## ICSP 2023 Program Davis, CA, USA July 24-28, 2023

(Tutorials July 22-23)

The International Conference on Stochastic Programming (ICSP) is the premier event of the Stochastic Programming Society (SPS), a technical section of the Mathematical Optimization Society that brings together researchers who work on decisions under uncertainty and practitioners in the industrial and institutional sectors to share recent theoretical and applied results. The conference aims to present the state-of-the-art in this field and neighboring scientific areas. This year it will be held at UC Davis at the Conference Center and Gallagher Hall, which is home to the Graduate School of Management.

## Contents

Sponsors	3
General Information	4
Timeline	5
Tutorials	6
Excursions on Wednesday Afternoon	8
Special Issues	9
Memorial Session	10
Session Summary	11
Titles Summary	16
Monday	27
Tuesday	55
Wednesday	83
Thursday	94
Friday	124
Raw Keyword Index	137

## Sponsors

We would like to acknowledge the important support of the

- The Air Force Office of Sponsored Research
- The National Science Foundation:
  - The Statistics Program
  - The Humans, Disasters, and the Built Environment (HDBE) Program



TEXAS A&M UNIVERSITY Wm Michael Barnes '64 Department of Industrial & Systems Engineering





EURO Working Group on Stochastic Optimization (EWGSO)





Northwestern ENGINEERING Industrial Engineering and Management Sciences

## General Information

### Location

The conference will take place in the Conference Center and Gallagher Hall at UC Davis. These two buildings are side-byside. Coffee and snacks during breaks and first thing in the morning will be in Ghallager Hall. Lunches will be distributed in the Conference Center. All sessions and plenaries will take place in the Conference Center.

The welcome reception on Monday evening will take place at the Conference Center. The conference dinner will take place outdoors at the Good Life Garden near the Robert Mondavi Institute for Wine and Food Science building, which is about a five minute walk from the Conference Center, if you walk slowly.

## Check-in

Check in at the Conference Center during these times:

Sunday 14:00 to 17:00 Monday 7:30 to 10:00 Tuesday 7:30 to 10:00 Wednesday 8:00 to 9:00

If you arrive after registration has ended, contact Dave Woodruff, Conference Chair.

## Lunch

During the weekdays of the conference, registered participants will receive a box lunch each day except Wednesday. On Wednesday, only those participants who pre-registered to the Sonoma trip will receive lunch.

For the tutorials, although there will be some snacks available during breaks, lunch will not be provided on the weekend. You can get a door-dash delivery to the Conference Center at UC Davis (550 Alumni Lane) or you can go to downtown Davis. The closest restaurants take ten to fifteen minutes to walk to, so it would be possible to walk if it is not too hot.

## Dinner

Apart from the conference dinner, the evening meal is not provided as part of the conference. On nights other than Thursday night, participants can find numerous restaurants in Downtown Davis, which require a walk of between 10 and 20 minutes from the Conference Center.

## Weather

In late July in Davis it is usually hot and dry, but it typically cools off in the evening. The average high temperature is 93F and the average low is about 60. It can be over 100F during the day some days. It might become cool (but not cold) and perhaps breezy during the evening and, in particular, during the conference dinner. We will provide weather forecast updates during week.

### Wifi

If you have eduroam, you should be able to connect to that wifi network. If you don't have eduroam or have trouble connecting to it, then use the ucd-guest network. It will ask you for you name and email and then give you access.

### Dress Code

There is no dress code, but participants will probably want to wear casual clothing that is appropriate for hot, dry weather.

4

## Timeline

monday, July 24	
8:00 to 8:30	Coffee in Gallagher Hall
8:30 to 9:00	welcome
9:00 to 10:00	Keynote
10:00 to 10:30	Break in Gallagher Hall
10:30 to 12:20	mini-symposia
12:20 to 13:19	lunch
13:20 to $15:00$	sessions
15:00 to 15:20	Break in Gallagher Hall
15:20 to 17:10	mini-symposia
17:15 to 18:15	plenary
18:20 to 20:20	Reception at the Conference Center
Tuesday, July 25	
8:00 to 8:30	Coffee in Gallagher Hall
8:30 to 10:20	mini-symposia
10:20 to 10:40	Break in Gallagher Hall
10:40 to 11:40	plenary
11:40 to 12:39	lunch
12:40 to $14:30$	mini-symposia
14:30 to 14:50	Break in Gallagher Hall
14:50 to $16:40$	mini-symposia
16:50 to 18:05	Memorials
Wednesday, July 26	
8:00 to 8:30	Coffee in Gallagher Hall
8:30 to 9:30	plenary
9:30 to 9:50	Break in Gallagher Hall
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9:00 to 11:30	sessions
9:50 to 11:30 12:00 to 17:00	sessions Free Time
9:50 to 11:30 12:00 to 17:00 Thursday, July 27	sessions Free Time
9:50 to 11:30 12:00 to 17:00 Thursday, July 27 8:00 to 8:30	Sessions Free Time Coffee in Gallagher Hall
9:50 to 11:30 12:00 to 17:00 Thursday, July 27 8:00 to 8:30 8:30 to 9:30	sessions Free Time Coffee in Gallagher Hall plenary
9:30 to 11:30 12:00 to 17:00 Thursday, July 27 8:00 to 8:30 8:30 to 9:30 9:30 to 9:50	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   9:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:00 to 16:20	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:00 to 16:20   16:20 to 17:20	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:00 to 16:20   16:20 to 17:20   17:30 to 18:25	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary COSP Business Meeting
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:00 to 16:20   16:20 to 17:20   17:30 to 18:25   18:30 to 20:30	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary COSP Business Meeting Conference Dinner
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:20 to 17:20   17:30 to 18:25   18:30 to 20:30   Friday, July 28	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary COSP Business Meeting Conference Dinner
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:20 to 17:20   17:30 to 18:25   18:30 to 20:30   Friday, July 28   9:00 to 9:30	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary COSP Business Meeting Conference Dinner Coffee in Gallagher Hall
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:20 to 17:20   17:30 to 18:25   18:30 to 20:30   Friday, July 28   9:00 to 9:30   9:30 to 11:20	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary COSP Business Meeting Conference Dinner Coffee in Gallagher Hall mini-symposia
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:00 to 16:20   16:20 to 17:20   17:30 to 18:25   18:30 to 20:30   Friday, July 28   9:00 to 9:30   9:30 to 11:20   11:30 to 12:30	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary COSP Business Meeting Conference Dinner Coffee in Gallagher Hall mini-symposia Plenary (sponsored by Gurobi) and lunch
9:30 to 11:30   12:00 to 17:00   Thursday, July 27   8:00 to 8:30   8:30 to 9:30   9:30 to 9:50   9:50 to 11:30   11:30 to 12:19   12:20 to 14:00   14:10 to 16:00   16:00 to 16:20   16:20 to 17:20   17:30 to 18:25   18:30 to 20:30   Friday, July 28   9:00 to 9:30   9:30 to 11:20   11:30 to 12:30   12:30 to 13:00	sessions Free Time Coffee in Gallagher Hall plenary Break in Gallagher Hall sessions lunch sessions mini-symposia Break in Gallagher Hall plenary COSP Business Meeting Conference Dinner Coffee in Gallagher Hall mini-symposia Plenary (sponsored by Gurobi) and lunch Closing

#### 6

## Tutorials

The tutorials will take place in the Conference Center.

### Saturday, July 22: Distributed computing and decomposition methods

Organized by Jean-Paul Watson (LLNL) 8:30 a.m.: Coffee will be served 9:00 a.m.: Tutorial begins

1. Carl Laird (CMU): Performant Serial and Parallel NLP Algorithms in Python

Abstract: The scale of emerging applications for optimization in science and engineering are pushing the boundaries of computational performance with existing general solvers and serial numerical algorithms. For example, the COVID-19 pandemic has clearly exposed significant challenges in effective mitigation of emerging infectious diseases, and given the impact of spatio-temporal heterogeneities, we require tools for inference and decision-making that are computationally tractable on national-scale models. The first part of this tutorial will briefly discuss structural parallel approaches in large-scale nonlinear programming (NLP) problems based on linear algebra decomposition. The second part of the tutorial will focus on PyNumero, a Python package for implementation of nonlinear programming algorithms, and ParaPint, a Python-based interior-point approach for decomposition of structured NLPs.

- 2. Merve Bodur (Toronto): Benders decomposition based approaches in two-stage stochastic integer programming Abstract: Stochastic programming is a useful framework for dealing with uncertainty and integrality requirements in optimization problems. In this talk, we focus on two-stage stochastic integer programs (2SIPs), in particular their sample average approximations which yield computationally challenging mixed-integer programming (MIP) models. For various classes of 2SIPs, we review commonly used decomposition approaches (most notably logic-based Benders decomposition variants), and present some important enhancement strategies such as incorporation of general purpose cutting planes from the MIP literature. We also introduce several recently proposed techniques, such as the uses of (i) decision diagrams to convexify the second-stage problems, (ii) machine learning to learn the recourse value functions as well as cut selection/generation, and (iii) MIP-based methodology for scenario reduction. For the presented methods, we provide numerical results on problems from a variety of application domains.
- 3. Jonathan Eckstein (Rutgers): Operator Splitting, Progressive Hedging, and Distributed Computing Abstract: "Operator splitting" refers to a large family of decomposition methods for optimization problems. This tutorial will explain some basics of Douglas-Rachford (DR) splitting, a frequently used family of operator splitting methods. A frequent application of DR splitting is the alternating direction method of multipliers (ADMM). Applied to stochastic programming on a finite scenario tree, the ADMM leads to progressive hedging (PH), a relatively easily implemented algorithm that handles multistage problems in a simple, natural way. The tutorial will close by discussing how to implement PH in a distributed computing environment like today's high-performance computing (HPC) clusters, avoiding a central "controller" or "master" processor.
- 4. Break for Lunch
- 5. Vincent Leclere (ENPC): Trajectory Following Dynamic Programming Algorithms (a.k.a SDDP & Co)

Abstract: For multistage stochastic optimization Dynamic Programming (DP) is a way of leveraging some stage-wise independence to decompose a large T-stage problem into a succession of one-stage problems each minimizing current cost plus expected cost-to-go. Vanilla DP consists in approximating, backward in time, those expected cost-to-go (or value) function on a predetermined grid of the state space, showing a complexity linear in the number of stages T which is to be contrasted with the exponential number of node in a stochastic tree of depth T. On the other hand, DP fall to the curses of dimensionality with a complexity exponential in the state dimension. In this tutorial we present a class of Trajectory Following Dynamic Programming (TFDP) algorithm, which leverages some problem structure to iteratively refine approximations of the (expected) cost-to-go functions without needing a pre-determined state-grid. We will in particular cover the Stochastic Dual Dynamic Programming (SDDP) algorithm, which has been so successful in the energy community in the last 30 years, as well as some of this extensions (e.g. to risk averse or robust settings) and variants (like SLDP, MIDAS...).

6. Kibaek Kim (ANL): Computational Aspect for the Dual Decomposition of Stochastic Mixed-Integer Programming Abstract:This tutorial presents Lagrangian dual decomposition method and its algorithmic approaches that have been developed for solving stochastic mixed-integer programming problems with a finite number of scenarios. The dual decomposition is well-suited for distributed/parallel computing and poses several interesting challenges. In this tutorial, we first discuss the problem structures for which dual decomposition may be preferred to the well-known Benders

7

- 7. Cosmin Petra (LLNL) with Jingyi "Frank" Wang: Decomposition strategies and high-performance computing for continuous stochastic programming
  - Abstract: Stochastic programming (SP) problems have rich decomposition properties that makes them a natural candidate for massively parallel computations on high-performance computing (HPC) platforms. This tutorial will cover the mathematical, computational, and implementation basics of two salient decomposition strategies for scenario treebased stochastic programming problems with continuous variables. The first strategy fits under the umbrella of linear algebra-based decomposition that leverages the structure inherent in SP to parallelize the linear algebra operations (e.g., linear solves, matrix-matrix, and vector-vector operations, etc.) within a standard interior-point method. A second strategy is an optimization-based decomposition that uses nonsmooth SQP-like algorithms to optimize a so-called root optimization subproblem that comprises of the first-stage subproblem and surrogate(s) of the recourse functions obtained via parametric optimization of the second-stage subproblems. The tutorial will conclude with the discussion of the performance of the memory-distributed implementations of these strategies on the DOE's HPC platforms for the solution of SP problems arising in the optimization of operations of large-scale electric power grids.

#### Sunday, July 23: Contextual Stochastic Optimization / End-to-end Learning

Organized by Phebe Vayanos (USC) 8:30 a.m.: Coffee will be served 9:00 a.m.: Tutorial begins

- Paul Grigas (UC Berkeley)
- Güzin Bayraksan (Ohio State University)
- Bryan Wilder (CMU)
- Elias Khalil (University of Toronto)
- Hamsa Bastani (Wharton School, University of Pennsylvania)
- Erick Delage (HEC Montréal)

Tentative Schedule:

9:00 AM 9:45 AM	Erick Delage	Overview
9:45 AM 11:00 AM	Paul Grigas	Method
11:00 AM 11:30 AM		COFFEE BREAK
11:30 AM 12:30 PM	Bryan Wilder	Method
12:30 PM 1:30 PM		LUNCH
1:30 PM 2:15 PM	Erick Delage	Method
2:15 PM 3:15 PM	Güzin Bayraksan	Method
3:15  PM 4:00  PM	Hamsa Bastani	Applications on real data
4:00  PM 4:30  PM		COFFEE BREAK
4:30  PM 5:15  PM	Bryan Wilder	Applications on real data
5:15 PM 6:15 PM	Elias Khalil	Software tools

### Lunch

Although there will be some snacks available during breaks, lunch will not be provided during the tutorials. You can get a door-dash delivery to the Conference Center at UC Davis or you can go to downtown Davis. The closest restaurants take ten to fifteen minutes to walk to, so it would be possible to walk if it is not too hot. (During the weekdays of the conference, registered participants will receive a box lunch each day).

## Excursions

Traditionally during ICSP there have been excursions during the free time on Wednesday afternoon. There was an excursion options offered during registration, along with a "self-guided tour" option. If you selected the excursion to Sonoma, it will depart from the Conference Center and you will be provided with lunch.

If you did not select the excursion to Sonoma, you are on your own for the afternoon including lunch. Here are a few suggestions for what you could do, but you should do whatever you want to do.

- Consider buying a round-trip ticket on the Capitol Corridor train between Davis and Sacramento (www.amtrak.com or https://www.capitolcorridor.org/). After visiting the museum, you can return to Davis or go to a restaurant in the Old Sacramento area (https://www.oldsacramento.com/), which is where the railroad museum is located.
- Consider taking the 14:10 (or 12:10) train to San Francisco.
- There are number of micro-breweries in Davis and nearby.
- There are few wineries very near Davis and many more within an hours drive.
- Consider the Davis Farmers Market (https://www.davisfarmersmarket.org/) which is from 4pm to 8pm on Wednesday. One can purchase dinner there, among other things.

## **Special Issues**

There will be two special issues associated with the conference, one in *Mathematical Programming – Series B* and the other in *Computational Management Science*.

### Mathematical Programming – Series B

#### Stochastic Programming and Distributionally Robust Optimization with Decision-dependent Uncertainty

Stochastic programming (SP) and distributionally robust optimization (DRO) with decision-dependent, or endogenous, uncertainty constitute an important class of optimization problems that have numerous practical and industrial applications. In the decision-dependent uncertainty setting, (some of) the decision variables in the optimization problem affect the probability space of the stochastic variables, either by altering directly the probability distribution (probabilities, atoms, parameters of distribution, type of distribution, etc.) or by determining the time at which information and uncertainty unfolds. The coupling between decision and random variables poses substantial modeling and computational challenges, which may explain, to some extent, that the literature on such problems is fairly scant as compared to that devoted to SP and DRO problems with exogenous uncertainty. Moreover, existing SP and DRO problems with decision-dependent uncertainty are more often expectation-based, risk-neutral models.

