University of Florida;

We consider concave minimization problems over nonconvex sets. Optimization problems with this structure arise in sparse principal component analysis. We analyze both a gradient projection algorithm and an approximate Newton algorithm where the Hessian approximation is a multiple of the identity. Convergence results are established. In numerical experiments arising in sparse principal component analysis, it is seen that the performance of the gradient projection algorithm is very similar to that of the truncated power method and the generalized power method. In some cases, the approximate Newton algorithm with a BarzilaiâĂŞBorwein Hessian approximation and a nonmonotone line search can be substantially faster than the other algorithms, and can converge to a better solution.

2. Large Scale Distributed Hessian-Free Optimization for Deep Neural Network

Xi He[1,*]*, Mikhail Smelyanskiy*[2]*, Dheevatsa Mudigere*[3]*, Martin Takac*[4]

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Training deep neural network is a high dimensional and a highly non-convex optimization problem. Stochastic gradient descent (SGD) algorithm and it's variations are the current state-of-the-art solvers for this task. However, due to non-covexity nature of the problem, it was observed that SGD slows down near saddle point. Recent empirical work claim that by detecting and escaping saddle point efficiently, it's more likely to improve training performance. With this objective, we revisit Hessian- free optimization method for deep networks. We also develop its distributed variant and demonstrate superior scaling potential to SGD, which allows more efficiently utilizing larger computing resources thus enabling large models and faster time to obtain desired solution. Furthermore, unlike truncated Newton method (Marten's HF) that ignores negative curvature information by using naÃŕve conjugate gradient method and Gauss-Newton Hessian approximation information - we propose a novel algorithm to explore negative curvature direction by solving the sub-problem with stabilized bi-conjugate method involving possible indefinite stochastic Hessian information. We show that these techniques accelerate the training process for both the standard MNIST dataset and also the TIMIT speech recognition problem, demonstrating robust performance with upto an order of magnitude larger batch sizes. This increased scaling potential is illustrated with near linear speed-up on upto 16 CPU nodes for a simple 4-layer network.

3. Improved Diagonalizable Conjugate Gradient Methods for Large-Scale Optimization

Mehiddin Al-Baali[1,*]

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Our recent class of diagonalizable conjugate gradient methods for large-scale unconstrained optimization will be considered. The class, with any line search, suggests strategies for enforcing the sufficient descent and other useful properties. Using a particular strategy, an improved subclass of conjugate gradient methods is obtained and tested in practice. Numerical results on a set of standard test problems will be described. They show that the proposed diagonalizable-strategy improves, substantially in several cases, the performance of several conjugate gradient methods (in particular, those of Fletcher-Reeves, Polak-Ribiere-Polyak, Hestenes-Stiefel and some of their modifications).

4. A Multi-Batch L-BFGS Method for Machine Learning

Martin Takac[1,*]*, Albert S. Berahas*[2]*, Jorge Nocedal*[2]

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The question of how to parallelize the stochastic gradient descent (SGD) method has received much attention in the literature. In this paper, we focus instead on batch methods that use a sizeable fraction of the training set at each iteration to facilitate parallelism, and that employ second-order information. In order to improve the learning process, we follow a multi-batch approach in which the batch changes at each iteration. This inherently gives the algorithm a stochastic flavor that can cause instability in L-BFGS, a popular batch method in machine learning. These difficulties arise because L-BFGS employs gradient differences to update the Hessian approximations; when these gradients are computed using different data points the process can be unstable. This paper shows how to perform stable quasi-Newton updating in the multi-batch setting, illustrates the behavior of the algorithm in a distributed computing platform, and studies its convergence properties for both the convex and nonconvex cases.

■ Management Decision Models

Room: **Room 184** (16:30 - 18:30) Chair: *Walter Gomez*

1. Modeling internal prices for organizations under collective rights systems

Walter Gomez[1,*], *Jorge Dresdner*[2]

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In this paper we consider a regulatory agency assigning a scarce resource to organizations based on a collective rights system. In this setting each organization is formed by a set of basic agents working together in order to get access to the scarce resource. The efficient use of the assigned resource and the distribution of the benefits among its agents are independently ruled by each organization, and beyond the control of the regulatory agency. One important concern for the regulator is the equity in the distribution of the final benefits among all the basic agents belonging to all organizations. We develop a basic model to analyze optimal decisions within the organizations. Moreover we study different models to explain the distribution of benefits inside each organization, including one based on an internal price for the scarce resource, and use the Theil index as a distributive measure of the equity. The price can be different for each organization reflecting the diversity of characteristics among them. An algorithm is developed to calculate the final benefits and equity index for each model and to compare the effect of different schemes regarding the assignment of the scarce recourse. The models and the algorithms are implemented for the common sardine and anchovies artisanal fisheries of central âĂŞ southern Chile.

2. Formulations and approximation algorithms for multi-level facility location problems

Camilo Ortiz Astorquiza[1,*], *Ivan Contreras*[1], *Gilbert Laporte*[2]

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We study multi-level uncapacitated p-location problems, a general class of facility location problems. We use a combinatorial representation of the general version of the problem where the objective function satisfies the submodularity property, and we exploit this characterization to derive worst-case bounds for a greedy heuristic. We obtain sharper bounds when the setup cost for opening facilities is zero. These results extend naturally from those obtained from the single level version once the representation of the problem is properly defined so as to satisfy submodularity in the objective function. Moreover, we introduce a mixed integer linear programming formulation for the problem based also on submodularity. Some computational results are summarized in the presentation.

3. The Expansion Decisions of Cassava Manufacturer Purchasing Locations

Pavee Siriruk[1,*]

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Nowadays, Cassava manufacturers face new challenges in acquiring raw materials due to high competition among cassava manufacturers. Decisions to expand purchasing locations are important in order to obtain more raw materials from farmers in new areas. This decision is crucial for the company to survive. Two major factors to draw farmers to sell their products to the firms are the distance from farmers to the manufacturers and cassava buying prices. This paper focuses on the strategy for a cassava processing firm to expand their cassava purchasing location. An algorithm to find the locations to establish manufacturer purchasing location while maximizing profit is proposed. The results show that the algorithm can find the price equilibrium in a timely fashion.

4. Remarks on the Stackelberg-Nash risk-averse control problems

Getachew Befekadu[1,*], *Alexander Veremyev*[2], *Vladimir Boginski*[3], *Eduardo L. Pasiliao*[4]

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In this talk and the associated paper (Befekadu et al. (2016)), we consider a risk-averse control problem for diffusion processes, in which there is a hierarchy of admissible controls or decision-making groups with different cost functionals and risk-averse satisfactions. We assume that there is a "global" decision-maker, which is the *leader*, and there are n "local" decision-makers, which are the *followers*. Our approach, based on a Stackelberg-Nash optimization framework, the *followers*, assuming that the *leader* has made an admissible control strategy, look for a Nash equilibrium of their cost functionals (i.e., the criteria, associated with stochastic target problems, in which the *followers* are interested in). Then, the *leader* makes its final decision for the whole system based on a certain level of risk-averse satisfaction that is required to be achieved for the *leader* as a priority over that of the *followers'* criteria. In particular, we formulate such a hierarchical risk-averse control problem using coupled *forward-backward stochastic differential equations* that allow us to introduce a family of time-consistent dynamic convex risk measures, based on backward-semigroup operators, w.r.t. the strategies of the *leader* and that of the *follower*. Moreover, under suitable conditions, we establish the existence of optimal Stackelberg-Nash risk-averse solutions, in the sense of viscosity solutions, to the associated risk-averse dynamic programming equations. Finally, we remark on the implication of our result in assessing the influence of the *leader's* risk-averse satisfaction on the achievable targets of the *followers'* in relation to the direction of *leader-followers* information flow.

G. K. Befekadu, A. Veremyev and E. L. Pasiliao, "On the hierarchical risk-averse control problems for diffusion processes", eprint arXiv:1603.03359, 20 pages, March 2016.