This Mathematical Programming B special issue aims at addressing this gap in the literature and at enticing the SP and DRO community to devote more attention to this class of problems. The objective will be to review, assess, and chart future directions in SP and DRO problems with decision-dependent uncertainty. This special issue will include papers devoted to (exact or approximate) provably computationally efficient modeling, reformulation, and algorithmic methods, as well as to studies dealing with well-motivated and innovative applications where accounting for decision-dependent uncertainty in SP and DRO models is needed. Additionally, papers that have a relation with the primary theme of decision dependent uncertainty will also be considered for inclusion in the special issue.

The participants of the upcoming XVI International Conference Stochastic Programming in Davis, CA (July 24-28, 2023) are invited to submit their research presented at the Conference to this special issue. We will accept and process manuscripts submitted by people other than those attending and presenting at the XVI International Conference Stochastic Programming.

#### Guest Editors: Miguel Lejeune (managing guest editor); Pavlo Krokhmal; Ward Romeijnders

Stochastic programming (SP) and distributionally robust optimization (DRO) with decision-dependent, or endogenous, uncertainty constitute an important class of optimization problems that have numerous practical and industrial applications. In the decision-dependent uncertainty setting, (some of) the decision variables in the optimization problem affect the probability space of the stochastic variables, either by altering directly the probability distribution (probabilities, atoms, parameters of distribution, type of distribution, etc.) or by determining the time at which information and uncertainty unfolds. The coupling between decision and random variables poses substantial modeling and computational challenges, which may explain, to some extent, that the literature on such problems is fairly scant as compared to that devoted to SP and DRO problems with exogenous uncertainty. Moreover, existing SP and DRO problems with decision-dependent uncertainty are more often expectation-based, risk-neutral models.

The motivation of this special issue *Mathematical Programming B* is to address this gap in the literature and to entice the SP and DRO community to devote more attention to this class of problems. The objective will be to review, assess, and chart future directions in SP and DRO problems with decision-dependent uncertainty. This special issue will include papers devoted to (exact or approximate) provably computationally efficient modeling, reformulation, and algorithmic methods, as well as to studies dealing with well-motivated and innovative applications where accounting for decision-dependent uncertainty in SP and DRO models is needed. Additionally, papers that have a relation with the primary theme of decision dependent uncertainty will also be considered for inclusion in the special issue.

#### **Computational Management Science**

#### Optimization Under Uncertainty: Research Presented at ICSP 2023

#### Guest Editor: David L. Woodruff

This collection of papers is selected from the best papers presented at the International Conference on Stochastic Programming. The conference is the premier event of the Stochastic Programming Society (SPS), a technical section of the Mathematical Optimization Society that brings together researchers who work on decisions under uncertainty and practitioners in the industrial and institutional sectors to share recent theoretical and applied results. The papers in this special issue reflect the state-of-the art in optimization under uncertainty, with an eye toward computation. The paper submission website is: https://link.springer.com/collections/ijeejjabgb

9

## Memorial Session

In the early evening on Tuesday, July 25, we will have a memorial session. Len MacLean will make a 15-20 minute presentation about the life and work of Bill Ziemba; Stan Yuryasev will make a 15-20 minute presentation on the life and work of Yuri Ermoliev.

After that we will have shorter rememberances without slides. The exact length and format will depend on how many people would like to talk, but you could plan on 5 minutes. If you would like to speak during this portion of the Memorial Session, please send an email to DLWoodruff@UCDavis.edu. So far, the following people will talk: Andrzej Ruszczynski, and Suvrajeet Sen.

## Session Summary

Monday, July 24	
8:00 to 8:30	Coffee In Gallagher Hall
8:30 to 9:00	Welcome
9:00 to 10:00	David Morton Keynote
10:00 to $10:30$	Break In Gallagher Hall
10:30 to 12:20	Mini-symposia
Ballroom A	Student Paper Prize Sponsored by the EWGSO
Ballroom B	Climate Impacts on Power System Planning and Operations
Ballroom C	Stochastic programming in energy systems: modelling and algorithms
Meeting A	Advances of Stochastic Dominance Theory and Applications I
12:20 to 13:19	Lunch
13:20 to $15:00$	Sessions
Ballroom A	Energy and Grid Planning
Ballroom B	Integers and Dynamics
Ballroom C	Finance and Related Topics
Meeting A	Critical Applications and Algorithmic Developments
Meeting B	Operational Applications
15:00 to $15:20$	Break In Gallagher Hall
15:20 to 17:10	Mini-symposia
Ballroom A	Hydropower planning and scheduling: Practical experiences and methodology advances
Ballroom B	Wildfire Prevention and Infrastructure Adaptation
Ballroom C	Algorithms and models for the energy transition
Meeting A	Theory and Applications of Robust and Stochastic Optimization
Meeting B	Recent Advances in Decision-Making Under Uncertainty
17:15 to $18:15$	Michel De Lara Plenary
18:20 to 20:20	Reception At The Conference Center

Tuesday, July 25	
8:00 to 8:30	Coffee In Gallagher Hall
8:30 to 10:20	Mini-symposia
Ballroom A	Step-sizes and Adaptations
Ballroom B	Structured stochastic optimization and statistical machine learning I
Ballroom C	Optimization Approaches in Estimation
Meeting A	Modeling stochastic problems
Meeting B	Applications of SDDP in Energy
10:20 to $10:40$	Break In Gallagher Hall
10:40 to 11:40	Dmitry Drusvyatskiy Plenary
11:40 to 12:39	Lunch
12:40 to $14:30$	Mini-symposia
Ballroom A	Solution Methods for Distributionally Robust Optimization Problems I
Ballroom B	Advances of Stochastic Dominance Theory and Applications II
Ballroom C	Data Driven Optimization: Models and Applications
Meeting A	Structured stochastic optimization and statistical machine learning II
Meeting B	Theoretical Advances in SDDP
14:30 to $14:50$	Break In Gallagher Hall
14:50 to $16:40$	Mini-symposia
Ballroom B	Distributionally Robust Optimization with Recent Advancements
Ballroom C	Algorithmic Advances in SDDP
Ballroom C	Recent advances in multistage stochastic optimization: structured policies and decision rules
Meeting A	Many Faces of Distributionally Robust Optimization
Meeting B	Solution Methods for Distributionally Robust Optimization Problems II
16:50 to $18:05$	Memorials

Wednesday, July 26	
8:00 to 8:30	Coffee In Gallagher Hall
8:30 to 9:30	Katya Scheinberg Plenary
9:30 to 9:50	Break In Gallagher Hall
9:50 to 11:30	Sessions
Ballroom A	Approximation guarantees
Ballroom B	Analysis, Approximation and algorithms
Ballroom C	Algorithmic Advances
Meeting A	Applications and Innovations
Meeting B	Regression and Robust Optimization
12:00 to 17:00	Free Time

Thursday, July 27	
8:00 to 8:30	Coffee In Gallagher Hall
8:30 to 9:30	Simge Kucukyavuz Plenary
9:30 to 9:50	Break In Gallagher Hall
9:50 to 11:30	Sessions
Ballroom A	Power Grid Planning and Resilience
Ballroom B	Learning with Applications
Ballroom C	Energy Operations and Planning
Meeting A	Estimation and Statistics
Meeting B	Robust and Chance Constrained Applications
11:30 to $12:19$	Lunch
12:20 to $14:00$	Sessions
Ballroom A	Uncertainty and Risk
Ballroom B	SDDP Advancements and Applications
Ballroom C	Bounds and Analysis
Meeting A	Theory and Applications in the Interface of OR and ML
14:10 to $16:00$	Mini-symposia
Ballroom A	Multistage Stochastic Programming and Applications
Ballroom B	Causal transport and multistage distributionally robust optimization
Ballroom C	Discrete Optimization under Uncertainty
Meeting A	Recent Advances to Solve Stochastic and Robust Optimizations Problems
Meeting B	Pessimistic and Optimistic Optimization
16:00 to $16:20$	Break In Gallagher Hall
16:20 to $17:20$	Daniel Kuhn Plenary
17:30 to $18:25$	Cosp Business Meeting
18:30 to 20:30	Conference Dinner

Friday, July 28	
9:00 to 9:30	Coffee In Gallagher Hall
9:30 to 11:20	Mini-symposia
Ballroom A	Data-driven approaches for nonconvex stochastic programming
Ballroom B	Recent Advances in Nonsmooth, Nonconvex Optimization, with Stochasticity
Ballroom C	Applications to National Security
Meeting A	Recent Advances in Distributionally Robust, Chance-Constrained and Risk-Averse Programs
	(available)
11:30 to 12:30	Plenary (Sponsored By Gurobi) And Lunch
12:30 to $13:00$	Closing

### **Titles Summary**

Monday, July 24 8:00 to 8:30 Coffee In Gallagher Hall 8:30 to 9:00 Welcome 9:00 to 10:00 Keynote David Morton 10:00 to 10:30 Break In Gallagher Hall 10:30 to 12:20 Mini-symposia Ballroom A: Student Paper Prize Sponsored by the EWGSO

Activated Benders Decomposition for Day-ahead Paratransit Itinerary Planning, Kayla Cummings

A Converging Benders' Decomposition Algorithm for Two-Stage Mixed-Integer Recourse Models, Niels van der Laan

A decomposition Method for Two-Stage Stochastic Programs with Nonconvex Recourse, Hanyang Li

General feasibility bounds for sample average approximation via Vapnik–Chervonenkis dimension, Fenpeng Li

Ballroom B: Climate Impacts on Power System Planning and Operations

Power System Expansion Planning for California Under Variable Climate Projections, Amelia Musselman

A Stochastic Model for Climate-Resilient Power System Expansion Incorporating Distributed Energy Resources, Tomas Valencia Zuluaga

Uncertainty-Aware Power-Natural Gas System Planning under deep decarbonization scenarios, Rahman Khorramfar

Modeling Impacts of Multistage Operational Uncertainty on Long Duration Energy Storage with Stochastic Dual Dynamic Programming, Thomas Lee

Ballroom C: Stochastic programming in energy systems: modelling and algorithms

Piecewise Linear Decision Rule for Two-stage Stochastic Mixed-binary Programs with Fixed Recourse, Can Li

A hybrid Benders decomposition to solve the network-constrained unit commitment problem involving stochastic renewable generation units, Ricardo M. Lima

A dual embedded forward-backward scenario decomposition method for convex stochastic programming, Felipe Atenas

Assessing the Capacity Value of Energy Storage that Provides Frequency Regulation, Hyeongjun Kim

Meeting A: Advances of Stochastic Dominance Theory and Applications I

Stochastic dominance principles applied to optimal financial planning, Giorgio Consigli

Learning to Optimize with Stochastic Dominance Constraints, Bo Dai

Multistage ALM with second-order stochastic dominance: implementation and computational results, Giovanni Micheli

Statistical inference of multivariate composite risk functionals and rate of convergence in sample-based approximation, Huihui Chen

#### 12:20 to 13:19 Lunch

#### 13:20 to 15:00 Sessions

Ballroom A: Energy and Grid Planning

Solving the security-constrained unit commitment problem using a hybrid decomposition technique that embeds a network reduction, Gonzalo Constante

Stochastic Energy and Reserve Scheduling and Pricing Schemes with Non-Convexities and Cost Recovery, Bruno Fanzeres

Optimization in carbon emissions markets, Jörgen Blomvall

Accommodating fairness in a shared-energy allocation problem with uncertainties., Zoe Fornier

Ballroom B: Integers and Dynamics

Single-Scenario Facet Preservation for Stochastic Mixed-Integer Programs, Aysenur Karagoz

Constrained Markov decision processes with uncertain transition probabilities, V Varagapriya

Introduction to Mpi-Sppy: Hub-and-Spoke Architecture, Jean-Paul Watson

Ballroom C: Finance and Related Topics

A reinforcement learning approach to dynamic optimization of fixed-mix portfolios, Jorge Zubelli

The role of discounting and compounding in infinite-horizon cash flow risk management, Wenjie Huang

Portfolio Diversification based on Stochastic Dominance and Relaxed Comonotonicity, Mingsong Ye

Comparisons of Mean-Variance Analysis and Entropy-Based Approaches to Portfolio Selection Under Asymmetric Returns in Bear and Bull Markets, Leonard MacLean

Meeting A: Critical Applications and Algorithmic Developments

Proactive Border Resource Staging via Stochastic Programming, Fatemeh Farajzadeh

Optimization with Superquantile Constraints: A Fast Computational Approach, Ying Cui

Multistage stochastic optimization of an elementary hydrogen infrastructure, Raian Noufel Lefgoum

Meeting B: Operational Applications

Dynamic Chance Constraints for Stochastic Capacitated Lot Sizing Problems, Azadeh Farsi

Using Empirical Bayes for Inventory Problems with Poisson Demand, Eddie Anderson

A Two-Stage Stochastic Programming for Constructing Volume Accumulation Curves for Amazon Middle Mile Truck Scheduling, Martin Bagaram

 $Incorporating\ Service\ Reliability\ in\ Multi-depot\ Vehicle\ Scheduling:\ A\ Chance-Constrained\ Approach,\ Margarita\ Castro$ 

### 15:00 to 15:20 Break In Gallagher Hall

#### 15:20 to 17:10 Mini-symposia

Ballroom A: Hydropower planning and scheduling: Practical experiences and methodology advances

Better Bidding of Hydroelectric Plants at Aneo, Kristine Klock Fleten and Stein-Erik Fleten

Randomized symplicial approximate stochastic dynamic programming approaches for the mid-term operations of hydropower systems, Luckny Zephyr

Adaptive distributionally robust optimization for long-term hydropower scheduling, Mari Haugen

Handling the Impact of Climate Change in the Long-Term Generation Scheduling Problem via Distributionally Robust SDDP, Renata Pedrini

#### Ballroom B: Wildfire Prevention and Infrastructure Adaptation

Reliability assessment of critical infrastructure under hybrid outages using robust optimization, Ignacio Aravena

Optimal Power System Topology Control Under Uncertain Wildfire Risk, Kaarthik Sundar

Power System Wildfire Risk Minimization under Stochastic Wildfire Disruptions, Noah Rhodes

A Two-Stage Risk-Averse Stochastic Programming Model for Integrated Wildfire Fuel Treatment and Initial Response Planning, Lina M. Villa-Zapata

Ballroom C: Algorithms and models for the energy transition

Models and algorithms for stochastic planning in the energy transition, Asgeir Tomasgard

A stochastic, two-level optimization model for compressed natural gas infrastructure investments in wastewater management, Steven A. Gabriel

High dimensional SDDP: A Hydrothermal Scheduling problem, Vitor de Matos

Integrated investment, retrofit and abandonment planning of energy systems with short-term and long-term uncertainty using enhanced Benders decomposition, Asgeir Tomasgard

Meeting A: Theory and Applications of Robust and Stochastic Optimization

Data-Driven Stochastic Dual Dynamic Programming: Performance Guarantees and Regularization Schemes, Hyuk Park

First-order distributionally robust optimization, Shimrit Shtern

A Stochastic Conjugate Subgradient Algorithm for Kernelized Support Vector Machines, Di Zhang

The Terminator: An Integration of Inner and Outer Approximations for Solving Regular and Ambiguous Chance Constrained Programs via Variable Fixing, Weijun Xie

Meeting B: Recent Advances in Decision-Making Under Uncertainty

Residuals-Based Contextual Stochastic Programming, Güzin Bayraksan

Distributionally Robust Stochastic Bilevel Linear Programs with Facility Location Applications, Yiling Zhang

An inexact column-and-constraint generation (i-C&CG) method to solve two-stage robust optimization problems, Man Yiu Tsang

Adjustability in Robust Linear Optimization, Ningji Wei

17:15 to 18:15 Plenary Michel De Lara

18:20 to 20:20 Reception At The Conference Center

18

#### Tuesday, July 25 8:00 to 8:30 Coffee In Gallagher Hall 8:30 to 10:20 Mini-symposia

Ballroom A: Step-sizes and Adaptations

Adaptive Stochastic Optimization Methods, Katya Scheinberg

A novel step size approach for deterministic optimization with an eye towards the stochastic case, Vivak Patel

Ranking and Contextual Selection, Bernardo Pagnoncelli

The Adaptive Fixed-Step Stochastic Gradient Algorithm, Ragu Pasupathy

Ballroom B: Structured stochastic optimization and statistical machine learning I

Computable and Asymptotically Exact Confidence Regions in Stochastic Programming, Raghu Pasupathy

Low rank approximation for faster optimization, Madeleine Udell

Robust ReLU Regression via Stochastic Optimization and Local Error Bounds, Jelena Diakonikolas

High-dimensional Scaling Limits of Least-square Online SGD Iterates and Its Fluctuations, Krishnakumar Balasubramanian

Ballroom C: Optimization Approaches in Estimation

Distributional Robustness and Coherent Measures of Risk, Terry Rockafellar

Factor Model of Mixtures, Cheng Peng

Optimization approaches to tailor regression spline for better fit, Jun-ya Gotoh

Risk-Adaptive Approaches to Learning and Decision Making, Johannes O. Royset

Meeting A: Modeling stochastic problems

Issues in Modeling Multistage Problems, Alan King

Modelling multistage problems in Aquaculture Operations, Benjamin S. Narum

Risk-averse production planning in the aquaculture industry, Peter Shütz

Meeting B: Applications of SDDP in Energy

Dynamic Hedging of Energy Portfolios with Stochastic Dual Dynamic Programming, Nils Löhndorf

Model Predictive Control and Stochastic Dynamic Programming, Dominic Keehan

Applying High Performance Computing to the European Resource Adequacy Assessment, Daniel Felipe Ávila

Node Aggregation and Parallelization in Stochastic Dual Dynamic Programming, Erlon Cristian Finardi

#### 10:20 to 10:40 Break In Gallagher Hall

10:40 to 11:40 Plenary Dmitry Drusvyatskiy

#### 11:40 to 12:39 Lunch

#### 12:40 to 14:30 Mini-symposia

Ballroom A: Solution Methods for Distributionally Robust Optimization Problems I

Bounding Multistage Mixed-Integer Distributionally Robust Optimization, Francesca Maggioni

Optimized Dimensionality Reduction for Moment-based Distributionally Robust Optimization, Jianqiang Cheng

Improved Bounds to Accelerate The Column and Constraint Generation for Two-stage Distributionally Robust Problems with First Moment Constraints, Alexandre Street

Mean Robust Optimization, Irina Wang

Ballroom B: Advances of Stochastic Dominance Theory and Applications II

Recent advances in optimization with stochastic dominance constraints, Darinka Dentcheva

Statistically Comparing Data-Driven Optimization Formulations: A Stochastic Dominance Perspective, Henry Lam

Optimality conditions in control problems with random state constraints in probabilistic or almost-sure form, Caroline Geiersbach

Multiperiod interval-based stochastic dominance, Brian David Vasquez Campos

Ballroom C: Data Driven Optimization: Models and Applications

Integrating Learning and Optimization in Data-Driven Problems, Tito Homem-de-Mello

Application-Driven Learning: A Closed-Loop Prediction and Optimization Approach Applied to Dynamic Reserves and Demand Forecasting, Joaquim Dias Garcia

The Value of Robust Assortment Optimization with Ranking-Based Choice Models, Bradley Sturt

Locally robust models for optimization under tail-based data imbalance, Karthyek Murthy

Meeting A: Structured stochastic optimization and statistical machine learning II

Stochastic Zeroth-order Riemannian Derivative Estimation and Optimization, Shiqian Ma

A One-Sample Decentralized Proximal Algorithm for Non-Convex Stochastic Composite Optimization, Tesi Xiao

A model-free first-order method for linear quadratic regulator, Caleb Ju

Meeting B: Theoretical Advances in SDDP

Markovian Stochastic Dual Dynamic Programming, David Wozabal

Multistage Distributionally Robust Convex Optimization: New Algorithms and Complexity Analysis, Andy Sun

Deterministic Upper Bounds For Multistage Stochastic Programs, Bernardo Freitas Paulo da Costa

#### 14:30 to 14:50 Break In Gallagher Hall

#### 14:50 to 16:40 Mini-symposia

Ballroom B: Distributionally Robust Optimization with Recent Advancements

Nonlinear Distributionally Robust Optimization with Wasserstein Ambiguity, Miguel Lejeune

Robust Contextual Portfolio Optimization with Gaussian Mixture Models, Grani A Hanasusanto

Unifying Distributionally Robust Optimization via Martingale-Constrained Optimal Transport, Jiajin Li

Data-driven Facility Location Problem with Multimodal Decision-Dependent Demand Ambiguity, Beste Basciftci

Ballroom C: Algorithmic Advances in SDDP

Convergence of Trajectory Following Dynamic Programming algorithms, Vincent Leclère

MSPLib: : A Library Of Problems For Benchmarking Stochastic Dual Dynamic Programming, Bonn Kleiford Seranilla

Bridging the gap between Reinforcement Learning and SDDP for Hydropower Scheduling, Martin Hjelmeland

Recent advances for Lagrangian cuts in multistage stochastic mixed-integer programming, Christian Füllner

Ballroom C: Recent advances in multistage stochastic optimization: structured policies and decision rules

Recent advances in multi-stage stochastic mixed integer programs, Yongjia Song

Markov Chain-based Policies for Multi-stage Stochastic Integer Linear Programming, Merve Bodur

Accelerating Benders decomposition for solving a sequence of sample average approximation problems, Jim Luedtke

On the Global Convergence of Risk-Averse Policy Gradient Methods with Dynamic Time-Consistent Risk Measures, Xian Yu

Meeting A: Many Faces of Distributionally Robust Optimization

A Nonparametric Approach with Marginals for Modeling Consumer Choice, Karthik Natarajan

Non-smooth, Hölder-Smooth, and Robust Submodular Maximization, Duksang Lee

Wasserstein Distributionally Robust Estimation in High Dimensions, Liviu Aolaritei

Mean-covariance robust risk measurement, Soroosh Shafieezadeh Abadeh

Meeting B: Solution Methods for Distributionally Robust Optimization Problems II

On distributionally robust MILP optimization with stochastic dominance risk averse functional in multi-horizon problems, Laureano F. Escudero

Decomposition methods for Wasserstein-based data-driven distributionally robust problems, Davi Michel Valladão

Enabling Data Valuation through Multi-Source Data-Driven Distributionally Robust Optimization, Robert Mieth

A Max-Min-Max Algorithm for Robust Optimization, Man-Chung Yue

#### 16:50 to 18:05 Memorials

#### Wednesday, July 26 8:00 to 8:30 Coffee In Gallagher Hall 8:30 to 9:30 Plenary Katya Scheinberg 9:30 to 9:50 Break In Gallagher Hall 9:50 to 11:30 Sessions Ballroom A: Approximation guarantees

A Gradually Reinforced Sample-Average-Approximation Differentiable Homotopy Method for a System of Stochastic Equations, Chuangyin Dang

A Gradually Reinforced Sample-Average-Approximation Differentiable Path-Following Method to Compute Perfect Stationary Points of Stochastic Variational Inequalities, Yiyin Cao

Transportation Distance Between Kernels and Approximate Dynamic Risk Evaluation in Markov Systems, Zhengqi Lin

Approximation Guarantees for Min-max-min Robust Optimization and K-Adaptability under Objective Uncertainty, Jannis Kurtz

Ballroom B: Analysis, Approximation and algorithms

Neur2SP: Neural Two-Stage Stochastic Programming, Justin Dumouchelle

Statistical Efficiency of a Stochastic Composite Proximal Bundle Method, Xinyang Hu

A Multilevel Stochastic Approximation Algorithm for Value-at-Risk and Expected Shortfall Estimation, Azar Louzi

Maximum Optimality Margin: A Unified Approach for Contextual Linear Programming and Inverse Linear Programming, Chunlin Sun

Ballroom C: Algorithmic Advances

Deriving the Projective Hedging Algorithm for Stochastic Programming, Jonathan Eckstein

Decomposition Methods for Dynamically Monotone Two-Time-Scale Stochastic Optimization Problems, Jean-Philippe Chancelier

Quadratic Optimization Models for Balancing Preferential Access and Fairness: Formulations and Optimality Conditions, Bismark Singh

An Adaptive Subsampled Hessian-Free Optimization Method for Statistical Learning, Fabian Bastin

Meeting A: Applications and Innovations

Non-parametric Stochastic Decomposition for Predictive Stochastic Programming in the Presence of Streaming Data, Shuotao Diao

Value of Stochastic Solution with Right-Hand Side Uncertainty, Haoming Shen

On a two-stage stochastic appoach for cross-dock door design and management, M. Araceli Garin

A two-timescale decision-hazard-decision formulation for prospective studies in energy systems under uncertainties, Camila Martinez Parra

#### Meeting B: Regression and Robust Optimization

On Generalization and Regularization via Wasserstein Distributionally Robust Optimization, Jonathan Li

Multistage Robust Classification with Fairness Constraints, Zhuangzhuang Jia

Decision-dependent distributionally robust optimization, Mauricio Junca

Wasserstein Logistic Regression with Mixed Features, Mohammad Reza Belbasi

#### 12:00 to 17:00 Free Time

#### Thursday, July 27 8:00 to 8:30 Coffee In Gallagher Hall 8:30 to 9:30 Plenary Simge Kucukyavuz 9:30 to 9:50 Break In Gallagher Hall 9:50 to 11:30 Sessions Ballroom A: Power Grid Planning and Resilience

 $\label{eq:climate-aware generation and transmission expansion planning: A three-stage robust optimization approach, Alexandre Moreira$ 

Tri-level stochastic optimization for power grid defense, Andrew Mastin

Power Grid Resilience Optimization Using Decision-Dependent Uncertainty, Samuel Affar

Multistage investment planning for renewable electricity systems, Andy Philpott

Ballroom B: Learning with Applications

Understanding Uncertainty Sampling as Distributionally Robust Optimizatin, Xiaocheng Li

Learning for Robust Optimization, Bartolomeo Stellato

Active Learning in the Predict-then-Optimize Framework, Mo Liu

Chance constrained two-player Zero-Sum Games with a Deep Learning Approach, Abdel Lisser

Ballroom C: Energy Operations and Planning

Risk-Averse Contextual Predictive Maintenance and Operations Scheduling with Flexible Generation under Wind Energy Uncertainty, Natalie Randall

Stochastic Optimization for Mid-Term Integrated Generation and Maintenance Scheduling of Cascaded Hydroelectric System with Renewable Energy Uncertainty, Zhiming Zhong

Optimizing vessel chartering strategies to support maintenance tasks at offshore wind farms, Vibeke Hvidegaard Petersen

Probabilistic Constrained Optimization on Gas Networks, Michael Schuster

Meeting A: Estimation and Statistics

data-based stochastic programming using bootstrap estimation, Xiaotie Chen

Assessing solution quality in risk-averse stochastic programs, Ruben van Beesten

Integrated Conditional Estimation and Optimization, Meng Qi

Empirical Gateaux Derivatives for Optimization-Based Estimators in Causal Inference, Angela Zhou

Meeting B: Robust and Chance Constrained Applications

Cooperative games under uncertainty: a robust chance-constrained approach, Xuan Vinh Doan

Robust Spare Parts Inventory Management, Ahmadreza Marandi

Robust Kidney Exchange, Hoda Bidkhori

#### 11:30 to 12:19 Lunch

12:20 to 14:00 Sessions

Ballroom A: Uncertainty and Risk

Risk-Averse Stochastic Programming for High-Impact, Low-Probability Events with Applications to Flash Flooding Climate Change Risk, Beau Groom

Data-driven two-stage conic optimization with rare, high-impact zero-one uncertainties, Anirudh Subramanyam

Variance Reduction and Low Sample Complexity in Stochastic Optimization via Proximal Point Methods, Jiaming Liang

Ballroom B: SDDP Advancements and Applications

23

A Multicut Approach to Calculate Upper Bounds for Risk Averse SDDP, Raphael Chabar

Backward resampling-based SDDP approach: application to the (very) large-scale power generation planning problem of the Brazilian system, Andre Luiz Diniz

Capacity planning using SDDP.jl, Jarand Hole

Ballroom C: Bounds and Analysis

High Probability Sample Complexity Bounds for Adaptive Optimization Methods with Stochastic Oracles, Miaolan Xie

A discussion of first-order information of probability functions, Wim van Ackooij

Support Vector Regression (SVR) is investigated in the framework of the Fundamental Risk Quadrangle, Anton Malandii

A Value Function Approach to Two-stage Stochastic Mixed-Integer Programs, Andrew Schaefer

Meeting A: Theory and Applications in the Interface of OR and ML

Learning the feasible set of an optimization problem from data, Angelos Georghiou

Learning Optimal Classification Trees Robust to Distribution Shifts, Nathan Justin

Contextual Stochastic Bilevel Optimization, Yifan Hu

Optimal Algorithms in Nonconvex Minimax Optimization, Siqi Zhang

#### 14:10 to 16:00 Mini-symposia

Ballroom A: Multistage Stochastic Programming and Applications

Stochastic Dynamic Linear Programming: A Sequential Sampling-based Multistage Stochastic Programming Algorithm, Harsha Gangammanavar

Risk-averse Regret Minimization in Multi-stage Stochastic Programs, Mehran Poursoltani

Robust and Stochastic Unit Commitment of an Isolated Industrial Microgrid, Vitor Luiz Pinto de Pina Ferreira

My Humble Response to Roger Wets' Challenges in SP, Suvrajeet Sen

Ballroom B: Causal transport and multistage distributionally robust optimization

Entropic Regularization of Optimal Transport, Alois Pichler

Decision-making with Side Information: A Causal Transport Robust Approach, Luhao Zhang

Dual Dynamic Programming for Data-driven Distributionally Robust Multistage Convex Optimization, Shixuan Zhang

Data-driven Multistage Distributionally Robust Optimization with Nested Distance, Rui Gao

Ballroom C: Discrete Optimization under Uncertainty

Benders' Decomposition Algorithms for Stochastic Mixed-integer Programs, Ward Romeijnders

Distributionally Ambiguous Network Interdiction Problems, Manish Bansal

Ensemble Variance Reduction Methods for Stochastic Mixed-Integer Programming and their Application to the Stochastic Facility Location Problem, Jiajun Xu

Novel Decision Rules in Sequential Decision-making Under Uncertainty, Maryam Daryalal

Meeting A: Recent Advances to Solve Stochastic and Robust Optimizations Problems

Dual Decomposition of Two-stage Distributionally Robust MIP, Kibaek Kim

A logic-based Benders decomposition approach to solve the K-adaptability problem, Ahmed Saif

Inexact Cuts in SDDiP and Enhancement Technologies for Lagrangian Cuts, Hanbin Yang

Multistage Distributionally Robust Optimization under Stochastic Disruptions, Haoxiang Yang

Meeting B: Pessimistic and Optimistic Optimization

24

Optimistic-Pessimistic Duality, Louis Chen

DFO: A Robust Framework for Data-driven Decision-making with Outliers, Nan Jiang

UCB-C: An Efficient UCB Algorithm for Contextual Bandit-Based Learning with Continuous Actions, Zhi Wang

16:00 to 16:20 Break In Gallagher Hall

16:20 to 17:20 Plenary Daniel Kuhn

17:30 to 18:25 Cosp Business Meeting

18:30 to 20:30 Conference Dinner

Ballroom A: Data-driven approaches for nonconvex stochastic programming

Nonconvex Stochastic Programmin, Jong-Shi Pang

Data-Driven Multistage Stochastic Optimization on Time Series, Rohit Kannan

A decomposition algorithm for distributionally robust two-stage stochastic linear programs with decision-dependent ambiguity, Hamed Rahimian

Data-drive Piecewise Affine Decision Rule Methods for Stochastic Optimization with Covariate Information, Junyi Liu