■ Convex and Conic Relaxations for Intractable Optimization Problems

Room: **Room 271** (16:30 - 18:30) Chair: *Ali Mohammad Nezhad*

1. Iterative LP and SOCP-based approximations to semidefinite programs

Georgina Hall[1,*], *Amir Ali Ahmadi*

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We develop techniques for approximating SDPs with LPs and SOCPs. Our algorithms iteratively grow an inner approximation to the PSD cone using a column generation scheme and/or a change of basis scheme involving Cholesky decompositions.

2. Linear, Conic, and Non-Convex Formulations of the High Contrast Imaging Problem

Robert Vanderbei[1,*]

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The are many possible formulations of high-contrast imaging problems. The most natural ones are nonconvex optimization problems. But, some good approximations can be employed to convert these problems to conic or even linear optimization problems. In this talk, I will present the various formulations along with some computational comparisons.

3. On Disjunctive Conic Cuts: When they exist, when they cut?

Mohammad Shahabsafa[1,*]

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The development of Disjunctive Conic Cuts (DCCs) for MISOCO problems has recently gained significant interest in the optimization community. Identification of cases when DCCs are not existing, or not useful, saves computational time. In this study, we explore cases where either the DCC methodology does not derive a DCC which is cutting off the feasible region, or a DCC does not exist. Additionally, we work on extending the DCCs to other conic optimization problems such as Mixed Integer p-order Cone Optimization and Mixed Integer Semidefinite Optimization.

4. Semidefinite Programming for Nash Equilibria in Bimatrix Games

Jeff Zhang[1,*], *Amir Ali Ahmadi*[1]

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We explore the problem of finding an additive approximate Nash Equilibrium for bimatrix games with the use of a series of SDP relaxations. We begin with an SDP relaxation of the standard Nash problem, and introduce a set of valid matrix inequalities to improve upon it. We explore the properties of the resulting SDP, give heuristics, and provide bounds on its performance. We also present a hierarchy of SDPs which address NP-hard quantities associated with Nash Equilibria. Finally we create algorithms based on the SDP by applying a number of iterative linearization procedures.

■ Recent Advances in First-Order Methods and Applications in Network Estimation

Room: **Room 085** (09:45 - 11:15) Chair: *Niao He*

1. Large Gaps Between Cyclic and Randomized Algorithms

Ruoyu Sun[1,*], *Yinyu Ye*[2], *Zhi-Quan Luo*[3]

[1]Stanford & Facebook; [*]sundirac@gmail.com;[2]Stanford University;[3]University of Minnesota;

A simple yet powerful idea for solving large-scale computational problems is to iteratively solve smaller subproblems. The applications of this idea include Gauss-Seidel (G-S), Kaczmarz, coordinate descent (CD), and ADMM. We show that for all these methods, there are large gaps between the deterministic cyclic versions and the randomized versions.
In particular, first we show that the cyclic CD/Kaczmarz/G-S can be $O(n^2)$ times slower than their randomized counterparts. Such a huge gap has been noticed in existing theoretical results, but was not observed in practice and thus considered to be a theoretical artifact. We construct an example to show that this gap indeed exists and establish the worst-case complexity of these methods.
Second we show a gap between divergence and convergence for ADMM. In particular, although cyclic multi-block ADMM was recently found to be possibly divergent, we show that RP-ADMM (randomly permuted ADMM) converges in expectation for solving linear systems.

2. Network topology inference from spectral templates

Gonzalo Mateos Buckstein[1,*], *Santiago Segarra*[2], *Antonio G. Marques*[3], *Alejandro Ribeiro*[2]

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Network topology inference is a cornerstone problem in statistical analyses of complex systems. In this context, the fresh look advocated here permeates benefits from convex optimization and graph signal processing, to identify the so-termed graph shift operator (encoding the network topology) given only the eigenvectors of the shift. These spectral templates can be obtained, for example, from principal component analysis of a set of graph signals defined on the particular network. The novel idea is to find a graph shift that while being consistent with the provided spectral information, it endows the network structure with certain desired properties such as sparsity. To that end we develop efficient inference algorithms stemming from provably-tight convex relaxations of natural nonconvex criteria suited for two particular shifts, namely the adjacency matrix and the normalized graph Laplacian. We initially propose algorithms along with theoretical performance guarantees for the case when the eigenbasis is perfectly known as well as when only an imperfect (noisy) version of it is available. We then investigate the challenging setting where only a subset of the eigenvectors is given, which is often encountered when dealing with bandlimited graph signals. Application domains include network topology identification from steady-state signals generated by a diffusion process, and design of a graph filter that facilitates the distributed implementation of a prescribed linear network operator. Numerical tests showcase the effectiveness of the proposed algorithms in recovering synthetic graphs as well as social and structural brain networks.

3. Fast and Simple Optimization for Poisson Likelihood Models

Niao He[1,*]

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Poisson likelihood models have been prevalently used in imaging, social networks, and time series analysis. We propose fast, simple, theoretically-grounded, and versatile, optimization algorithms for Poisson likelihood modeling. The Poisson log-likelihood is concave but *not Lipschitz-continuous*. Since almost all gradient-based optimization algorithms rely on Lipschitz-continuity, optimizing Poisson likelihood models with a guarantee of convergence can be challenging, especially for large-scale problems.
We present a new perspective allowing to efficiently optimize a wide range of penalized Poisson likelihood objectives. We show that an appropriate saddle point reformulation enjoys a favorable geometry and a smooth structure. Therefore, we can design a new gradient-based optimization algorithm with $O(1/t)$ convergence rate, in contrast to the usual $O(1/\sqrt{t})$ rate of non-smooth minimization alternatives. Furthermore, in order to tackle problems with large samples, we also develop a randomized block-decomposition variant that enjoys the same convergence rate yet more efficient iteration cost.
Experimental results on several point process applications including social network estimation and temporal recommendation show that the proposed algorithm and its randomized block variant outperform existing methods both on synthetic and real-world datasets.

■ Machine Learning

Room: **Room 091** (09:45 - 11:15) Chair: *Afshin oroojlooy*

1. Deep Learning for Newsvendors

Afshin oroojlooy[1,*], *Lawrence Snyder*[1], *Martin Takac*[1]

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We study a newsvendor problem in which each demand observation also has a set of features. We propose an algorithm based on deep learning that optimizes the order quantity based on the features. It integrates the forecasting and inventory-optimization steps, rather than solving them separately. The algorithm does not require probability distributions. Numerical experiments on real-world data suggest that our algorithm outperforms approaches from the literature, including data-driven and SVM approaches, especially for volatile demands.

2. A Deep Learning Model to Predict Stockouts in Multi-Echelon Inventory Systems

Afshin oroojlooy[1,*], *Lawrence Snyder*[1], *Martin Takac*[1]

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We introduce a model to predict stockouts in a multi-echelon inventory system based on a snapshot of the current system state. Our algorithm is based on deep learning and does not require probability distributions. We tested our algorithm on simulated inventory systems with various topologies (tree, serial, and general networks) and find that our model is able to predict stockouts with an accuracy of approximately 94%, on average.

3. Machine Learning For Predicting Heart Failure Readmission

Wei Jiang[1,*]

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Predicting risk of heart failure (HF) readmission has gained increasing attention, with existing studies mainly using administrative data. We will focus on using clinical data from EMR for predicting HF readmission by doing pattern recognition with time series clinical data. We will then use classification models for predicting the drivers of readmission.

■ Convexification Techniques in Mixed-Integer Programming

Room: **Room 184** (09:45 - 11:15) Chair: *Sercan Yildiz*

1. Centerpoints: A link between optimization and convex geometry

Amitabh Basu[1,*], *Timm Oertel*

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We introduce a concept that generalizes several different notions of a "centerpoint" in the literature. We develop an oracle-based algorithm for convex mixed-integer optimization based on centerpoints. Further, we show that algorithms based on centerpoints are "best possible" in a certain sense. Motivated by this, we establish several structural results about this concept and provide efficient algorithms for computing these points.