Ballroom B: Recent Advances in Nonsmooth, Nonconvex Optimization, with Stochasticity

Mini-Batch Risk Forms, Andrzej Ruszczynski

Solving stochastic composite minimization, with applications to noisy phase retrieval and nonlinear modeling, Feng Ruan

Decentralized Stochastic Bilevel Optimization, Xuxing Chen

On the solution of nonsmooth and nonconvex models for chance constraints and buffered probabilities, Gregorio M. Sempere

Ballroom C: Applications to National Security

Physically Realizable Adversarial Perturbations of Acoustic Signals, Robert Bassett

Inference with Constrained Hidden Markov Models, Bill Hart

Optimizing Supply Blocks for Expeditionary Units, Jefferson Huang

Software tools for hybrid microgrid planning, Daniel Reich

Meeting A: Recent Advances in Distributionally Robust, Chance-Constrained and Risk-Averse Programs

Optimization under Rare Chance Constraints, Anirudh Subramanyam

A Tensor Train Approach to Risk Averse Optimization, Akwum Onwunta

Sparsity-based nonlinear reconstruction of optical parameters in two-photon photoacoustic computed tomography, Madhu Gupta

11:30 to 12:30 Plenary (Sponsored By Gurobi) And Lunch 12:30 to 13:00 Closing

## Sessions

Monday, July 24

#### Keynote

## $9{:}00\ {\rm to}\ 10{:}00\ {\rm Design},\ {\rm calibration},\ {\rm and}\ {\rm optimization}\ {\rm of}\ {\rm pandemic}\ {\rm alert}\ {\rm systems}$

Speaker: David Morton, Northwestern University

Coauthors: Nazlican Arslan, Daniel Duque, Linda Pei, Bismark Singh, Özge Sürer, Haoxiang Yang, Zhanwei Du, Spencer J. Fox, Remy Pasco, Kelly Pierce, Paul Rathouz, Victoria Valencia, Michael Pignone, S. Claiborne Johnston, Mark E. Escott, Desmar Walkes, Stephen I. Adler, Lauren Ancel Meyers

During the COVID-19 pandemic, governments worldwide developed staged-alert systems to monitor data streams and trigger changes in intervention policies. However, many tracked unreliable data indicators, used heuristic policy triggers, failed to articulate measurable goals, and were implemented and communicated inconsistently. Beginning in April 2020, we worked closely with local officials in Austin, Texas to develop and maintain the COVID-19 alert system that guided public communications and policy decisions. Over a two-year period, the system was instrumental in preventing overwhelming healthcare surges, minimizing socioeconomic disruption, and contributing to Austin's significantly lower COVID-19 mortality rate than comparable cities across the US. In this talk, we will describe a data-driven modeling framework, and stochastic optimization model, for designing pathogen alert systems that can ensure consistent situational awareness, provide policy guideposts that reduce uncertainty and decision complexity, and enhance public trust and policy adherence.

Keywords: chance-constrained program; mathematical epidemiology; staged-alert system

Mini-symposium Monday 10:30 to 12:20

## Student Paper Prize Sponsored by the EWGSO

Organized by Johannes Royset

10:30 to 11:05 Activated Benders Decomposition for Day-ahead Paratransit Itinerary Planning Speaker: Kayla Cummings, MIT

11:05 to 11:30 A Converging Benders' Decomposition Algorithm for Two-Stage Mixed-Integer **Recourse Models** 

Speaker: Niels van der Laan, University of Groningen

11:30 to 11:55 A decomposition Method for Two-Stage Stochastic Programs with Nonconvex Recourse Speaker: Hanyang Li, University of Minnesota

11:55 to 12:20 General feasibility bounds for sample average approximation via Vapnik–Chervonenkis dimension

Speaker: Fenpeng Li, Columbia University

#### Mini-symposium Monday 10:30 to 12:20

## **Climate Impacts on Power System Planning and Operations**

Organized by Amelia Musselman

# 10:30 to 11:05 Power System Expansion Planning for California Under Variable Climate Projections

Speaker: Amelia Musselman, Lawrence Livermore National Laboratory

Coauthors: Tomas Valencia Zuluaga, Jean-Paul Watson

Climate change is increasingly impacting power system operations, not only through more frequent extreme weather events but also through shifts in routine weather patterns. Factors such as increased temperatures, droughts, changing wind patterns, and solar irradiance shifts can impact generator, storage, and transmission efficiencies, production, and lifetimes. Furthermore, some of these factors also impact electric load. The current power system was not designed to be resilient towards future climates. In this work, we aim to find cost-optimal solutions for expanding the power system to develop a climate-resilient system that is able to meet future load.

We analyze the impact of climate change on power systems via a novel climate-resilient capacity expansion planning model, which seeks to minimize costs while ensuring power system resilience and reliability under a changing climate. We model the problem as a stochastic mixed-integer program, which we implement in Pyomo and solve using the recently developed stochastic programming library, mpi-sppy, along with Gurobi. We extend a synthetic but realistic test case for California, found in the literature, to include parameters required for our capacity expansion planning problem. Leveraging climate data from the CMIP6 model repository, we map future climate projections onto power system parameters, focusing initially on changes in temperature, wind speed, and solar irradiance, which affect load, and wind and solar generator availability, respectively. We define a set of climate-based load and generator availability scenarios, both for the present day and for various future years. We compare investment decision based on present-day climate with future-climate resilient solutions and solve the stochastic program across various years to recommend a power system that is resilient to both the present and future climate. Prepared by LLNL under Contract DE-AC52-07NA27344.

Keywords: Capacity expansion planning; climate; resilience

# 11:05 to 11:30 A Stochastic Model for Climate-Resilient Power System Expansion Incorporating Distributed Energy Resources

Speaker: Tomas Valencia Zuluaga, University of California, Berkeley

#### Coauthors: Amelia Musselman, Jean-Paul Watson

An increasing penetration of renewable, intermittent, and decentralized generation resources is rapidly transforming the power grid and increasing its sensitivity to the weather. At the same time, we are already starting to perceive how, because of human-made climate change, the frequency and intensity of extreme events increasingly deviate from historical meteorological behavior. Conventional modeling tools for generation and transmission expansion planning, based on historical data, are inadequate to inform investment decisions for a resilient and decarbonized power grid under this changing landscape. Incorporating climate projections into expansion planning tools can improve the relevance of these tools to decision makers but the results are only meaningful if the uncertainty associated with these projections is also considered. Stochastic programming is well-suited for this purpose.

We propose a stochastic generation and transmission expansion planning model and a method to incorporate the output from downscaled global climate models into the optimization framework. We utilize the parallelization capabilities and overall versatility of mpi-sppy, a python library currently in development for stochastic programming, to overcome the challenges of dimensionality through scenario decomposition techniques. Building on existing literature, we present model modifications to handle the challenges of solving our problem while maintaining sufficient realism. We also present the work undertaken to include distributed energy resources into our model and, based on an application example, analyze the importance of this consideration for the resulting expansion plan.

Prepared by LLNL under Contract DE-AC52-07NA27344.

Keywords: Capacity expansion planning; climate; resilience; progressive hedging; mpi-sppy

# $11:30 \ {\rm to} \ 11:55 \ {\rm Uncertainty-Aware Power-Natural Gas System Planning under deep decarbonization scenarios}$

Speaker: Rahman Khorramfar, MIT Energy Initiative

Coauthors: Rahman Khorramfar, Dharik Mallapragada, Saurabh Amin

Our work is motivated by the challenge faced by energy system planners in ensuring that the future grid is resilient to interannual variations in demand and renewable energy supply. This challenge is magnified by the uncertain impacts of climate change on renewable energy potential and shifting demand patterns in many socio-economically vulnerable regions. An expansion plan that does not account for these uncertainties can stall the intended transition efforts to low-carbon grid and increase the risk of disruptions in energy supply, especially during extreme weather conditions. We focus on the problem of designing uncertainty-aware planning decisions for the interdependent power-natural gas infrastructure. Our stochastic programming formulation considers interannual variations in both energy demand and renewable energy supply, and accounts for the operational constraints of the joint system. We develop a computational approach that exploits the spatial correlation between electric power and natural gas demands both within and across load zones, resulting in a mixed-integer programming (MILP) formulation. Furthermore, we show that a similar MILP formulation can be used to solve an alternative planning problem based on distributionally robust optimization, where the uncertainty is captured by moment-based ambiguity sets. We compare the resulting uncertainty-aware designs with the certainty equivalent problem for a realistic power-gas systems in the U.S. New England region and highlight the importance of systematic modeling of inter-annual variability in demand and renewable energy supply.

Keywords: Inter-annual weather variation; energy infrastructure planning

## 11:55 to 12:20 Modeling Impacts of Multistage Operational Uncertainty on Long Duration Energy Storage with Stochastic Dual Dynamic Programming Speaker: Thomas Lee, MIT

#### Coauthors: Andy Sun

Long duration energy storage may play a crucial role in highly decarbonized energy systems, in order to alleviate renewable energy shortages on multi-day and even seasonal timescales. However, out of system planning models to date which incorporate long duration storage, most assume perfect foresight during the operations of storage resources due to computational tractability. This conflicts with the limited skill of meteorological forecasts over climatology beyond the 1 to 2 week horizon, due to data/model limitations and inherent chaos in the weather system. The realism of this perfect foresight assumption is reexamined by considering a stochastic scenario tree based on historical weather data. Stochastic dual dynamic programming is used to study the behavior of long duration storage dispatch within an energy systems model under multistage operational uncertainty. Implications are studied for system planning, investment, and operations of energy storage portfolios with long duration technologies.

Keywords: multistage stochastic programming; stochastic dual dynamic programming; storage

#### Mini-symposium Monday 10:30 to 12:20

### Stochastic programming in energy systems: modelling and algorithms

Organized by Hongyu Zhang

# 10:30 to 11:05 Piecewise Linear Decision Rule for Two-stage Stochastic Mixed-binary Programs with Fixed Recourse

Speaker: Can Li, Purdue University

Coauthors: Kibaek Kim

Two-stage stochastic mixed-integer linear programming (TS-SMILP) is a very challenging class of problems, especially for problems with mixed-integer second-stage variables. In process systems engineering, a large number of applications under uncertainty can be modelled using TS-SMILP, such as supply chain management, clinical trial, and energy systems. However, solving TS-SMILP remains to be computationally very challenging. In this presentation, we propose an algorithm based on piecewise linear decision rules for TS-SMILP with continuous distributions. The domain of the uncertainty parameter is partitioned into several subsets. In each subset, the second stage continuous variables adopt a linear decision rule with respect to the uncertain parameters and the second-stage binary variables are constant. Several theoretical properties are proved. First, we prove that there exists a piecewise decision rule that is optimal for TS-SMILP. Second, under uniform partition, the convergence rate of the piecewise decision rule is proved and compared with the convergence rate of sample average approximation. In the proposed algorithm, the partition of the uncertainty set is adaptively updated. Several adaptive partition schemes including uniform partition, strong partition, and reliability partition, are proposed. The proposed algorithms have superior computational performance compared with sample average approximation in problems with low-dimension uncertain parameters.

Keywords: Decision rules; Integer Recourse

### 11:05 to 11:30 A hybrid Benders decomposition to solve the network-constrained unit commitment problem involving stochastic renewable generation units

Speaker: Ricardo M. Lima, King Abdullah University of Science and Technology

Coauthors: Ricardo M. Lima, Gonzalo Constante-Flores, Antonio J. Conejo, Omar M. Knio

We propose a new hybrid method based on Benders decomposition and a column-and-constraint generation step tailored for network-constrained stochastic unit commitment (SNCUC) problems. This problem is formulated as a two-stage stochastic program with continuous and binary variables in the first stage and only continuous variables in the second stage. The proposed method decomposes the SNCUC problem into an augmented master problem and subproblems. A key feature of the method concerns the formulation of the augmented master problem, which includes dispatch decisions over all scenarios (excluding transmission variables and constraints) in addition to the first-stage commitment decisions. A second characteristic concerns embedding a column-and-constraint generation step at each iteration to add specific transmission variables and constraints per scenario to the master problem. By lifting the dispatch decisions over the scenarios to the master problem, the complete second-stage cost is calculated in the master problem, which generates strong lower bounds and feasible commitment and dispatch solutions. We target large-scale instances of the SNCUC problem, involving stochastic renewable generation units, hundreds of thermal generation units, thousands of transmission lines and nodes, and uncertain demand. The performance of the proposed decomposition is contrasted with solving the extensive formulation via branch-and-cut and Benders decomposition available in commercial solvers and with traditional Benders decomposition variants. The computational experiments show that the proposed method generates bounds of superior quality and finds solutions for instances where other approaches fail.

Keywords: stochastic unit commitment;Benders decomposition;Column-&-Constraint Generation

# $11:30\ {\rm to}\ 11:55\ {\bf A}$ dual embedded forward-backward scenario decomposition method for convex stochastic programming

Speaker: Felipe Atenas, IMECC, Unicamp

Coauthors: Jonathan Eckstein, Paulo J. S. Silva

Multistage stochastic optimization problems form a class of large-scale problems with decomposable objective functions and coupling constraints. We propose a new decomposition method that combines a generalized approximate proximal point algorithm with forward-backward steps for a dual version of the Augmented Lagrangian subproblem. Primal-dual convergence guarantees are obtained for a variant of the progressive hedging algorithm, and also conditions to achieve linear and superlinear convergence with varying stepsizes. We evaluate the numerical performance of our method in a stochastic electric power expansion planning problem, and compare it with two variants of progressive hedging: the standard form and a proximal bundle version.

Keywords: progressive hedging; splitting methods; proximal point; augmented Lagrangians

# 11:55 to 12:20 Assessing the Capacity Value of Energy Storage that Provides Frequency Regulation

Speaker: Hyeongjun Kim, The Ohio State University

#### Coauthors: Ramteen Sioshansi

Due to complexity in determining its state of energy (SOE), multi-use applications complicate the assessment of energy storage's resource-adequacy contribution. SOE impacts resource-adequacy assessment because energy storage must have stored energy available to mitigate a loss of load. This paper develops a three-step process to assess the resource-adequacy contribution of energy storage that provides frequency regulation. First, we use discretized stochastic dynamic optimization to derive decision policies that tradeoff between different energy-storage applications. Next, the decision policies are used in a mixed-integer optimization that determines actual energy-storage operation in a rolling-horizon fashion. Finally, simulation is used to assess energy storage's resource-adequacy contribution. The methodology is demonstrated using a simple example and a case study that is based on actual system data. We benchmark our proposed model to another that neglects frequency regulation.

Mini-symposium Monday 10:30 to 12:20

## Advances of Stochastic Dominance Theory and Applications I

Organized by Darinka Dentcheva, Giorgio Consigli

## 10:30 to 11:05 Stochastic dominance principles applied to optimal financial planning

Speaker: Giorgio Consigli, Khalifa University of Science and Technology

We present recent developments on asset allocation and asset-liability management (ALM) under stochastic dominance constraints. In case of an investment problem the optimal control is required to stochastically dominate a benchmark investment policy or a market portfolio such as an equity index, while in an ALM problem the dominance relationship may be directly associated with the liability profile of an intermediary. We present a recent ALM model formulation capturing the core elements of a complex capital allocation problem in which the dominance relationship is defined with respect to a liability distribution and summarize recent results at the crossroad between ALM and stochastic dominance of different order.

 $Keywords:\ stochastic\ programming,\ stochastic\ dominance,\ asset-liability\ management$ 

## 11:05 to 11:30 Learning to Optimize with Stochastic Dominance Constraints

Speaker: Bo Dai, Google Brain & Georgia Tech

Coauthors: Hanjun Dai, Yuan Xue, Niao He, Bethany Wang, Na Li and Dale Schuurmans

In real-world decision-making, uncertainty is important yet difficult to handle. Stochastic dominance provides a theoretically sound approach to comparing uncertain quantities, but optimization with stochastic dominance constraints is often computationally expensive, which limits practical applicability. In this paper, we develop a simple yet efficient approach for the problem, Light Stochastic Dominance Solver (light-SD), by leveraging properties of the Lagrangian. We recast the inner optimization in the Lagrangian as a learning problem for surrogate approximation, which bypasses the intractability and leads to tractable updates or even closed-form solutions for gradient calculations. We prove convergence of the algorithm and test it empirically. The proposed lightSD demonstrates superior performance on several representative problems ranging from finance to supply chain management.

Keywords: stochastic dominance, learning for optimization

# 11:30 to 11:55 Multistage ALM with second-order stochastic dominance: implementation and computational results

Speaker: Giovanni Micheli, University of Bergamo

Coauthors: Giorgio Consigli, Darinka Dentcheva, Francesca Maggioni

The ALM model is applied to a multistage problem of a European intermediary with an extended set of computational results. The scenario generation, approximation of SSD contraints and problem instance implementation are discussed in detail and the effectiveness of a nested Benders approach to ensure SSD feasibility and lead to fast convergence of the solution method for large scale problems.

# $11:55\ to\ 12:20\ Statistical inference of multivariate composite risk functionals and rate of convergence in sample-based approximation$

Speaker: Huihui Chen, Stevens Institute of Technology

Coauthors: Darinka Dentcheva, Yang Lin, Gregory J. Stock

This paper explores the statistical inference of composite risk functions, which find extensive applications in finance, insurance, and other related fields. Our specific focus lies on law-invariant coherent measures of risk, which exhibit nonlinearity in probability measures. While a central limit theorem for the optimal value of univariate such functions is already available

in the literature, we extend these findings in several significant directions. Firstly, we present an extension to vectorvalued functionals, allowing for the evaluation of the joint asymptotic behavior of multiple risk measures. Additionally, we establish a novel central limit theorem for the smoothed sample-based estimators of such functionals, which is also applicable to the univariate case. Furthermore, we explore the rate of convergence of the average sample approximation for composite functionals using the Large Deviation Principle and its exponential bounds. This approach provides a more accurate confidence interval for portfolio optimization problems. Our findings carry important implications for risk management practices, and our methodology can be effectively applied to various areas where composite risk functions are utilized.

Keywords: Risk Measures; Composite Functionals; Multivariate CLT; Large Deviation;

## Energy and Grid Planning

#### Chaired by Zoe Fornier

# 13:20 to 13:45 Solving the security-constrained unit commitment problem using a hybrid decomposition technique that embeds a network reduction

Speaker: Gonzalo Constante, Purdue University

Coauthors: Gonzalo E. Constante-Flores, Antonio J. Conejo

We present a solution method to address the day-ahead security-constrained unit commitment problem using a decomposition technique that embeds a reduced network model. This problem aims to minimize the cost of scheduling generating units throughout a network to supply the demand while ensuring uneventful operation under any single-branch failure. We formulate this problem as a two-stage stochastic programming problem with binary and continuous variables in the first stage and only continuous variables in the second stage. The proposed solution method uses a Benders framework to decompose the problem into (i) a reduced-network master problem, which is a mixed-integer linear problem that approximately models the first stage and provides trial solutions of the binary (scheduling) decisions based on a reduced network model, (ii) a full-network auxiliary problem, which is a linear problem that considers the entire network model and determines trial solutions of the continuous first-stage decisions, and (iii) the subproblems, which are linear and correspond to the secondstage operations under any single-branch failure. The proposed reduced network model represents the original network using a significantly smaller number of variables and constraints that depends on the number of congested lines, which in practice is small as compared to the total number of lines. Additionally, to improve the convergence of the algorithm, we enhance the communication between the master/auxiliary problem and the subproblems by dynamically transferring primal information (column and constraint information) from a selected subset of subproblems. Our computational experiments on a realistic power grid show the effectiveness of the proposed approach with respect to the solution of the extensive formulation via branch-and-cut and standard Benders decomposition.

Keywords: Benders decomposition; network reduction; unit commitment

# $13:45\ to\ 14:10\ Stochastic\ Energy\ and\ Reserve\ Scheduling\ and\ Pricing\ Schemes\ with\ Non-Convexities\ and\ Cost\ Recovery$

Speaker: Bruno Fanzeres, Pontifical Catholic University of Rio de Janeiro

#### Coauthors: Bruno Fanzeres, Nuran Cihangir

Over the past years, most market and system operators around the globe are facing two key sources of challenges when pricing and operating modern power production systems. On the one hand, as weather-dependent renewables become the main source of generation around the globe, their intrinsic intermittent supply nature requires system operators to account for uncertainty in market price formation and scheduling. In fact, renewable generation forecast errors are recognized as one of the key sources of high system-balancing costs. Conventional generators, on the other hand, have non-convex cost structures which incentivize misalignment with marginal pricing-based market outcomes. In this context, out-of-market mechanisms, which blur price signals, are recurrently used to reimburse generators for their opportunity costs. Therefore, by leveraging on a risk-averse two-stage stochastic programming framework, this talk elaborates on enhancements of state-of-the-art pricing and scheduling methodologies by discussing a robust decision-making tool for system and market operators. Based on a primal-dual pricing, this tool endogenously balances energy and reserve scheduling market-clearing procedure is formulated as a Mixed Integer Bi-Linear Programming problem. A hybridization of McCormick envelopes and binary expansion is proposed to enhance the computational capability to solve the problem. Two case studies are conducted to illustrate the effectiveness of the proposed procedure.

Keywords: Pricing Non-Convexities; Cost-Recovery; Bi-Linear Stochastic Program; Renewables
### 14:10 to 14:35 Optimization in carbon emissions markets

Speaker: Jörgen Blomvall, Linköping university

The term structure representing future carbon emission costs cannot be directly observed, it has to be estimated by an inverse problem. A non-parametric inverse problem to obtain accurate measurements of the term structure of EU emission allowances (EUA) within the emission trading system (ETS) for carbon credits is presented. From a time series of measurements, factor analysis is used to determine the systematic risk factors, which allow determination of the risk and to do performance attribution for EUA portfolios. A stochastic programming model for hedging the risk in a EUA portfolio, shows that significant improvements can be made relative to a traditional back-to-back hedge.

Keywords: Inverse problem ; Stochastic programming ; Carbon emissions

## 14:35 to 15:00 Accommodating fairness in a shared-energy allocation problem with uncertainties. Speaker: Zoe Fornier, ENPC

Coauthors: Pierre Pinson, Vincent Leclère

With the recent emergence of prosumers (who are both energy producers and consumers), some companies propose to aggregate prosumers in the energy market. This is since prosumers are generally too small to directly enter the electricity market themselves. To implement those aggregators, there is a practical need to study how those who compose the portfolio, based on their assets and production/consumption profiles, are going to be treated fairly. We introduce and discuss ways to accommodate fairness by design in the modeling of the problem. Following paradigm, the allocation decided by the aggregator has to be fair at the cost of an objective deterioration. This problem translates to a shared-resource fair allocation problem and can be modeled as a mixed-integer linear program in the deterministic case. First, we revisit conventional approaches to accommodate fairness including, e.g., the minimax approach, favouring the least well-off agent and the proportional approach, derived from Nash's bargaining problem. We also examine measuring the proportional savings of agents instead of their costs. There, we minimize the agent with least-proportional savings, or we add equal proportional savings constraints. Those different approaches are compared based on application case studies of limited size, yet respecting realistic features of assets to be aggerated in electricity markets. Importantly, we eventually take into consideration the uncertainties in the energy market: in prices or energy loads. Accommodating fairness in stochastic resource allocation problem has been less studied in the literature. As we basis, we extend the previous approaches and related investigations to a two-stage stochastic program, by rethinking the previous fairness constraints or objectives in an uncertain case. Using the same case studies, we finally discuss the specifics of the stochastic setup compared to the deterministic one.

Keywords: Energy Aggregator, Fairness, Uncertainties, Stochastic Optimization

## **Integers and Dynamics**

Chaired by Jean-Paul Watson

### 13:20 to 13:45 **Single-Scenario Facet Preservation for Stochastic Mixed-Integer Programs** Speaker: Aysenur Karagoz, Rice University

Coauthors: Aysenur Karagoz, David Mildebrath, Andrew J. Schaefer

We consider improving the polyhedral representation of the extensive form of an SMIP. Given a facet-defining valid inequality for a single-scenario version of the SMIP, we provide conditions under which the same inequality remains facet-defining for the extensive form. Our main result gives necessary and sufficient conditions for a facet-defining inequality for a single-scenario version to be facet-defining for the extensive form. We then present several implications, which show that various recourse structures from the literature satisfy these conditions. For example, for an SMIP with simple recourse, any single-scenario facet is also a facet for the extensive form. More general recourse structures require additional mild assumptions for these conditions to hold.

#### 13:45 to 14:10 **Constrained Markov decision processes with uncertain transition probabilities** Speaker: V Varagapriya, Indian Institute of Technology Delhi

We consider an infinite-horizon discounted constrained Markov decision process with uncertain transition probabilities where the uncertainty is influenced by a single parameter. We formulate a robust CMDP problem and construct an equivalent bilinear programming problem. We propose a linear programming-based algorithm to compute an optimal policy of the robust CMDP problem. We provide sufficient conditions under which the uncertainty becomes redundant. As an application, we study a machine replacement problem and compare the performance of our algorithm with known bilinear optimization solvers by considering randomly generated instances of various sizes.

### 14:10 to 14:35 Introduction to Mpi-Sppy: Hub-and-Spoke Architecture

Speaker: Jean-Paul Watson, Lawrence Livermore National Laboratory

Coauthors: Bernard Knueven, Christopher Muir, John Siirola, David L. Woodruff

We describe the open source package mpi-sppy, in which efficient and scalable parallelization is a central feature. We report computational experiments that demonstrate the ability to solve very large stochastic programming problems - including mixed-integer variants - in minutes of wall clock time, efficiently leveraging significant parallel computing resources. We report results for the largest publicly available instances of stochastic mixed-integer unit commitment problems, solving to provably tight optimality gaps. In addition, we introduce a novel software architecture that facilitates combinations of methods for accelerating convergence that can be combined in plug-and-play manner.

14:35 to 15:00 **Open** 

## Finance and Related Topics

Chaired by Azar Louzi

### 13:20 to 13:45 **A reinforcement learning approach to dynamic optimization of fixed-mix portfolios** Speaker: Jorge Zubelli, Khalifa University

#### Coauthors: Giorgio Consigli, Alvaro A. Gomez

This talk concerns a mathematical framework and the implementation details of a reinforcement learning algorithm based on a deterministic gradient policy evaluation and an objective function which maximizes the expected cumulative return of the policy over a finite horizon. The reward function adopted in the recursive learning procedure is based on the assessment of the period-by-period portfolio return evaluation. An implementation adopting a relative performance measure with respect to a benchmark is also presented. Two deep feed forward neural networks for the evaluation of the gradient and the derivation of the fixed mix updates have been implemented to reinforce the learning approach.

The motivation for this research comes from the fact that Institutional investors often adopt as portfolio management a constant-proportion investment rule. According to the latter, given an initial specified portfolio composition the portfolio is rebalanced so as to retain that initial composition in response to market dynamics. Strategic asset allocation approaches typically derive such policy from the solution of medium-term problems with a given risk-reward function that do not explicitly consider any fixed mix constraint. The requirement in an optimization problem of the fixed mix constraints, by imposing a buying and selling decision on individual assets relative to the overall portfolio composition, leads however to a non-convex optimization problem. A possible approach to overcome such issues is to derive the fixed mix strategy through a machine learning approach for which the action space of buying and selling decisions is progressively refined to maximize the value function of the problem.

Keywords: reinforcement learning; fixed-mix portfolio; portfolio optimization;

## $13{:}45\ {\rm to}\ 14{:}10$ The role of discounting and compounding in infinite-horizon cash flow risk management

Speaker: Wenjie Huang, The University of Hong Kong

Coauthors: Erick Delage, Abhilash Chenreddy

An accurate characteristic of decision maker's time preference is important for cash flow analysis and sequential decisionmaking problems. In this work, we first use case studies to clarify the role and the importance of an accurate time preference (i.e., discount factor) settings. We also introduce existing field experiments where the estimated discount factors of decisionmakers are abnormally low, which suggest that the existing models fail to capture certain "implicit behaviors". A principled constructive model is proposed that explains these behaviors and brings new managerial insights. The model prescribes actions that account for the subjective stopping time, and can be further reformulated as a recursive compounding model on the probabilities of stopping. We derive relevant theoretical results between compounding model with existing discounted dynamic risk models. Finally, field experiments show the evidences of supporting the compounding model. And an illustrative example of technology search problem shows the impacts of compounding on decision-making problems.

Keywords: Risk measure; Discount factor; Cash flow analysis; Optimal stopping

## $14{:}10\ to\ 14{:}35\ \textbf{Portfolio}\ \textbf{Diversification}\ based on Stochastic Dominance and Relaxed Comonotonicity$

Speaker: Mingsong Ye, Stevens Institute of Technology

Second-order Stochastic dominance (SSD) is a widely known concept about risk aversion, that is, the preferred random variable is one that has a better expected utility than another random variable across all concave non-decreasing functions. While various empirical optimization approaches (see, Dentcheva and Ruszczynski, 2007; Kuosmanen, 2004; Kopa and Post, 2011) have been developed to find a portfolio that dominates a benchmark based on SSD, they may not reflect its theoretical

superiority in real-life applications, possibly due to the sensitivity to empirical distribution accuracy, particularly in highdimensional asset return estimation. To address this issue, we propose a quantitative relaxation of the comonotonicity assumption and examine the trade-off between risk caused by sampling and the comonotonicity to the benchmark. We also investigate the impact of comonotonicity on the utility function with respect to SSD constraints. The comonotonicity assumption in SSD diversification coincidences the risk sharing concept in economics and actuarial science (see, Mao and Wang, 2019). Finally, the authors demonstrate a risk aversion frontier in an empirical study based on the quantitative relaxation of comonotonicity.

Keywords: stochastic dominance; portfolio choice; comonotonicity; empirical optimization

#### 14:35 to 15:00 Comparisons of Mean-Variance Analysis and Entropy-Based Approaches to Portfolio Selection Under Asymmetric Returns in Bear and Bull Markets Speaker: Leonard MacLean, Dalhousie University

Coauthors: Yonggan Zhao

This paper considers dynamic portfolio selection models where uncertainty in the financial market is characterized by business cycles. We assume that the financial market is defined by factors and present a regime switching autoregressive model for macro-economic factors to reflect financial cycles. It is assumed that the regime dynamics are Markovian and the parameters in the autoregressive model depend on regime dynamics. We then define a factor model for asset returns, with returns depending on regimes through the factors. The joint distribution of regimes and asset returns is the input to optimal portfolio selection models. Contrasting approaches to risk measurement of returns on investment are variance and exponential Rényi entropy. We compare portfolio models with minimum variance and minimum entropy objectives. Portfolio decisions are constrained with the wealth surplus being greater than or equal to the shortfall over a target and the probability of shortfall being less than or equal to a specified level. In the empirical analysis, we use the select sector ETFs to test the asset pricing model and examine the portfolio performance. Weekly financial data from 31 December 1998 to 30 December 2018 is employed for the estimation of the hidden Markov model including the asset return parameters, while the out-of-sample period from 3 January 2019 to 30 April 2022 is used for portfolio performance testing. It is found that, under both the empirical Sharpe and return to entropy ratios, the dynamic portfolio strategy with the entropy objective is an improvement on mean variance models.