2. On Some Polytopes Contained in the 0,1 Hypercube that Have a Small Chvátal Rank

Dabeen Lee[1,*], *Gerard Cornuejols*[1]

[1]Carnegie Mellon University; *dabeenl@andrew.cmu.edu;

In this talk, we provide conditions on the set of infeasible 0,1 vectors that guarantee that P has a small Chvatal rank. Our conditions are in terms of the subgraph induced by these infeasible 0,1 vertices in the skeleton graph of the unit hypercube. In particular, we show that when this subgraph contains no 4-cycle, the Chvatal rank is at most 3; and when it has tree width 2, the Chvatal rank is at most 4. We also give polyhedral decomposition theorems when this graph has a vertex cutset of size one or two. We also show that optimizing a linear function over the set of the feasible integer solutions is polynomially solvable when the Chvatal rank of a canonical polytope for the set of feasible integer solutions is constant.

3. Low-Complexity Relaxations and Convex Hulls of Disjunctions on the Positive Semidefinite Cone and General Regular Cones

Sercan Yildiz[1,*], *Fatma Kilinc-Karzan*[2]

[1]Statistical and Applied Mathematical Sciences Institute; *syildiz@andrew.cmu.edu;[2]Carnegie Mellon University;

This talk concerns two-term disjunctions on a regular cone K. The resulting disjunctive sets provide fundamental non-convex relaxations for mixed-integer conic programs. We develop a family of structured convex valid inequalities for a set of this form. Under mild assumptions on the choice of disjunction, these inequalities together characterize the closed convex hull of the disjunctive set in the original space, and if additional conditions are satisfied, a single inequality from this family is enough for a closed convex hull description. In the case where K is the positive semidefinite cone or a direct product of second-order cones and a nonnegative orthant, we show that these inequalities can be represented in an appropriate conic form for certain disjunctions. For more general disjunctions, we present tight conic relaxations.

■ Optimization in Energy II

Room: **Room 271** (09:45 - 11:15) Chair: *Boris Defourny*

1. Using Market Information to Imply Link Failure Probabilities

Xiameng Hua[1,*], *Boris Defourny*[1]

[1]Lehigh University ISE; *xiameng.hua@lehigh.edu;

A model is proposed to derive failure rates of transmission lines in the electricity power grid from electricity derivatives market prices, for the purpose of calibrating stochastic decision-making models without delving into the engineering details of the physical power grid.

2. Stochastic Optimal Power Flow with Forecast Errors and Failures in Communication

Basel Alnajjab[1,*], *Alberto Lamadrid*[2], *Rick S Blum*[1], *Lawrence V. Snyder*[2], *Shalinee Kishore*[1]

[1]Lehigh University, Department of Electrical and Computer Engineering; *balnajjab@gmail.com;[2]Lehigh University, Department of Economics;[2]Lehigh University, Department of Industrial and Systems Engineering;

The role of communication networks in supporting the operation and control of power grids will become increasingly more critical as we continue to integrate renewable energy sources, which tend to be stochastic and intermittent in nature, into power grids, since communication networks are employed to continually update system operators about the status of generators and loads in the system. We present a stochastic optimal power flow formulation in which we account for errors in forecasting future load and renewable generation while also considering random failures in the communication network employed to communicate the realized values of the quantities for which we have forecasts. The communication network is also assumed to be employed for the control of loads and generators in the power system. Thus, a failure in the communication between the grid operator and a certain entity in the power gird will also result in the loss of the controllability of any such entity. We present results comparing different topologies for the communication network as well as different strategies for decisions under lost communications. Computational analysis is carried out for a standard IEEE test instance.

3. Self-enforcing Pricing Scheme for Load Aggregators

Alberto J. Lamadrid[1,*], *Kwami Senam Sedzro*[1], *Mooi Choo Chuah*[1]

[1]Lehigh University; *ajlamadrid@lehigh.edu;

We analyze a novel electricity retail pricing scheme. This scheme is designed so that a threshold band envelops a negotiated reference consumption profile. We consider a cooperative group of customers pooling together their flexible loads and participating in the energy market via an aggregator. Consequently, customers can benefit by shifting their purchases from peak to off-peak periods when electricity prices are low, and helping to mitigate the uncertainty of wind generation. The aggregator computes an optimal daily profile taking into account the gross daily demand from the consumer group and the energy market's expected conditions and opportunities, and assigns prices and rate zones accordingly. The consumer group reacts by deferring and curtailing the flexible loads in order to minimize their daily cost consisting of the energy bill, the utility cost and the curtailment reward. This paper compares the effects of two different rate structures, on the bills charged to customers. Using a 40-home aggregate energy profile, we show that consumers can match a test supply profile with 5% maximum error and 2% average error while TOU and RTP can lead respectively to 163% and 97% maximum error, and 37% and 25% average error.

■ Nonlinear Optimization: Algorithms, Theory, and Applications

Room: **Room 085** (13:30 - 15:00) Chair: *Mohammadreza Samadi*

1. A Polyhedral Study on Chance Constrained Program with Random Right-Hand Side

Bo Zeng[1,*]

[1]University of Pittsburgh; *bzeng@pitt.edu;

The essential structure of the mixed–integer programming formulation for chance–constrained program (CCP) with stochastic right–hand side is the intersection of multiple mixing sets with a 0-1 knapsack. In this study, we first present a family of strong inequalities that subsumes known facet-defining ones for the single mixing set. Then, we study lifting and superadditive lifting on knapsack cover inequalities, and provide an implementable procedure on deriving another family of strong inequalities for the single mixing set. Finally, different from the traditional approach that aggregates original constraints to investigate polyhedral implications due to their interactions, we propose a novel blending procedure that produces strong valid inequalities for CCP by integrating those derived from individual mixing sets. We show that, under certain conditions, they are the first type of facet-defining inequalities describing intersection of multiple mixing sets. In the computational experiments, we perform a systematic study and illustrate the efficacy of the proposed inequalities on solving chance constrained static probabilistic lot-sizing problems. This is a joint work with Ming Zhao (University of Houston) and Kai Huang (McMaster University).

2. A Geometry Driven Active-Set Method For Elastic-Net Minimization

Daniel P. Robinson[1,*]

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We propose an efficient and provably correct active-set based algorithm for solving the elastic net problem. The proposed algorithm exploits the fact that the nonzero entries of the elastic-net solution fall into an *oracle region*, which we use to define and efficiently update our active-set estimate. The proposed update rule leads to an iterative algorithm that is shown to converge to the optimal solution in a finite number of iterations. We present experiments for subspace clustering on computer vision datasets that demonstrate the superiority of our method in terms of clustering accuracy and scalability.

3. A Sequential Algorithm for Chance-Constrained Nonlinear Optimization

Frank E. Curtis[1,*], *Andeas Wachter*[2], *Victor Zavala*[3]

[1]Lehigh University; *frank.e.curtis@gmail.com
;[2]Northwestern University;[3]University of Wisconsin-Madison;

An algorithm is presented for solving chance-constrained nonlinear optimization problems. Designed for large-scale settings, the algorithm follows a penalty-SQP-type strategy by computing search directions through the minimization of piecewise-quadratic models of the objective function. Theoretical convergence results are proved and the results of numerical experiments are presented, which show that the algorithm efficiently yields nearly-globally-optimal solutions to challenging chance-constrained problems.

■ Robust and Bi-Level Optimization

Room: **Room 091** (13:30 - 15:00) Chair: *Juan S. Borrero*

1. Improving the Affine Policy in Two-Stage Adjustable Robust Linear Programming with Uncertain Right-Hand Side

Guanglin Xu[1,*], *Samuel Burer*[1]

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We study a two-stage adjustable robust linear programming minimization problem where the right-hand side is uncertain and belongs to a convex, compact uncertainty set. This problem is NP-hard, and the affine policy is a popular, tractable approximation. We propose a new class of upper bounds based on semidefinite programming and show that the new upper bounds are always at least as strong as the value of the affine policy. We also investigate several examples from the literature that demonstrate our bounds can significantly improve the affine-policy value.