Keywords: Portfolio selection; Mean-variance; Entropy; Regimes

Paper Session Monday 13:20 to 15:00

## Critical Applications and Algorithmic Developments

Chaired by Raian Noufel Lefgoum

### 13:20 to 13:45 Proactive Border Resource Staging via Stochastic Programming

Speaker: Fatemeh Farajzadeh, Worcester Polytechnic Institute (WPI)

Coauthors: Andrew C. Trapp

The world is amid unprecedented international migration, with total forced displacements now exceeding 100 million people in 2023. This is a significant (13%) increase over the previous year and is largely due to persecution, conflict, violence, and human rights that few would have expected even a decade ago [1]. Many are externally displaced asylum seekers and refugees pursuing protection by crossing international borders. There are significant operational challenges in addressing the movement and volumes of migrant flows at national borders. And, while border operations personnel must necessarily consider security, a large majority of countries worldwide are signatories to the 1951 Refugee Convention and its 1967 Protocol, declaring the paramount importance of refugee welfare [2]. We formulate a two-stage stochastic program that informs cost-minimizing decisions to locate processing facilities and preallocate critical and scarce support resources at national borders, while considering fairness measures that balance short-term expected needs with longer-term planning. This study is positioned among the growing body of dynamic facility location models that progressively adjusts location decisions and introduces an unexplored form of interplay between location, resource allocation, and time in managing complex emergencies. We account for uncertain and fluctuating flows through a set of probability-weighted scenarios that are generated using United States Customs and Border Protection (CBP) data on encounters at the southern border. Our proposed, proactive framework improves strategic and operational resource allocation for migrant flows at international borders.

References [1] United Nations High Commissioner for Refugees. Mid-Year Trends. In: UNHCR Technical Report. Available: https://www.unhcr.org/mid-year-trends.html. [2] The 1951 Convention relating to the Status of Refugees and its 1967 Protocol. In: UNHCR Technical Report.

Keywords: Stochastic Programming; Border Operations; Humanitarian; Analytics;

13:45 to 14:10 **Optimization with Superquantile Constraints: A Fast Computational Approach** Speaker: Ying Cui, University of Minnesota / University of California, Berkeley

Coauthors: Jake Roth

We present an efficient and scalable second-order computational framework for solving large-scale optimization problems with superquantile constraints. Unlike empirical risk models, superquantile models have non-separable constraints that make typical first-order algorithms difficult to scale. We address the challenge by adopting a hybrid of the second-order semismooth Newton method and the augmented Lagrangian method, which takes advantage of the structured sparsity brought by the risk sensitive measures. The key to make the proposed computational framework scalable in terms of the number of training data is that the matrix-vector multiplication in solving the resulting Newton system can be computed in a reduced space due to the aforementioned sparsity. The computational cost per iteration for the Newton method is similar or even smaller than that of the first-order method. Our developed solver is expected to help improve the reliability and accuracy of statistical estimation and prediction, as well as control the risk of adverse events for safety-critical applications.

14:10 to 14:35 Multistage stochastic optimization of an elementary hydrogen infrastructure Speaker: Raian Noufel Lefgoum, CERMICS and PERSEE

Coauthors: Raian Noufel Lefgoum, Pierre Carpentier, Jean-Philippe Chancelier, Michel De Lara, Laurence Grand-Clément

Hydrogen displays promising features for decarbonization industry, transportation and building sectors. The desired transition towards a hydrogen economy requires hydrogen costs to come down, through optimal choices of infrastructure design and operation. Most of the literature models hydrogen problems in a deterministic manner and solves them using linear programming. In this talk, we present an approach based on multistage stochastic optimization mixing design choices with operational decisions taken on an hourly basis.

We consider an elementary hydrogen infrastructure which consists of an electrolyzer, a compressor and a storage to serve a transportation demand. This infrastructure is powered by three sources of energy (on site photovoltaics, renewable electricity

Keywords: Stochastic optimization, Hydrogen infrastructure control, Dynamic programming

14:35 to 15:00 Open

## **Operational Applications**

Chaired by Margarita Castro

# 13:20 to 13:45 Dynamic Chance Constraints for Stochastic Capacitated Lot Sizing Problems Speaker: Azadeh Farsi, University of Arizona

Coauthors: Azadeh Farsi, Jianqiang Cheng, Boshi Yang

The economic lot-sizing problem is a production planning problem that seeks to find the optimal production plan over a certain number of periods that satisfies demand at the lowest cost. In practice, future demand is often uncertain, and dynamic uncertainty strategies are useful in addressing this issue. One approach to solving dynamic problems is through affine decision rules, which relate decisions to the revealed uncertainties. This presentation focuses on the dynamic capacitated lot sizing problem and examines both individual and joint chance constraint cases to guarantee demand satisfaction. We develop a deterministic reformulation for the individual chance constraint, while applying the Partial Sample Average Approximation method to obtain an approximate deterministic formulation for the joint chance constraint. To solve the obtained mixed-integer nonlinear approximation, we develop a sequential convex approximation algorithm. Through numerical tests, we demonstrate that our proposed dynamic model is superior to the static model in terms of cost-effectiveness in meeting demand satisfaction requirements.

Keywords: Dynamic lot-sizing; Chance Constraint; Partial Sample Average Approximation

## 13:45 to 14:10 Using Empirical Bayes for Inventory Problems with Poisson Demand

Speaker: Eddie Anderson, Imperial College Business School

Coauthors: Nam Ho-Nguyen, Peter Radchenko

The fundamental problem for inventory management is to adjust inventory levels to achieve the right trade-off between the costs of holding inventory and the costs of a stockout. This requires knowledge of the distribution of demand, which is obtained through looking at the history of demand for this product. We are interested in how much inventory to hold for each of a large number of different items when each item has demand which occurs as a Poisson process, and where the rate parameter for each item is estimated on the basis of past demand. This problem matches that faced by a book retailer. We will use an empirical Bayes approach that does not require a prior distribution for the demand rates to be specified in advance, but instead makes use of the entire set of observations to make deductions about the prior. We show the effectiveness of this approach, and by looking at some asymptotic cases we demonstrate the importance of making a full estimate of probabilities rather than just the rate parameter. There are a number of computational choices that need to be made when applying these ideas in practice and we make some recommendations. In practical inventory applications two questions naturally arise: should the data be grouped together according to characteristics of the items; and what should be done when there are trends over time.

Keywords: Empirical Bayes; Inventory; Poisson demand

## 14:10 to 14:35 A Two-Stage Stochastic Programming for Constructing Volume Accumulation Curves for Amazon Middle Mile Truck Scheduling

Speaker: Martin Bagaram, Amazon.com

Coauthors: Sam Hansen, Shauna Robertson, Bryan Maybee, Ted Pantelidis, Meltem Ozmadenci

Volume accumulation curves describe how volume is accumulating over time on a given lane defined as a tuple of origin, destination, and latest departure time, to be loaded onto trucks at fulfillment centers and sort centers. The prediction of these curves is used in Amazon middle mile truck scheduling, such that a truck is planned to depart only when enough volume is expected to accumulate to fill it. However, the actual volume accumulation is highly uncertain and a poor prediction of the curves' pattern has detrimental effects: A volume accumulation curve predicted to the left of the actual leads to 'too early truck placement' with trucks departing almost empty, whereas a right shifted curve increases package dwell at the origin

and deteriorates the chance to meet the demand at the downstream site. In this document, we expose a novel approach to create synthetic volume accumulation curves that are robust to the aforementioned issues that predicting curves poses. The approach relies on developing a two-stage stochastic programming model where, in the first stage, we schedule equipment on each lane without the full knowledge of the forecasted volume and how it will accumulate; in the second stage, we can take two recourse actions: a-) schedule cancellations if the actual volume does not warrant scheduling an equipment at a given time, and b-) schedule additional trucks if the materialized volume requires more equipment than what was scheduled in the first stage or there were too many cancellations. However, there is a cost for cancellation and addition of trucks. In addition, we penalize the miss of meeting demand at downstream site. Finally, we transform the first stage decision variables into expected volume that we interpolate to obtain volume accumulation curves.

Keywords: truck scheduling; supply chain; uncertain supply; e-commerce

## 14:35 to 15:00 Incorporating Service Reliability in Multi-depot Vehicle Scheduling: A Chance-Constrained Approach

Speaker: Margarita Castro, Pontificia Universidad Católica de Chile

Coauthors: Margarita P Castro, Merve Bodur, Amer Shalaby

The multi-depot vehicle scheduling problem (MDVSP) is one of the main planning problems for transit agencies. However, only few works in the literature consider travel time uncertainty and its impact on the service quality for the users. We present a novel stochastic variant of the MDVSP that guarantees service reliability, measured by on-time performance (OTP) at route terminals. We propose a chance-constrained programming model for this problem and two different optimization approaches to solve it. The first one is an exact approach based on a branch-and-cut procedure. The second approach is a heuristic algorithm based on Lagrangian decomposition that utilizes our exact methodology to solve each sub-problem. We test our procedure on randomly generated and real-world instances based on the city of Halifax, Canada. Our experimental evaluation shows the value of our stochastic variant to achieve OTP when compared to alternatives currently used by practitioners, as well as the computational advantages of our methodologies and their theoretical guarantees.

Keywords: chance constraints; vehicle scheduling; transportation

# Hydropower planning and scheduling: Practical experiences and methodology advances

Organized by Stein-Erik Fleten

### 15:20 to 15:55 Better Bidding of Hydroelectric Plants at Aneo

Speaker: Kristine Klock Fleten and Stein-Erik Fleten, Aneo, and Norwegian University of Science and Technology

Coauthors: Ellen K Aasgard, Stein-Erik Fleten, Hanne H Grøttum, Odd-Erik Gundersen, Liyuan Xing

Aneo is the first Nordic power company to apply stochastic programming as decision support for day-ahead bidding of hydropower. Although there is a long history of applying stochastic programming to hydropower scheduling, such methods have so far mostly been applied to medium and long-term planning. For short-term scheduling, however, stochastic programming methods have been defined and tested in the literature but have so far not gained too much traction in industrial settings. However, in later years, it has been recognized that inflow and price have significant variations also within the 2-week period covered by most short-term models. This is specifically important for bid generation, i.e. the daily process where hydropower producers determine their bids to the day-ahead market. This paper describes the experiences of applying the stochastic version of SINTEF Energy's SHOP (Short-term Hydro Optimization Program) to hydropower bidding at Aneo. The implementation process has entailed technical challenges such as modelling choices and opportunities/limitations in the optimization model, how to create high quality, feasible and explainable bids as well as the technical integration to operative systems used for hydropower scheduling. This paper describes the steps made to create bids from stochastic optimization which, to secure feasibility and robustness, must be post-processed. The paper also explores the experiences of deploying a stochastic-programming-based bidding in practice on an industrial scale. Additionally, changing current practice requires dedicated and continuous work efforts to explain and internalize the mathematical and performance characteristics of stochastic-programming-based bidding compared to the existing method, and, from that, establish confidence in the new bidding process.

Keywords: electricity market offering; hydroelectric scheduling; practical experience

# 15:55 to 16:20 Randomized symplicial approximate stochastic dynamic programming approaches for the mid-term operations of hydropower systems

Speaker: Luckny Zephyr, Laurentian University

Coauthors: Bernard F. Lamond, Kenjy Demeester, Marco Latraverse

We propose a randomized simplicial approximate dynamic programming scheme to tackle hydropower management problems. The proposal is based on a Monte Carlo version of a previous simplicial methodology we developed a few years ago. The original method was plagued by its exponential complexity and would be hardly applicable to even modest size problems. The new proposal alleviates this issue by avoiding keeping track of a potentially large list of created simplices; instead, at each iteration, a simplex is randomly selected to locally improve the approximation of the underlying cost-to-go function. Both theoretical and industrial results confirm the superiority of the improved approach in terms of computation time and accuracy.

Keywords: Approximate dynamic programming; simplex; Monte Carlo simulation

#### 16:20 to 16:45 Adaptive distributionally robust optimization for long-term hydropower scheduling

Speaker: Mari Haugen, SINTEF Energy Reserach/NTNU

Coauthors: Mari Haugen, Hossein Farahmand, Stefan Jaehnert, Stein-Erik Fleten

To properly value hydropower flexibility in future decarbonized power systems, a detailed description of the hydropower assets and short-term variations, in addition to the long-term uncertainty in hydro inflows, will become more important. Formulating the long-term hydrothermal scheduling problem as a two-stage stochastic linear problem solved in a rolling horizon using Benders' decomposition has been proposed to better value this flexibility compared to traditional approaches. However, the number of scenarios in the scenario fan must be limited to obtain a tractable model, and the most extreme scenarios that are included will impact the operational strategy for the reservoirs. The approaches based on stochastic programming operate under the premise that the underlying probability distributions are accurately identified, even though the scenarios themselves may be inherently uncertain. To ensure the robustness of the scheduling scheme, Robust Optimization (RO) defines an uncertainty set that encompasses all uncertain variables and optimizes for the worst-case scenario within the set. Consequently, RO results could be conservative. Distributionally Robust Optimization (DRO) seeks to strike a balance between the conservative approach of RO and stochastic optimization by identifying the worst possible probability distribution within a family of distributions and performing optimization within this ambiguity set. In addition, stochastic optimization models that minimize expected values may result in reservoirs being managed quite aggressively. DRO formulation will be more risk averse toward emptying reservoirs as the worst-case average cost over all distributions is minimized. In this work, we explore how the distributionally robust formulation of the two-stage scenario fan problem affects the long-term strategy for hydropower reservoirs. We also evaluate if this formulation can improve the strategy and give more realistic operation of hydropower reservoirs.

Keywords: Distributionally robust optimization, hydropower scheduling,

#### 16:45 to 17:10 Handling the Impact of Climate Change in the Long-Term Generation Scheduling Problem via Distributionally Robust SDDP

Speaker: Renata Pedrini, Federal University of Santa Catarina / The Ohio State University

Coauthors: Guzin Bayraksan, Erlon Cristian Finardi, Felipe Beltràn

The long-term generation scheduling (LTGS) problem presented important developments over the years. In this work, we analyze different risk aversion strategies for handling the impact of climate change in the LTGS problem in hydro-dominated power systems using stochastic dual dynamic programming (SDDP). Despite the advances in modeling and solution strategy, there are important issues related to the distributions of inflows (and other random variables), especially with climate change. First, even though time series or other statistical methods are used to model these random parameters, the true probability distribution is never fully known. Furthermore, historical values used to devise the statistical models may no longer be valid as processes shift. We focus on solutions to mitigate these issues protecting the system from deviations from the inflow scenario distribution, achieved by a Distributionally Robust Optimization (DRO) framework. Instead of a single distribution, DRO considers all distributions that are sufficiently close to this nominal distributions. DRO is more realistic because it explicitly considers existing data while recognizing that forecasts may contain errors. The DRO policies are tested against risk-neutral (expected value minimization) and CVaR risk-averse approaches using data from the Brazilian power system. Policies are compared as well as the practical application of different algorithms. The results indicate that incorporating DRO improves the out-of-sample performance of policies.

Keywords: SDDP; climate change; long-term generation scheduling problem;

Mini-symposium Monday 15:20 to 17:10

## Wildfire Prevention and Infrastructure Adaptation

Organized by Amelia Musselman

## $15:20 \ {\rm to} \ 15:55$ Reliability assessment of critical infrastructure under hybrid outages using robust optimization

Speaker: Ignacio Aravena, Lawrence Livermore National Laboratory

Coauthors: Ignacio Aravena, Heather Scott, Mike Nygaard

The reliability and security of critical infrastructure systems is typically assessed in terms of their ability to withstand unforeseen events or adversarial manipulations under normal operational conditions. The increasing frequency of extreme weather events affecting critical infrastructure in recent years have made this type of assessment insufficient, as infrastructure might have different and more severe failure modes when already weaker than in normal conditions. In this work, we propose metrics to quantify the effects of extreme events on reliability. In particular, we focus on electric power systems and study two metrics of reliability effects of extreme events: (i) increase in impact of worst-case failure modes due to the extreme event, and (ii) worst-opportunistic failure mode impact difference, where worst-opportunistic refers to the failure mode that presents the largest difference in impact between normal conditions and under the extreme event. We find worst-case failure modes by formulating and solving bilevel models, similar to attacker-defender, but with the structure  $max_x(min_yf(x, y) - min_zg(x, z))$ , which are also reformulated as single-level problems. We test these models using synthetic instances for ice storms in Texas and wildfires in California. We find that while widespread extreme events mostly increase the effects of worst-case failures, localized extreme events can significantly amplify the effects of worst-opportunistic failures modes, suggesting the need for continuous reliability and security monitoring in real-time, whenever there is a high-likelihood of infrastructure weakening from extreme events.