2. Robust (Network) Optimization and Statistical Learning

Dimitri Papadimitriou[1,*]

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This paper deepens on the interplay between mathematical programming for solving robust network optimization problems and statistical (machine) learning models and methods. Indeed, machine learning shares deep connections with robust optimization as they both perform by characterizing uncertainty, introducing / accounting for uncertainty as part of the model specification (and its selection), formulating the optimization problem, and exploiting mathematical programming to solve it. On the one hand thus many machine learning problems (can be) reduce(d) to optimization problems such as training vs. generalization error minimization. On the other hand, machine learning finds also applicability at i) the uncertainty modeling level by automating the processing of noisy or aleatory input data to extract features when describing uncertainty in data using compact perturbation sets and by inferring the parameters governing the distributions from such data samples when uncertainty sets find a probabilistic description, ii) the formulation level by automating the production of robust formulation and the analysis of their properties but also by adapting decision rules associated to adjustable variables which depend on uncertain data, and iii) the computational level by exploiting their output but also learning about the behavior of resolution algorithm(s) and tune its execution with the aim of improving its performance. In this paper, we develop the corresponding procedures to illustrate these applications of statistical learning when formulating and solving the robust-counterpart of three important network optimization problems, namely the multicommodity network flow, the facility location and the hub location problem.

3. Sequential Max-Min Bilevel Linear Programming with Incomplete Information and Learning

Juan S. Borrero[1,*], *Oleg A. Prokopyev*[1], *Denis Saure*[2]

[1]University of Pittsburgh; *jsb81@pitt.edu;[2]Universidad de Chile;

We consider an adversarial bilevel problem where the leader and follower interact repeatedly. At each period the leader implements an upper-level solution after which the follower reacts by solving the lower-level problem. The leader has incomplete information about the variables, constraints, and data of the follower's problem, and learns about them from observing his reaction to her actions. Given that the leader's objective is to maximize the costs the follower incurs across all periods, we study a set of greedy and robust leader decision policies that are able to find an optimal solution to the full-information bilevel problem in finite time periods, and moreover, are worst-case optimal.

■ Meta-heuristic

Room: **Room 184** (13:30 - 15:00) Chair: *Francis Vasko and Yun Lu*

1. Application of Metaheuristic Algorithms to Structural Mechanics Problems

Y. Cengiz Toklu[1,*]

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Metaheuristic algorithms, which are introduced towards the end of the 20th century, have found many application areas for structural engineers. Being stochastic optimization techniques, they are very effective in finding best or nearly best solutions for structural design problems. In the literature one can see many applications on trusses, frames, grids and more complicated structural systems using various metaheuristic algorithms like genetic algorithms, simulated annealing, harmony search, big bang âĂŞ big crunch algorithm, ant colony optimization, etc. Besides complete systems, one can find also applications on design of reinforced concrete elements, steel cross sections, dampers etc.
Besides design applications, there are also applications on analysis of structures. In this area, optimization is applied on the total potential energy of the system, following the principle that the stable equilibrium position of a structural system corresponds to the configuration with minimum energy. This application gave way to the method called Total Potential Optimization using Metaheuristic Algorithms (TPO/MA) which is shown to be very efficient in solving nonlinear structural analysis problems.
The success of metaheuristic algorithms come from the fact that these algorithms are very versatile, they can be applied to continuous and discrete problems, they don't necessitate elaborate mathematical formulations, they can be applied to problems where the gradient is not defined, and they are very effective in tackling all types of constraints of the problems. Considering these advantages, it is not difficult to foresee that metaheuristic algorithms will be much more important in the future in structural design works and in analyzing structures.

2. The Euclidean Steiner Cable-Trench Problem

Dylan Gaspar and Eric Landquist[1,*]

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The Cable Trench Problem (CTP) is a spanning tree problem on a weighted graph that combines the Minimum Spanning Tree Problem and the Shortest Path Spanning Tree Problem. As its name suggests, the CTP is motivated by the problem of minimizing the cost to connect buildings on a campus to a hub housing the central server so that each building is connected directly to the server via a dedicated underground cable. The vertices of a graph represent buildings, edges represent the allowable routes for digging trenches and laying cables between two buildings, and edge weights represent distance. In this talk, we define a new and natural generalization of the CTP: the Euclidean Steiner CTP (ESCTP), which considers the case that the vertices correspond to points in 2-dimensional Euclidean space and allows for auxiliary points, called Steiner vertices, to be included in the graph. We will describe a heuristic for approximating optimal solutions to the ESCTP and will give preliminary results on the extent to which Euclidean CTP solutions can be improved with this mode

3. What is the Best Continuous Metaheuristic to Solve the Set covering Problem?

Francis Vasko[1,*], *Yun Lu*[1]

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Recently, a number of metaheuristics originally designed for solving continuous problems have been adapted to solve the Set covering Problem (SCP) which is a well-known discrete optimization problem. Many of these metaheuristics are bio-inspired and include Cat Swarm Optimization, Cuckoo Search, Bee colony, Firefly Optimization, Electromagnetism-Like, and Teaching-Learning Based optimization algorithms. In this talk we will discuss how these metaheuristics are adapted to solve the SCP and evaluate their performance on 65 SCPs from Beasley's OR library.

■ Applications of Optimization in Networked Control Systems – Part I

Room: **Room 271** (13:30 - 15:00) Chair: *Milad Siami*

1. Price-Based Control of Flow Networks

Shuo Han[1,*], *Ufuk Topcu*[2], *George J. Pappas*[1]

[1]University of Pennsylvania;
*hanshuo@seas.upenn.edu;[2]University of Texas at Austin;

In real-time ridesharing (e.g., Uber and Lyft), a common way to balance demand (passengers) and supply (drivers) is through pricing, which incentivizes drivers to relocate to regions with higher demand. Motivated by this, we consider flow networks in which the flows are controlled by nodal prices, and the cost is characterized by the total flow incurred. We adopt a proportional price control model, which assumes that the flow on each edge is proportional to the price difference between the connected nodes. We show that, although price-based control can balance any mismatch in supply and demand, it always yields a higher cost than direct control of the flows. Furthermore, for a number of special networks, we are able to give closed-form expressions for the gap in cost between direct and priced-based control. Finally, we present numerical studies on the differences between direct and price-based control for a realistic network.

2. Distributed Newton Method for Global Consensus Problem

Rasul Tutunov[1,*], *Rasul Tutunov*[2], *Haitham Bou Ammar*[3], *Ali Jadbabaie*[2]

[1]UPenn; *tutunov@seas.upenn.edu;[2]University of Pennsylvania;[3]Princeton University;

We propose a distributed second order method for general consensus. Our approach is the fastest in literature so-far as it outperforms state-of-the-art methods, including ADMM, by significant margins. This is achieved by exploiting the sparsity pattern of the dual Hessian and transforming the problem to a one of efficiently solving a sequence of symmetric diagonally dominant system of equations. We validate the above claim both theoretically and empirically. On the theory side, we prove that similar to exact Newton, our algorithm exhibits superlinear convergence within a neighborhood of the optimal solution. Empirically, we demonstrate the superiority of this new method on a variety of machine learning problems and show that our improvements arrive at low communication overhead between processors.

3. Resource Management for Wireless Sensor-Actuator Systems

Konstantinos Gatsis[1,*], *Alejandro Ribeiro*[1], *George Pappas*[1]

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Modern cyber-physical systems in, e.g, smart homes, building and industrial automation, or infrastructure monitoring, leverage wireless communication to spatially separate sensing and actuation. Wireless sensors collect measurements of the dynamical process of interest from various locations and transmit them wirelessly to controllers and actuators. To achieve desirable performance for the physical system and to overcome the inherent uncertainties of wireless communication, it is important to efficiently manage the available communication resources. This work focuses on the design of resource allocation mechanisms that adapt to the control requirements of the physical system and exploit wireless medium opportunities. Recent developments include management of transmit power resources, as well as mechanisms for sensor-actuator systems over shared wireless channels.