15:55 to 16:20 **Optimal Power System Topology Control Under Uncertain Wildfire Risk** Speaker: Kaarthik Sundar, Los Alamos National Laboratory

Coauthors: Deepjyoti Deka, Yuqi Zhou, Hao Zhu

Wildfires pose a significant threat to the safe and reliable operation of electric power systems. They can quickly spread and cause severe damage to power infrastructure. To reduce the risk, public safety power shutoffs are often used to restore power balance and prevent widespread blackouts. However, the unpredictability of wildfires makes it challenging to implement effective counter-measures in a timely manner. In this talk, we shall formulate an optimization-based topology control problem as a solution to mitigate the impact of wildfires. The goal is to find the optimal network topology that minimizes total operating costs and prevents load shedding during power shutoffs under uncertain line shutoff scenarios caused by uncertain spreading wildfires. The solution involves solving two-stage stochastic mixed-integer linear programs, with preventive and corrective control actions taken when the risk of a wildfire and corresponding outage line scenarios are known with low and high confidence, respectively. The Progressive Hedging algorithm is used to solve both problems. The effectiveness of the proposed approach will be demonstrated using data from the RTS-GMLC system that is artificially geo-located in Southern California, including actual wildfire incidents and risk maps. Our work provides a crucial study of the comparative benefits due to accurate risk forecast and corresponding preventive control over real-time corrective control that may not be realistic.

Keywords: Topology control, wildfire, line outage failures, stochastic optimization

#### 16:20 to 16:45 **Power System Wildfire Risk Minimization under Stochastic Wildfire Disruptions** Speaker: Noah Rhodes, University of Wisconsin-Madison

Coauthors: Hanbin Yang, Haoxiang Yang, Line Roald, Lewis Ntaimo

As climate change evolves, wildfire risk is increasing globally, posing a growing threat to power systems, with grid failures fueling the most destructive wildfires. During high-wildfire risk operations, preemptive de-energization of equipment is an effective tool to mitigate the risk of igniting wildfires . However, these actions can have significant impacts on customers with power outages lasting for days. Optimizing the tradeoff of wildfire risk reduction and customer power outages can greatly improve outcomes. Previous works have developed deterministic models for maximizing wildfire risk reduction through equipment de-energization, while minimizing customer power outages. However, deterministic models do not fully capture the wildfire risk. We propose a novel framework for planning preemptive de-energization of power systems to mitigate wildfire risk and damage. We model wildfire disruptions as stochastic disruptions with random magnitude and timing and formulate a two-stage stochastic program that maximizes the electricity delivered while proactively reducing the risk of wildfires by selectively de-energizing components over multiple time periods. We also develop a decomposition algorithm to efficiently solve this problem and generate adaptive de-energization plans before a disruption occurs. Our method is tested on an augmented version of the synthetic RTS-GLMC test case, with geographic coordinates in Southern California, and we compare the solutions' against two benchmark cases. We find that our method reduces both wildfire damage costs and power outages over multiple time periods, and our nominal plan is robust against the uncertainty model perturbation.

Keywords: Optimal Power Flow; Wildfire Risk; Lagrangian Cut; Stochastic MILP;

## $16:45 \ {\rm to} \ 17:10 \ {\rm A} \ {\rm Two-Stage} \ {\rm Risk-Averse} \ {\rm Stochastic} \ {\rm Programming} \ {\rm Model} \ {\rm for} \ {\rm Integrated} \ {\rm Wildfire} \ {\rm Fuel} \ {\rm Treatment} \ {\rm and} \ {\rm Initial} \ {\rm Response} \ {\rm Planning}$

Speaker: Lina M. Villa-Zapata, Texas A&M University

Coauthors: Lewis Ntaimo

Fuel accumulation contributes to high risk of intense and extensive wildfires. Fuel reduction programs such as prescribed burning, thinning, or mechanical mowing can help to reduce hazardous fuels. Fuel treatment planning plays an important role in fire management to protect life and property. However, selecting the optimal locations for each treatment option is challenging when considering uncertainty in vegetation growth, weather, and fire behavior. This work integrates fuel treatment planning and deployment of fighting resources to operations bases to minimize wildfire risk. We consider a twostage risk-averse stochastic programming model targeted at grassland regions. Given a target level of damage cost, the objective is to minimize the expected excess over this level. Fuel treatment options and deployment of resources are decided in the first stage before fires occur, while operational decisions are made in the second stage regarding the optimal mix of resources to dispatch to multiple fires when they occur. We parameterize our model through vegetation growth and wildfire impact simulation using standard wildfire behavior software. This model allows managers to assemble information from possible future fires to make data-driven strategic fuel treatment and operational fire response decisions under uncertainty. In this talk, we report on the implementation and application of our model to historical data for a study area in West Texas under different weather scenarios.

Keywords: Risk-averse stochastic programming; wildfire risk; fire behavior

Mini-symposium Monday 15:20 to 17:10

## Algorithms and models for the energy transition

Organized by Stein W. Wallace

## 15:20 to 15:55 Models and algorithms for stochastic planning in the energy transition Speaker: Asgeir Tomasgard, NTNU

This presentation gives an overview of some of the challenges in stochastic energy planning for the energy transition. We look at both multiscale formulations, sector coupling and integrated models as well as multilevel or gaming formulations. Often energy models for the energy transition include both long-term decisions, related to investments or capacity expansion, as well as short-term decisions that are related to how to operate the energy system. When stochastic programming with recourse is used, it is possible to include both short-term and long-term uncertainty. One example of such multiscale approache with uncertainty in both horizons, is multistage, multihorizon stochastic programming. We look at both formulations and algorithms. Another aspect with high importance in the energy transition is sector coupling. With an increased share of intermittent renewables in the energy system, increased flexibility is achieved by planning for several energy sources and carriers in integrated models, like electricity, natural gas and hydrogen. Sector coupling may also be achieved by addressing waste management, water management, and the thermal heating systems in buildings in integrated approaches. Often energy system models assume perfect competition or similarly that a central planner makes decisions that maximizes the social surplus for society. Another approach is to recognize that decisions may be made by several players and that some of these may act strategically. This often leads to stochastic complementarity models with simultaneous decisions or bilevel models with sequential decisions by different agents.

Keywords: energy transition, multiscale, multilevel

### 15:55 to 16:20 A stochastic, two-level optimization model for compressed natural gas infrastructure investments in wastewater management

Speaker: Steven A. Gabriel, University of Maryland

Coauthors: Steven A. Gabriel, Chalida U-tapao, Seksun Moryadee

In this presentation, we present a stochastic two-level optimization model whose upper-level problem depicts a wastewater treatment plant deciding on the size of compressed natural gas (CNG) filling stations and their locations. These upper-level decisions are integrated with operational decisions for the plant as well as downstream markets including agriculture, CNG transportation, residential natural gas, and electricity markets at the lower level. The top-level problem is a stochastic program with recourse. The overall two-level problem, expressed as a stochastic mathematical program with equilibrium constraints (SMPEC), is reformulated as mixed-integer linear program (MILP) using SOS1 transformations and linearizations. As a case study, the SMPEC is used to evaluate the options for CNG investment for a wastewater treatment plant located in the Washington, DC metro area. Our results indicate that the CNG produced from the wastewater treatment plant could meet approximately 20% of the expected total transportation demand in Washington, DC. In addition, CNG produced from the wastewater treatment plant could reduce CO2 emissions by a significant amount. The CNG benefits are traded off with less on-site wastewater-derived power production.

Keywords: Bilevel optimization; stochastic; MPEC; sustainability

#### 16:20 to 16:45 High dimensional SDDP: A Hydrothermal Scheduling problem Speaker: Vitor de Matos, Norus

Coauthors: Paulo Vitor Larroyd, Erlon Cristian Finardi, Felipe Beltán, Lucas Borges Picarelli

The use of stochastic programming (SP) models play an important role in energy systems with renewable resources, as the number of storages and their relevance to the system operation increases (hydro power plants with reservoirs and large batteries, for instance) we face a multi-stage stochastic dynamic programming (SDP) problem. In this case, each storage is a state at any given stage for the SDP, this leads to the well-known curse of dimensionality. In 1991, Pereira and Pinto proposed a novel algorithm named Stochastic Dual Dynamic Programming (SDDP), in which we build a linear piecewise approximation of the future in a set of states that we might be interested instead of using the partition of the state space. There are several practical applications of the SDDP algorithm, and the Brazilian Long-Term Hydrothermal Scheduling (LTHS) is one of them.

In 2023 the Brazilian power system has 160 hydro power plants with at least 30 MW of installed capacity, in which 41 of them have reservoirs larger than 1000 hm3. The official models for the Brazilian LTHS, NEWAVE, considers an aggregation of the hydro plants into Energy Equivalent Reservoirs (EER), the hydro plant used to be aggregated into 4 EERs and they are now group in 12 EERs. The increased number of reservoirs comes from the growth of computer processing power, but also from the evolution of the algorithm to be more effective when building the policy (future cost approximation). In this paper aim at solving the Brazilian LTHS considering individual hydro plants, and we focused our efforts on additional strategies that may help the effectiveness of SDDP.

Therefore, we present our proposed strategies and compare our simulations to the official results, the latter is computed in a rolling horizon framework. We show that it is possible to obtain good results in a limited amount of computational time, this is extremely useful practical cases. However, we were not able to measure the quality of the computed policy.

Keywords: Hydrothermal Scheduling; SDDP; Dynamic Programming

# 16:45 to 17:10 Integrated investment, retrofit and abandonment planning of energy systems with short-term and long-term uncertainty using enhanced Benders decomposition Speaker: Asgeir Tomasgard, Norwegian University of Science and Technology

Coauthors: Ignacio E. Grossmann, Brage Rugstad Knudsen, Ken McKinnon, Rodrigo Garcia Nava, Hongyu Zhang

We first present the REORIENT (REnewable resOuRce Investment for the ENergy Transition) model for energy systems planning with the following novelties: (1) integrating capacity expansion, retrofit and abandonment planning, and (2) using multi-horizon stochastic mixed-integer linear programming with short-term and long-term uncertainty. The model is then applied to the European energy system considering: (a) investment in new hydrogen infrastructures, (b) capacity expansion of the European power system, (c) retrofitting oil and gas infrastructures in the North Sea region for hydrogen production and distribution, and abandoning existing infrastructures, and (d) long-term uncertainty in oil and gas prices and short-term uncertainty in time series parameters. We utilise the special structure of multi-horizon stochastic programming and propose an enhanced Benders decomposition to solve the model efficiently. We first conduct a sensitivity analysis on retrofitting costs of oil and gas infrastructures. We then compare the REORIENT model with a conventional investment planning model regarding costs and investment decisions. Finally, the computational performance of the algorithm is presented. The results show that: (1) when the retrofitting cost is below 20 percent of the cost of building new ones, retrofitting is economical for most of the existing pipelines, (2) platform clusters keep producing oil due to the massive profit, and the clusters are abandoned in the last investment cost in the North Sea region, and (4) the enhanced Benders algorithm is up to 6.8 times faster than the reference algorithm.

Keywords: Integrated energy system planning; Multi-horizon stochastic programming

## Theory and Applications of Robust and Stochastic Optimization

Organized by Weijun Xie

## 15:20 to 15:55 Data-Driven Stochastic Dual Dynamic Programming: Performance Guarantees and Regularization Schemes

Speaker: Hyuk Park, University of Illinois Urbana-Champaign

### Coauthors: Zhuangzhuang Jia, Grani A. Hanasusanto

We propose a data-driven scheme for multistage stochastic linear programming with Markovian random parameters by extending the stochastic dual dynamic programming (SDDP) algorithm. In our data-driven setting, only a finite number of historical trajectories are available. The proposed SDDP scheme evaluates the cost-to-go functions only at the observed sample points, where the conditional expectations are estimated empirically using kernel regression. The scheme thus avoids the construction of scenario trees, which may incur exponential time complexity during the backward induction step. However, if the training data is sparse, the resulting SDDP algorithm exhibits a high optimistic bias that gives rise to poor out-of-sample performances. To mitigate the small sample effects, we adopt ideas from the distributionally robust optimization (DRO), which replaces the empirical conditional expectation in the cost-to-go function with a worst-case conditional expectation over a polyhedral ambiguity set. We derive the theoretical out-of-sample performance guarantee of the data-driven SDDP scheme and demonstrate its effectiveness through extensive numerical experiments.

Keywords: MSLP; SDDP; DRO; Nadaraya-Watson; Markov dependence

### 15:55 to 16:20 First-order distributionally robust optimization

Speaker: Shimrit Shtern, Technion - Israel Institute of Technology

#### Coauthors: Shimrit Shtern

In this work, we show how distributionally robust linear optimization based on Wasserstein-type ambiguity sets can be solved using first order methods. We consider one- and two-stage optimization, with and without relatively complete recourse. When any first stage solution is feasible (relatively complete recourse), we show how existing first-order algorithm can be used to solve the problem for the case where the number of data points is known in advance and for the case where the data arrives in an online fashion. We also provide probabilistic guarantees for the latter. For the case, where with non-complete recourse we discuss possible ways of approximating feasible solutions, using first order methods.

Keywords: Distributionally robust optimization, online mirror descent

# 16:20 to 16:45 A Stochastic Conjugate Subgradient Algorithm for Kernelized Support Vector Machines

Speaker: Di Zhang, University Of Southern California

#### Coauthors: Suvrajeet Sen

Kernel Support Vector Machines (Kernel SVM) provide a powerful set of tools for classifying data whose classes are best identified via a nonlinear function. While a Kernel SVM is usually treated as a Quadratic Program (QP), its solution is usually obtained using stochastic gradient descent (SGD) which needs to know all the data points at the beginning. In this presentation, we treat the Kernel SVM as a Stochastic Quadratic Linear Programming (SQLP) problem which motivates a decomposition- based stochastic conjugate subgradient (SCS) algorithm that can be effective for classification of streaming data. We will present this new class of methods, and discuss its mathematical structure and properties. We will also present computational evidence which illustrates that the method maintains the scalability of SGD, while improving the accuracy of classification/optimization.

Keywords: Kernelized SVM, Stochastic Programming, Non-Smooth Convex Optimization

## 16:45 to 17:10 The Terminator: An Integration of Inner and Outer Approximations for Solving Regular and Ambiguous Chance Constrained Programs via Variable Fixing

Speaker: Weijun Xie, Georgia Institute of Technology

Coauthors: Nan Jiang

We present a novel approach to enhance the effectiveness of solving regular and ambiguous chance constrained programs with an empirical reference distribution. These programs can be, in general, reformulated as mixed-integer programs (MIPs) by introducing binary variables for each scenario, indicating whether a scenario should be satisfied. While existing methods have focused on either inner or outer approximations, this paper bridges this gap by proposing a scheme that effectively combines these approximations through variable fixing. By probing the restricted outer approximations and comparing them with the inner approximations, we derive optimality cuts that significantly reduce the number of binary variables, fixing them to either one or zero. Our numerical results demonstrate the clear advantages of our approach in terms of computational time and solution quality.

Keywords: Chance Constraint, CVaR, Distributionally Robust, Conservative Approximation

#### Mini-symposium Monday 15:20 to 17:10

## Recent Advances in Decision-Making Under Uncertainty

Organized by Karmel S. Shehadeh, Yiling Zhang

### 15:20 to 15:55 Residuals-Based Contextual Stochastic Programming

Speaker: Güzin Bayraksan, The Ohio State University

Coauthors: Rohit Kannan, Jim Luedtke

We consider data-driven approaches that integrate a machine learning prediction model within stochastic programming, given joint observations of uncertain parameters and covariates. Given a new covariate observation, the goal is to choose a decision that minimizes the expected cost conditioned on this observation. We first examine a Sample Average Approximation (SAA) approach for approximating this problem and examine its asymptotic and finite-sample properties. Then, in the limited-data regime, we consider Distributionally Robust Optimization (DRO) variants of these models. Our framework is flexible in the sense that it can accommodate a variety of learning setups and DRO ambiguity sets. We investigate the asymptotic and finite sample properties of solutions obtained using Wasserstein, sample robust optimization, and phi-divergence-based ambiguity sets and explore cross-validation approaches for sizing these ambiguity sets. Computational experiments validate our theoretical results and demonstrate the potential advantages of our data-driven formulations.