■ Nonlinear Optimization

Room: **Room 085** (16:30 - 18:00) Chair: *Janos D. Pinter*

1. How Difficult is Nonlinear Optimization? A Practical Solver Tuning Approach, with Illustrative Results

Janos D. Pinter[1,*]

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Nonlinear optimization (NLO) per definitionem covers a vast range of problems, from trivial to practically intractable. For this reason, it is impossible to offer "fully guaranteed" advice to NLO software users. This fact becomes apparent, when facing unusually hard and/or previously unexplored NLO challenges.
Here we propose a heuristic approach and suggest corresponding option settings for use with the Lipschitz Global Optimizer (LGO) solver suite. LGO serves for general âĂŞ global and local âĂŞ NLO. The LGO option settings proposed are directly related to the "expectably sufficient" computational effort to handle a broad range of NLO problems. These option settings are then evaluated experimentally, by solving a collection of widely used NLO test problems which are based on various real-world optimization applications and academic challenges. Our tests also include results for several well-known scalable optimization problems which are scientifically relevant and increasingly difficult as the size of the model-instances grows.
Based on our computational test results, it is possible to offer careful guidance to LGO users, and âĂŞ arguably, mutatis mutandis âĂŞ to users of other NLO software products with a similarly broad mandate. An additional practical benefit of our tests is that the aggregated results assist the quick evaluation and verification of NLO solver performance during software development.

2. A Bayesian Optimization Algorithm for Multi Information Source Optimization

Matthias Poloczek[1,*], *Peter I. Frazier*[1], *Jialei Wang*[1]

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In the multi-information source optimization problem we study complex optimization tasks arising for instance in engineering or the natural sciences, where our goal is to optimize a design specified by multiple parameters. In order to assess the true value of some design, we only have access to a variety of information sources, e.g., numerical simulations that employ models of the true objective function of varying complexity. These information sources are subject to model discrepancy, i.e. their internal model inherently deviates from reality. Note that our notion of model discrepancy goes considerably beyond typical noise that is common in multi-fidelity optimization: in our scenario information sources can be biased and are not required to form a hierarchy. Moreover, we do not require access to the true objective, which has severe implications for the machinery that can be applied to tackle the optimization problem. We present a novel algorithm that is based on a rigorous mathematical treatment of the uncertainties arising from the model discrepancies. Its optimization decisions rely on a stringent Bayesian value of information analysis that trades off the predicted benefit and its cost. Moreover, we present experimental evaluations that demonstrate that our method consistently outperforms other state-of-the-art techniques: it finds designs of considerably higher objective value and additionally inflicts less cost in the exploration process.

3. Optimized Ellipse Packings in Regular Polygons using Embedded Lagrange Multipliers

Ignacio Castillo[1,*], *Janos D. Pinter*[2], *Frank J. Kampas*[3]

[1]Wilfrid Laurier University; *icastillo@wlu.ca;[2]Pinter Consulting and Lehigh University;[3]Physicist at Large Consulting;

In this work we present model development and numerical solution approaches to the general problem of packing given collections of ellipses into an optimized regular polygon. Our modeling and solution strategy is based on the concept of embedded Lagrange multipliers. This concept should be applicable to a wide range of optimization problems in which explicit analytical expressions for the objective function and/or constraints are not available. Within this Lagrangian setting, we aim at optimizing the apothem (and thereby the area) of a regular polygon while preventing ellipse overlaps: we proceed simultaneously towards these two objectives. To solve the packing models, we use the LGO solver system for global-local nonlinear optimization, and (for larger model instances) a "naÃŕve" combination of pure random start and local search. The numerical results presented demonstrate the applicability of our modeling and optimization approach to a broad class of highly non-convex ellipse packing problems, by consistently providing high quality feasible solutions in all model instances considered.

■ Optimization and Machine Learning

Room: **Room 091** (16:30 - 18:00) Chair: *Hao Wang*

1. Matrix support functionals for inverse problems, regularization, and learning

Tim Hoheisel[1,*], *James V. Burke*[2]

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A new class of matrix support functionals is presented which establish a connection between optimal value functions for quadratic optimization problems, the matrix-fractional function, the pseudo matrix-fractional function, the nuclear norm, and multi-task learning. The support function is based on the graph of the product of a matrix with its transpose. Closed form expressions for the support functional and its subdifferential are derived. In particular, the support functional is shown to be continuously differentiable on the interior of its domain, and a formula for the derivative is given when it exists.

2. Feature-distributed sparse regression

Yuekai Sun[1,*]

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Most existing approach to distributed sparse regression assume the data is partitioned sample-wise. However, for high-dimensional data, it is often more natural to partition the data by features. We propose an approach to distributed sparse regression when the data is partitioned by features rather than samples. Our approach allows the user to tailor the approach to various distributed computing platforms by trading-off the total amount of data (in bits) sent over the communication network and the number of rounds of communication. We show that an implementation of our approach is capable of solving regression problems with millions of features in minutes.

3. When are nonconvex optimization problems not scary?

Ju Sun[1,*], *Qing Qu*[1], *John Wright*[1]

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General nonconvex optimization problems are NP-hard. In applied disciplines, however, nonconvex problems abound, and heuristic algorithms are often surprisingly effective. The ability of nonconvex heuristics to find high-quality solutions for practical problems remains largely mysterious.
In this talk, I will describe a family of nonconvex problems which can be solved efficiently. This family has the characteristic structure that (1) every local minimizer is also global, and (2) the objective function has a negative directional curvature around all saddle points ("ridable saddle"). Natural (nonconvex) formulations for a number of important problems in signal processing and machine learning lie in this family, including the eigenvector problem, complete dictionary learning (CDL), generalized phase retrieval (GPR), orthogonal tensor decomposition, and various synchronization problems. This benign geometric structure allows a number of optimization methods to efficiently find a global minimizer, without special initializations. To corroborate this, I will describe the second-order trust-region method. This geometric approach to solving nonconvex problems has led to new computational guarantees for several practical problems, such as CDL and GPR.
To complete and enrich the framework is an ongoing research effort. I will highlight challenges from both theoretical and algorithmic sides. An overview article on this is available online:
http://arxiv.org/abs/1510.06096;
see also my PhD thesis http://sunju.org/pub/docs/thesis.pdf for details.

■ Conic Optimization

Room: **Room 184** (16:30 - 18:00) Chair: *Ali Mohammad Nezhad*

1. A Subgradient Method for Solving General Convex Optimization Problems

James Renegar[1,*]

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An algorithm is presented for solving convex optimization problems generally, the main requirement being that a strictly-feasible point is known. A feasible sequence of iterates is generated, which converges to within user-specified error of optimality. Feasibility is maintained with only a line-search at each iteration, avoiding the need for orthogonal projections onto the feasible region (the operation that makes traditional subgradient methods practical only for highly-structured problems). Lipschitz continuity is not required, and yet the algorithm is shown to possess a convergence rate analogous to those for traditional methods, albeit with error measured relatively, whereas traditionally error has been absolute. The algorithm is derived using an elementary framework that can be utilized to design other such algorithms.

2. Solving Conic Systems via Projection and Rescaling

Javier Pena[1,*], *Negar Soheili*

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We propose a simple *projection and rescaling algorithm* to solve the feasibility problem find $x \in L \cap \Omega$,
where L and Ω are respectively a linear subspace and the interior of a symmetric cone in a finite-dimensional vector space V.
This projection and rescaling algorithm is inspired by previous work on rescaled versions of the perceptron algorithm and by Chubanov's projection-based method for linear feasibility problems. As in these predecessors, each main iteration of our algorithm contains two steps: a *basic procedure* and a *rescaling* step. When $L \cap \Omega \neq \emptyset$, the projection and rescaling algorithm finds a point $x \in L \cap \Omega$ in at most $(\log(1/\delta(L \cap \Omega)))$ iterations, where $\delta(L \cap \Omega) \in (0, 1]$ is a measure of the most interior point in $L \cap \Omega$. The ideal value $\delta(L \cap \Omega) = 1$ is attained when $L \cap \Omega$ contains the center of the symmetric cone Ω.
We describe several possible implementations for the basic procedure including a perceptron scheme and a smooth perceptron scheme. The perceptron scheme requires $O(r^4)$ perceptron updates and the smooth perceptron scheme requires $O(r^2)$ smooth perceptron updates, where r stands for the Jordan algebra rank of V.

3. Dimension reduction for semidefinite programs via Jordan algebras

Frank Permenter[1,*], *Pablo Parrilo*

[1]Electrical Engineering and Computer Science, Massachusetts Institute of Technology; [*]fperment@mit.edu;

We propose a new method for simplifying semidefinite programs inspired by symmetry reduction. Specifically, we show if a projection satisfies certain invariance conditions, restricting to its range yields an equivalent primal-dual pair over a lower-dimensional symmetric cone—namely, the cone-of-squares of a Jordan subalgebra of symmetric matrices. We then give a simple algorithm for minimizing the rank of this projection and hence the dimension of this cone. Finally, we explore connections with *-algebra-based reduction methods, which, along with symmetry reduction, can be seen as special cases of our method.

■ The Application of Optimization in Structural Design Problems

Room: **Room 271** (16:30 - 18:00) Chair: *Mohammad Shahabsafa*

1. Composite Structural Optimization with MISOCO

Sicheng He[1,*], *John Hwang*[1], *Joaquim R.R.A Martins*[1], *Mohammad Shahabsafa*[2], *Ali Mohammad Nezhad*[2], *Luis Zuluaga*[2], *Tamas Terlaky*[2]

[1]University of Michigan; *hschsc@umich.edu;[2]Lehigh University;

The composite material is widely used in aircraft structure. In academia, researchers have studied structural weight minimization with stress constraint problem with discrete choice variables for material or orientation selection. Such problem has been modeled with MINLP and solved with general NLP with techniques to penalize the fractional solution for integral variables. In our study, we found the continuous relaxation of such problem actually can be constructed as SOCP which can be efficiently solved by commercial software like Gurobi. We will present one model with MISOCP and a heuristic model with SOCP.

2. Design of composite systems for wear performance using topology optimization

Xiu Jia[1,*], *Mark Sidebottom*[1], *Brandon Krick*[1], *Natasha Vermaak*[1]

[1]Department of Mechanical Engineering and Mechanics, Lehigh University; *xij214@lehigh.edu;

As the demand for low wear materials grows so does the need for accurate, fast, and efficient wear predictions. A great deal of attention has been given to predicting the topographical evolution of a wear surface, which involves applying physics-based models that relate geometry, pressure, and material wear properties for a given configuration of materials. A new continuous formulation for rotary wear systems has been derived that substantially simplifies computation compared to traditional iterative methods. With the steady-state solution directly determined from known material distributions, time-independent shape optimization is applied to improve the wear performance of bi-material composites. Various wear objectives, such as target steady-state equivalent wear rates and surface roughness are investigated.

3. Towards optimal elastoplastic design with shakedown bounds

Mathilde Boissier[1,*], *Mathilde Boissier*[1], *Georgios Michailidis*[2], *Natasha Vermaak*[1]

[1]Department of Mechanical Engineering and Mechanics, Lehigh University; *mab916@lehigh.edu;[2]SIMaP-UniversitÃľ de Grenoble, INPG;

In many cyclic structural design problems elastoplastic behaviors provide critical constraint, and structural response is limited to the elastic domain. However, designing beyond the elastic limit and allowing shakedown (a safe elastoplastic response) can provide significant robustness, loading domain, and weight benefits. While elasticity in structural topology optimization is well developed (introducing partial-differential equation constraints), elastoplastic behaviors remain a challenge. Shakedown involves inelastic stresses that don't result from a partial-differential equation, complicating the constraints. The work presented here proposes a formulation for shape optimization under shakedown constraints using level-set methods.

■ Stochastic models in resource allocation

Room: **Room 085** (09:45 - 11:15) Chair: *Sasha Stolyar*

1. Robust control of flexible processing networks

Yuan Zhong[1,*], *Ramtin Pedarsani*[2], *Jean Walrand*[2], *Yuan Zhong*[1]

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We consider general flexible processing networks, motivated by applications in cloud computing, manufacturing, and healthcare, in which jobs have complex structures, and servers are flexible with overlapping capabilities. A major challenge in designing efficient scheduling policies is the lack of reliable estimates of system parameters. We propose a general framework for the design of robust policies, that does not depend on system parameters. We illustrate our approach in two classes of processing systems and and analyze the performance properties of the proposed policies.

2. A queueing system with on-demand servers: local stability of fluid limits

Lam Nguyen[1,*], *Lam Nguyen*[1], *Alexander Stolyar*[1]

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We study a system, where a random flow of customers is served by servers (called agents) invited on-demand. Each invited agent arrives into the system after a random time, and leaves it with some fixed probability after each service completion. Customers and/or agents may be impatient, that is, while waiting in queue, they leave the system at a certain rate (which may be zero). We consider the queue-length-based feedback scheme, which controls the number of pending agent invitations, depending on the customer and agent queue lengths and their changes. The basic objective is to minimize both customer and agent waiting times.
We establish the system process fluid limits in the asymptotic regime where the customer arrival rate goes to infinity. We use the machinery of switched linear systems and common quadratic Lyapunov function to approach the stability of fluid limits at the desired equilibrium point, and derive a variety of sufficient local stability conditions. For our model, we conjecture that local stability is in fact sufficient for global stability of fluid limits; the validity of this conjecture is supported by numerical and simulation experiments. When local stability conditions hold, simulations show good overall performance of the scheme.

3. Optimal Control of General Dynamic Matching System

Mohammadreza Nazari[1,*], *Alexander L. Stolyar*[1]

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Consider a system with random arrivals of items of multiple types. There is a finite number of possible matchings, each being a subset of item types. Each matching has associated fixed "reward", and matched items leave the system. We propose a matching algorithm and prove its asymptotic optimality in the sense of maximizing the long-term average reward, while keeping the item queues stable. This algorithm applies an extended version of the greedy primal-dual (GPD) algorithm to a virtual system, which allows negative item queues.

■ Parallel Optimization and Machine Learning

Room: **Room 091** (09:45 - 11:15) Chair: *Cho Cho-Jui Hsieh*

1. On Convergence of Model Parallel Proximal Gradient Algorithm for Stale Synchronous Parallel System

Yaoliang Yu[1,*], *Yi Zhou*[2], *Wei Dai*[3], *Yingbin Liang*[2], *Eric P. Xing*[3]

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With ever growing data volume and model size, an error-tolerant, communication efficient, yet versatile parallel algorithm has become a vital part for the success of many large-scale applications. In this work we propose mspg, an extension of the flexible proximal gradient algorithm to the model parallel and stale synchronous setting. The worker machines of mspg operate asynchronously as long as they are not too far apart, and they communicate efficiently through a dedicated parameter server. Theoretically, we provide a rigorous analysis of the various convergence properties of mspg, and a salient feature of our analysis is its seamless generality that allows both nonsmooth and nonconvex functions. Under mild conditions, we prove the whole iterate sequence of mspg converges to a critical point (which is optimal under convexity assumptions). We further provide an economical implementation of mspg, completely bypassing the need of keeping a local full model. We confirm our theoretical findings through numerical experiments.

2. Limited-memory Common-directions Algorithm for Parallel/Distributed Optimization and its Application on Regularized Empirical Risk Minimization

Ching-pei Lee[1,*], *Po-Wei Wang*[2], *Weizhu Chen*[3], *Chih-Jen Lin*[4]

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Distributed optimization has become an important research topic for dealing with extremely large volume of data available in the Internet companies nowadays. Additional machines may make computation less expensive. However, inter-machine communication becomes prominent in the optimization process, and efficient optimization methods should reduce the amount and the rounds of communication to facilitate the training procedure. In this work, we absorb the advantages of both the recently proposed, theoretically fast-convergent common-directions method, and the spatially and computationally low-cost limited-memory BFGS algorithm to propose an efficient, linear-convergent optimization method for parallel/distributed optimization. We further discuss how our method can utilize the special problem struture to efficiently train regularized empirical risk minimization (ERM) models. Experimental results show that our method outperforms state-of-the-art distributed methods for ERM problems.

3. Exploiting Primal and Dual Sparsity for Extreme Classification

Ian En-Hsu Yen[1,*], *Xiangru Huang*[2], *Kai Zhong*[2], *Pradeep Ravikumar*[2], *Inderjit S. Dhillon*[2]

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In this talk, we discuss how Extreme Multiclass and Multilabel Classification problems enjoy better sparsity in both primal and dual compared to traditional binary classification problem, and how this affects our algorithmic choice, which leads to a per-iteration complexity sublinear to the number of both primal and dual variables. Our experiment on several benchmark data sets shows that, by exploiting sparsity inherent to the problem, a simple convex optimization algorithm gives better accuracy than other state-of-the-art extreme classification methods and can be orders-of-magnitude faster than standard one-versus-all and Multiclass SVM.

■ Conic Optimization

Room: **Room 184** (09:45 - 11:15) Chair: *David Papp*

1. Polynomial optimization with sum-of-squares interpolants

David Papp[1,*]

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One of the most common tools in polynomial optimization is the approximation of the cone of nonnegative polynomials with the cone of sum-of-squares polynomials. While deciding membership in the first cone is NP-hard, the latter cone is semidefinite representable.
Solving the semidefinite programs (SDPs) arising this way is practically very challenging if the polynomials involved are of high degree. One difficulty is that the number of decision variables in the SDP is roughly the square of the number of original decision variables. Additionally, serious numerical difficulties arise from the ill-conditioning of the SDP representation of sum-of-squares polynomials.
This talk will focus on the second, numerical, issue. We show that a reformulation of the sum-of-squares SDP using polynomial interpolants yields a substantial improvement over the standard formulation, and problems involving sum-of-squares interpolants of hundreds of degrees can be handled without difficulty by every commonly used semidefinite programming solver, such as SeDuMi, SDPT3, and CSDP. Numerical results align with the theoretical predictions; in all problems considered, available memory is the only factor limiting the degrees of polynomials.

2. A rounding procedure for a maximally complementary solution of second-order conic optimization

Ali Mohammad Nezhad[1,*], *Tamas Terlaky*[1]

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The concept of optimal partition was originally introduced for linear optimization, and later the concept was extended to second-order conic optimization. In this paper, we present a rounding procedure, which uses optimal partition information to generate a pair of maximally complementary optimal solutions. The rounding procedure starts from a strictly interior solution, close to the optimal set. It either gives an exact maximally complementary optimal solution in strongly polynomial time, or provides a fast iterative procedure to approximate a maximally complementary optimal solution.âĂÍ

3. Effects of Disjunctive Conic Cuts within a Branch and Conic Cut Algorithm to Solve Asset Allocation Problems

Sertalp Cay[1,*], *Julio C. Goez*[2], *Tamas Terlaky*[1]

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Recently, Mixed Integer Second Order Cone Optimization (MISOCO) has gained attention. This interest has been driven by the availability of efficient and mature methods to solve second order cone optimization (SOCO) problems and the wide range of applications of MISOCO. Financial optimization is an important application of MISOCO, where the variants of Markowitz' classical mean-variance portfolio optimization problem leads to MISOCO problems. In this work we show that the recently developed methodology of Disjunctive Conic Cuts (DCC) and Disjunctive Cylindrical Cuts (DCyC) provides a powerful tool to solve variations of portfolio problems. Our aim is to contribute to narrowing the gap between theoretical developments and practical implementation. We analyze the effect of these cuts on portfolio optimization problems within a Branch and Conic Cut (BCC) framework. The proposed methodology shows that DCCs and DCyCs are effective in practical settings.

■ Power Flow and Renewable Energy

Room: **Room 271** (09:45 - 11:15) Chair: *Luis Zuluaga*

1. A Game-Theoretic Framework for Resilient and Distributed Generation Control of Renewable Energies in Microgrids

Quanyan Zhu[1,*]

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The integration of microgrids that depend on the renewable distributed energy resources with the current power systems is a critical issue in the smart grid. In this paper, we propose a non-cooperative game-theoretic framework to study the strategic behavior of distributed microgrids that generate re- newable energies and characterize the power generation solutions by using the Nash equilibrium concept. Our framework not only incorporates economic factors, but also takes into account the stability and efficiency of the micriogrids, including the power flow constraints and voltage angle regulations. We develop two decentralized update schemes for microgrids, and show their convergence to a unique Nash equilibrium. Also, we propose a novel fully distributed PMU-enabled algorithm which only needs the information of voltage angle at the bus. To show the resiliency of the distributed algorithm, we introduce two failure models of the smart grid. Case studies based on the IEEE 9-bus system are used to corroborate the effectiveness and resiliency of the proposed algorithms.

2. Power System State Estimation with Line Measurements

Yu Zhang[1,*], *Ramtin Madani*[1], *Javad Lavaei*[1]

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This talk deals with the non-convex power flow (PF) and power system state estimation (PSSE) problems. The objective of these two problems is to obtain the state of the system from a set of noiseless and noisy measurements, respectively. We assume that at least two groups of measurements are available: (i) nodal voltage magnitudes, (ii) branch active power flows over a spanning tree of the network. We cast the PF problem as a minimization problem by adding a suitable objective. The semidefinite programming (SDP) and second-order cone programming (SOCP) relaxations are then used to cope with its inherent non-convexity. It is shown that both SDP and SOCP relaxations recover the true solution of the PF problem as long as the voltage angle difference across each line of the network is not too large. By capitalizing on this result, a penalized SDP is designed to solve PSSE. Strong theoretical results are derived to quantify the optimal solution of the penalized SDP, which is shown to possess a dominant rank-one component formed by lifting the true voltage vector. An upper bound on the estimation error is also derived as a function of the noise power. By leveraging the underlying sparsity of the network, the complexity of the penalized SDP problem is reduced for large-scale power systems. Numerical results on benchmark systems corroborate the merits of the proposed convexification framework.

3. Electric Vehicles as Grid Resources

Mushfiqur Sarker[1,*], *Mushfiqur Sarker*[2], *Miguel Ortega-Vazquez*[2]

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The global trend is aiming towards the transition of the transportation sector from internal combustion engine vehicles, which use gasoline for motion, to electric vehicles (EVs), which use electricity for motion. This is in part due to the benefits EVs provide to consumers, which include lower day-to-day operating costs along with the social benefits of being a stand-out technology. In addition to such benefits, EVs are poised as effective power grid resources due to their ability to charge and discharge energy from their batteries. Their widespread adoption, however, is hindered because of issues relating to range anxiety, slow charging times, lack of infrastructure, and upfront costs. This talk will focus on frameworks to optimally exploit EVs as grid resources in order to mitigate adoption issues.

■ Polynomial optimization and interior point methods

Room: **Room 085** (13:30 - 15:30) Chair: *Ali Mohammad Nezhad*

1. Non-Symmetric Interior Point Method In Non-Negative Polynomial And Moment Conic Optimization

Mohammad Mehdi Ranjbar[1,*], *Mohammad Mehdi Ranjbar, Farid Alizadeh*

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Moment conic optimization and it's dual single variable non-negative polynomial conic optimization have been investigated. Using the fact that Moment cone and single variable non-negative polynomial cone are semidfinite representable, these conic optimizations can be cast as semidfinite programming. Formulating these conic optimization as semidifnite programming, squares the number of variables in each block. Therefore time and memory us- age increases quadratically. Using recently developing non-symmetric interior point method, we can keep the number of variables unchanged. Furthermore, due to the nature of monomial basis, these problem in monomial basis are very ill-conditioned. Therefore orthogonal change of basis is proposed. The barrier functions of those cones are defined and non-symmetric homogeneous self-dual interior point method has been proposed. Lastly, numerical results and applications are shown.

2. Primal-Dual Interior-Point Methods with Domain-Driven Barriers.

Mehdi Karimi[1,*], *Levent Tuncel*[1]

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While primal-dual algorithms have yielded efficient solvers for convex optimization problems in conic form over symmetric cones, many other highly demanded convex optimization problems lack comparable solvers. To close this gap, we develop infeasible-start primal-dual interior-point algorithms for convex optimization problems. Our approach is "domain-driven" in the sense that we directly apply our techniques to the given "good" formulation without necessarily reformulating the given problem in a conic form. Moreover, our approach also naturally handles the cone constraints and hence the conic form. We introduce our Matlab-based code that solves a large class of problems including LP, SOCP, SDP, QCQP, Geometric programming, and Entropy programming among others, and mention some numerical challenges. We show numerical results to compare our code with some other well-known convex optimization solvers.

■ Applications of Optimization in Networked Control Systems – Part II

Room: **Room 184** (13:30 - 15:30) Chair: *Mirsaleh Bahavarnia*

1. An Optimization-based Approach to Decentralized Controllability

Alborz Alavian[1,*], *Michael Rotkowitz*[1]

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We discuss the controllability of linear time-invariant (LTI) systems with decentralized controllers. Whether an LTI system is controllable (by LTI controllers) with respect to a given information structure can be determined by testing for fixed modes, but this gives a binary answer with no information about robustness. Measures have been developed to further determine how far a system is from having a fixed mode, in particular the decentralized assignability measure of Vaz and Davison in 1988, but these measures cannot actually be computed in most cases. We thus seek a computable, non-binary measure of controllability for LTI systems with decentralized controllers of arbitrary information structure.
In this talk, we address this problem by utilizing modern optimization techniques to tackle the decentralized assignability measure. The main difficulties which have previously precluded its widespread use, are that it involves the minimization of the n-th singular value of a matrix, which must further be minimized over a power set of the subsystems. We show how the power set minimization can be cast as binary constraints, and then discuss methods for determining upper and lower bounds on the metric. In particular, an approach using the nuclear norm and the Alternating Direction Method of Multipliers (ADMM) is discussed for the upper bound, and an approach using sum-of-squares is discussed for the lower bound. These methods are shown to produce results which closely track the assignability measure across a variety of fixed mode types.
Embedded in this problem is the fundamental issue of how to minimize a particular singular value of a matrix variable; time permitting, we discuss some lessons learned for this more general problem as well.

2. On the Convexity of Optimal Decentralized Control Problem and Sparsity Path

Salar Fattahi[1,*], *Javad Lavaei*[1]

[1]University of California, Berkeley; [*]fattahi@berkeley.edu;

This talk is about an important special case of the optimal stochastic decentralized control problem, where the objective is to design a static structured controller for a stable stochastic system. We show that if either the noise covariance or the input weighting matrix is not too small, the problem is locally convex. In the case where these conditions are not satisfied, we modify the problem by a penalization term to convexify it, leading to a near-global solution. We also study the problem of designing a sparse controller using a regularization technique. Under some genericity assumptions, we prove that this method is able to design a controller with any arbitrary sparsity level.

3. $\mathcal{H}_2/\mathcal{H}_\infty$ Feedback Controller Sparsification Under Parametric Uncertainties

MirSaleh Bahavarnia[1,*], *Reza Arastoo*[2], *Mayuresh V. Kothare*[3], *Nader Motee*[1]

[1]Department of Mechanical Engineering and Mechanics, Packard Lab., Lehigh University, Bethlehem, PA.; [*]mirsaleh.bahavarnia@lehigh.edu;[2]Control Systems Engineer, Apple Inc.;[3]Department of Chemical and Biomolecular Engineering, Iaccoca Hall, Lehigh University, Bethlehem, PA.;

The problem of output feedback sparsification for systems with parametric uncertainties is considered. An optimization scheme is developed which minimizes the performance loss from that of a pre-designed well-performing centralized controller, while promoting sparsity pattern of the feedback controller. To enhance temporal proximity of the pre-designed control system and its sparsified counterpart, an extra constraint is also incorporated into the problem formulation such that the output of the controlled system is imposed to remain in the vicinity of the output of the pre-designed system. It is shown that the resulting non-convex optimization problem can be equivalently reformulated as a rank-constrained problem. Afterwards, a minimization problem is formulated along with a globally convergent algorithm to obtain a sub-optimal solution which satisfies the rank constraint with an arbitrary tolerance. Finally, a sub-optimal sparse controller synthesis for IEEE 39-bus New England power network is utilized to show the effectiveness of our proposed method.

■ Resource Allocation

Room: **Room 271** (13:30 - 15:30) Chair: *Miao Bai*

1. Reactive Surgery Rescheduling on the Day of Surgery

Miao Bai[1,*], *R.H. Storer*[1], *G.L. Tonkay*[1]

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Surgery schedules are subject to disruptions on the day of surgery due to random surgical durations, insufficient resource, unpunctual patients and emergency. We incorporate a sample-based gradient descent algorithm in a rescheduling strategy to make timely adjustment to alleviate the negative consequences of schedule disruptions. Our objective is to minimize the cost of patient waiting time, surgeon idle time, OR blocking time, OR overtime and post-anesthesia care unit (PACU) overtime in multiple operating rooms (OR) with PACU capacity constraints. Numerical results demonstrate the effectiveness of our method in reducing the overall cost on the day of surgery.

2. A Novel Technique for Scheduling of Pumps in Water Distribution Systems

Varghese Kurian[1,*], *Saravanan C*[1], *Sridharakumar Narasimhan*[1], *Shankar Narasimhan*[1]

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Operators of urban water distribution systems report that energy expenses for pumping water account for 25-30% of operating expenses. Hence, it is important to minimize energy consumption while meeting consumer demands at required pressures. The system we consider consists of pumps delivering water to different reservoirs in a network, with each reservoir catering to a time varying demand. Pumps and ON/OFF valves are used as manipulated variables to control the flow and pressure. The decision variables are the number of pumps to be turned on and the state of the valves in the network over a given horizon and the objective is to minimize energy consumption while meeting the time varying demand. Given the nonlinear nature of the pump operating curve and the hydraulics, this results in a Mixed Integer NonLinear Program (MINLP). We propose to solve this MINLP by decomposing it into series of sub-problems that can be solved efficiently. The first level of decomposition is to decouple the network simulation from the optimization. The network state is uniquely determined by the state of the pumps and valves. The state space is finite and hence, given a particular state, hydraulic simulation software such as EPANET is used to determine the energy consumption and flows and pressures in the entire network. This information is used to assign the different states to different time periods over the horizon. Given the potentially large number of states, this can be computationally intensive and therefore we further decompose the problem into two sequential sub-problems. In the first sub-problem, we ignore the time varying nature of demands and determine how long each state has to be active such that total consumption over the time horizon is met utilizing minimum energy. This is a standard Linear Program which can be solved efficiently using state of the art software. Moreover, only a small fraction of the initial states, equal to the number of reservoirs in the network is active. The next step is to arrive at an optimal schedule where each state is assigned to a time period within the time horizon. This results in an integer linear program of a much smaller size (as compared to the original problem) and hence can be solved efficiently. The technique was applied to a proposed network for a municipality in the state of Tamil Nadu, India. The system consisted of eight storage tanks and one pump delivering water from a single source. The developed schedule offered a 9.3 % reduction in energy in comparison to a schedule developed through heuristics and a 43% reduction in energy in comparison to the worst supply policy. The procedure was also used in scheduling the operations of a multi village scheme in the state of Maharashtra, India. In this network, the objective was to maximize the amount of water supplied in the given time. The results showed an 80% improvement in the amount of water supplied in comparison with the current schedule if the proposed schedule is implemented.

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