Keywords: contextual stochastic programming; Sample Average Approximation (SAA)

## 15:55 to 16:20 Distributionally Robust Stochastic Bilevel Linear Programs with Facility Location Applications

Speaker: Yiling Zhang, University of Minnesota

Coauthors: Akshit Goyal, Chuan He

This talk is about a pessimistic distributionally robust two-stage stochastic bilevel program (DRBP) in the context of sequential two-player games, where the leader makes a here-and-now decision, and the follower responds a continuous waitand-see decision after observing the leader's action and revelation of uncertainty. We show that under proper conditions of the ambiguity set, the pessimistic DRBP is equivalent to generic two-stage distributionally robust stochastic (nonlinear) programs (TSDRs) with uncertainties in both the objective and constraints. The conditions can be met with mild assumptions for typical choices of ambiguity sets such as moment-based sets and Wasserstein ball sets. Then we focus on the DRBP under two moment-based sets with binary leader's decision. Under an ambiguity set of continuous distributions, using linear decision rules, 0-1 semidefinite programming (SDP) approximations and an exact 0-1 copositive programming reformulation are derived; under an ambiguity set of discrete distributions, an exact 0-1 SDP reformulation is developed and explicit construction of the worst-case distribution is provided. To further improve the computation of the proposed 0-1 SDPs, a cutting-plane framework is developed. The effectiveness and efficiency of the proposed models and algorithms are demonstrated on a facility location problem.

### 16:20 to 16:45 An inexact column-and-constraint generation (i-C&CG) method to solve twostage robust optimization problems

Speaker: Man Yiu Tsang, Lehigh University

Coauthors: Karmel S. Shehadeh, Frank E. Curtis

We propose a new inexact column-and-constraint generation (i-C&CG) method to solve two-stage robust optimization problems. The method allows solutions to the master problems to be inexact, which is desirable when solving large-scale and/or challenging problems. Furthermore, it is equipped with a backtracking routine that controls the trade-off between bound improvement and inexactness. Importantly, this routine allows us to derive theoretical finite convergence guarantees for our i-C&CG method. Numerical experiments demonstrate the computational advantages of our i-C&CG method over state-ofthe-art column-and-constraint generation methods.

Keywords: Two-stage robust optimization; column-and-constraint generation

53

#### 16:45 to 17:10 Adjustability in Robust Linear Optimization

Speaker: Ningji Wei, Texas Tech University

Coauthors: Peter Zhang

We investigate the concept of adjustability – the difference in objective values between two types of dynamic robust optimization formulations: one where (static) decisions are made before uncertainty realization, and one where uncertainty is resolved before (adjustable) decisions. This difference reflects the value of information and decision timing in optimization under uncertainty, and is related to several other concepts such as interchangeability in games and optimality of decision rules in robust optimization. We develop a theoretical framework to quantify adjustability based on the input data of a robust optimization problem with linear objective, linear constraints, and fixed recourse. We make very few additional assumptions. In particular, we do not assume constraint-wise separability or parameter nonnegativity that are commonly imposed in the literature for the study of adjustability. This allows us to study important but previously under-investigated problems, such as formulations with equality constraints and problems with both upper and lower bound constraints. Based on the discovery of an interesting connection between the reformulations of the static and fully adjustable problems, our analysis gives a necessary and sufficient condition – in the form of a theorem-of-the-alternatives – for adjustability to be zero when the uncertainty set is polyhedral. Based on this sharp characterization, we provide a mixed-integer optimization formulation as a certificate of zero adjustability. Then, we develop a constructive approach to quantify adjustability when the uncertainty set is general, which results in an efficient and tight algorithm to bound adjustability. We demonstrate the efficiency and tightness via both theoretical and numerical analyses.

Keywords: Adjustability; Adjustable Robust Optimization

Plenary

# 17:15 to 18:15 Biodiversity and Climate: a Mathematical Perspective on Sustainability and Resilience

Speaker: Michel De Lara, École des Ponts

The management of biodiversity and climate change is delicate, due to conflicts with economic development, long decision times and pervasive uncertainties. This makes it a relevant area for decision under uncertainty methods. I will provide an overview of the Intergovernmental Panel on Climate Change (IPCC) and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reports, present theory and examples related to sustainability and resilience, and discuss opportunities for the stochastic optimization community.

Keywords: sustainability, resilience, viability, stochastic optimization, risk

Tuesday, July 25

## **Step-sizes and Adaptations**

Organized by Raghu Pasupathy

## 8:30 to 9:05 Adaptive Stochastic Optimization Methods

Speaker: Katya Scheinberg, Cornell University

Coauthors: Albert Berahas, Liyuan Cao, Billy Jin, Miaolan Xie

Recently a variety of stochastic variants of adaptive methods have been developed and analyzed. These include stochastic step search, trust region and cubicly regularized Newton methods. Such methods adapt the step size parameter and use it to dictate the accuracy required or stochastic approximations. The requirements on stochastic approximations are, thus, also adaptive and in principle can be biased and even inconsistent. The step size parameters in these methods can increase and decrease based on the perceived progress, but unlike the deterministic case they are not bounded away from zero. This creates obstacles in complexity analysis of such methods. We will show how we can derive bounds on expected complexity that also apply in high probability. We also show that it is possible to derive a lower bound on step size parameters in high probability for the methods in this general framework.

Keywords: unconstrained optimization, stochastic trust region, step search

## $9{:}05\ {\rm to}\ 9{:}30\ {\rm A}$ novel step size approach for deterministic optimization with an eye towards the stochastic case

Speaker: Vivak Patel, University of Wisconsin – Madison

Coauthors: Vivak Patel, Christian Varner

Robustness in gradient-based optimization algorithms is delivered through line search methods or trust region. However, such approaches are often infeasible for data science problems, as they require multiple objective function evaluations. Motivated by the extreme case of quasi-likelihood models for which objectives are expensive yet gradients are inexpensive, we introduce a novel step-size selection methodology that uses substantially fewer objective function evaluations and can handle non-decreasing steps, yet still has convergence guarantees. In practice, our novel approach works surprisingly well and often outperforms classical approaches even for problems with inexpensive objective function evaluations. We then discuss preliminary efforts to adapt our methodology to the stochastic case.

Keywords: Gradient Methods; Step Size Selection; Data Science

## 9:30 to 9:55 Ranking and Contextual Selection

Speaker: Bernardo Pagnoncelli, SKEMA Business Scholl

Coauthors: Gregory Keslin, Barry L. Nelson, Matthew Plumlee, Hamed Rahimian

The widespread availability of data allowed for numerous applications in the realm of predictive analytics. In the prescriptive analytics setting, different approaches have been appearing recently that try to leverage data to make better decisions. I will present a new ranking and selection method, called ranking and contextual selection, in which covariates provide context for the decisions. The method optimizes over the covariate design points offline, and then given an actual observation of the covariate makes an online decision based on classification. I will show results for a pointwise probability of good selection guarantee and offer a post-assessment of the procedure that is useful for future covariates we hope to classify. I will illustrate the method with an application on assortment optimization using real-world data from Yahoo.

Keywords: Ranking & Selection, contextual optimization, assortment planning

Speaker: Ragu Pasupathy, Purdue University

Coauthors: Akshita Gupta, Raghu Bollapragada, Raghu Pasupathy, Aaron Yip

A folklore *adaptive fixed-step* stochastic gradient algorithm works as follows. Execute stochastic gradient with a fixed step  $\eta > 0$  until the iterates approach *stationarity*; now re-execute stochastic gradient but starting from the final iterate of the previous execution and with the revised fixed step  $\eta \leftarrow \beta_0 \eta, \beta_0 < 1$  until the iterates again approach stationarity, and so on. This restart scheme is attractive on two accounts: (i) it is simple to implement, and (ii) each execution of fixed-step stochastic gradient generates iterates that (provably) attain stationarity *exponentially fast*. A particular version of this scheme was originally conceived by G. Pflug in 1983 and developed further by Yousefian, Niedich and Shanbhag in 2011. And while many enhancements, e.g., SASA (Lang et al., 2019), during 2018–2021 have reported strikingly positive numerical results, the key step of statistically detecting stationarity has remained heuristic. We present the adaptive fixed-step stochastic gradient algorithm, formalized to rigorously subsume various functionals for detecting stationarity along with a parameter that controls testing frequency.

Keywords: stochastic gradient, statistical testing

Mini-symposium Tuesday 8:30 to 10:20

## Structured stochastic optimization and statistical machine learning I

Organized by Guanghui Lan, Krishnakumar Balasubramanian, Saeed Ghadimi

#### 8:30 to 9:05 Computable and Asymptotically Exact Confidence Regions in Stochastic Programming

Speaker: Raghu Pasupathy, Purdue University

Coauthors: Yi Chu

Consider the following canonical problem settings.

(A) unconstrained smooth stochastic optimization, e.g., logistic regression, M-estimation; (B) non smooth convex stochastic optimization, e.g., classification with hinge loss, two-stage stochastic programming; (C) solution to systems of stochastic non linear equations, e.g., Z-estimation; (D) multiobjective simulation optimization; (E) stochastic PDEs.

Under surprisingly weak conditions, the optimal value and optimal solution sequences of the sample-average approximation (SAA) versions of (A)-(E) exhibit a type of process regularity that is described by Donsker's theorem (also known as a "functional CLT"). What is more, the steps to demonstrating such process regularity follow a similar simple pattern in each of (A)-(E). Why is a functional CLT important? First, virtually any random observable sequence converging to an object of interest, and satisfying a functional CLT, can be readily exploited using batching to form asymptotically exact confidence regions that are ?" computable" in a sense that will be described. Second, attainment of iterate stationarity in non-convergent fixed-step gradient algorithms for solving (A)-(E) can be statistically detected in principle, and exploited to construct fast and convergent adaptive fixed step solution algorithms.

Keywords: confidence regions, batching

## 9:05 to 9:30 Low rank approximation for faster optimization

Speaker: Madeleine Udell, Stanford University

Coauthors: Zachary Frangella, Pratik Rathore, Shipu Zhao, Joel Tropp

Low rank structure is pervasive in real-world datasets. This talk shows how to accelerate the solution of fundamental computational problems, including eigenvalue decomposition, linear system solves, composite convex optimization, and stochastic optimization (including deep learning), by exploiting this low rank structure. We present a simple method based on randomized numerical linear algebra for efficiently computing approximate top eigendecompositions, which can be used to replace large matrices (such as Hessians and constraint matrices) with low rank surrogates that are faster to apply and invert. The resulting solvers for linear systems (NystromPCG), composite convex optimization (NysADMM), and deep learning (SketchySGD) demonstrate strong theoretical and numerical support, outperforming state-of-the-art methods in terms of speed and robustness to hyperparameters.

Keywords: randomize numerical linear algebra; preconditioning; stochastic optimization

## 9:30 to 9:55 Robust ReLU Regression via Stochastic Optimization and Local Error Bounds Speaker: Jelena Diakonikolas, UW-Madison

### Coauthors: Ilias Diakonikolas, Puqian Wang, Nikos Zarifis

I will discuss recent results on learning a single neuron with ReLU and other activation functions, in the agnostic (i.e., adversarial label noise) setting. The key ingredient of this work is a surrogate stochastic convex optimization problem that we show can be solved with low sample and computational complexity while achieving near-optimal error guarantees. Our results are enabled by local error bounds from optimization theory that we establish for this problem under mild distributional assumptions that capture sub-exponential, heavy tailed (with polynomial tails), and even some discrete distributions. Surprisingly, for all these distributional families, the constant in the error bound is a constant — independent of the problem dimension. This is quite a rare property to hold for optimization problems: even deterministic convex quadratic optimization problems, which are known to satisfy a local error bound, can have a constant that is exponentially small in the dimension.

Based on joint work with Ilias Diakonikolas, Puqian Wang, and Nikos Zarifis.

Keywords: ReLU regression, local error bounds, sharpness

## $9:55\ {\rm to}\ 10:20\ {\rm High-dimensional}\ {\rm Scaling}\ {\rm Limits}\ {\rm of}\ {\rm Least-square}\ {\rm Online}\ {\rm SGD}\ {\rm Iterates}\ {\rm and}\ {\rm Its}\ {\rm Fluctuations}$

Speaker: Krishnakumar Balasubramanian, UC Davis

Stochastic Gradient Descent (SGD) is widely used in modern data science. Existing analyses of SGD have predominantly focused on the fixed-dimensional setting. In order to perform high-dimensional statistical inference with such algorithms, it is important to study the dynamics of SGD under high-dimensional scalings. In this talk, I will discuss high-dimensional limit theorems for the online least-squares SGD iterates for solving over-parameterized linear regression. Specifically, focusing on the asymptotic setting (i.e., when both the dimensionality and iterations tend to infinity), I will present the mean-field limit (in the form of an infinite-dimensional ODE) and fluctuations (in the form of an infinite-dimensional SDEs) for the online least-squares SGD iterates. A direct consequence of the result is obtaining explicit expressions for the mean-squared estimation/prediction errors and its fluctuations, under high-dimensional scalings.

Keywords: SGD, Inference,

59

#### Mini-symposium Tuesday 8:30 to 10:20

## Optimization Approaches in Estimation

Organized by Stan Uryasev

### 8:30 to 9:05 Distributional Robustness and Coherent Measures of Risk

Speaker: Terry Rockafellar, University of Washington

An important topic now in machine learning and elsewhere is distributional robustness. To guard against an empirical probability distribution being too special, in coming from a generated training set say, worst-case analysis is carried out with respect to a collection of alternative distributions. Proponents seem not fully aware that this prescription exactly characterizes the deployment of coherent measures of risk. For that, there is already a highly developed theory with roots in finance applications in the late 1990s and many explorations in stochastic optimization since.

A particular emphasis of distributional robustness is producing a neighborhood out of some "distance" or "divergence" expression for comparing distributions, such as Wasserstein distance. The wider picture of that will be explained in this talk along with its implications for the fundamental quadrangle of risk.

Keywords: distributional robustness, coherent risk, Wasserstein distance

9:05 to 9:30 Factor Model of Mixtures

Speaker: Cheng Peng, Stony Brook University

#### Coauthors: Stan Uryasev

This paper proposes a new approach to estimating the distribution of a response variable conditioned on observing some factors. The proposed approach possesses desirable properties of flexibility, interpretability, tractability and extendability. The conditional quantile function is modeled by a mixture (weighted sum) of basis quantile functions, with the weights depending on factors. The estimation problem is formulated as a convex optimization problem. It can be viewed as conducting quantile regressions for all confidence levels simultaneously while avoiding quantile crossing by design. The estimation problem is equivalent to minimizing the continuous ranked probability score (CRPS). Based on the canonical polyadic (CP) decomposition of tensors, we propose a dimensionality reduction method that reduces the rank of the parameter tensor and propose an alternating algorithm for estimation. Additionally, based on Risk Quadrangle framework, we generalize the approach to conditional distributions defined by Conditional Value-at-Risk (CVaR), expectile and other functions of uncertainty measures. Although this paper focuses on using tensor product B-splines as the weight functions, it can be extended to neural networks. Numerical experiments demonstrate the effectiveness of our approach.

Keywords: Conditional distribution estimation; convex optimization; quantile regression

## 9:30 to 9:55 Optimization approaches to tailor regression spline for better fit

Speaker: Jun-ya Gotoh, Chuo university

Coauthors: Shotaro Yagishita, Shichen Zuo

B-spline regression is a fundamental device to estimate a nonlinear model through unconstrained convex quadratic optimization. In this talk, several extensions of the estimation will be considered. In particular, we focus on selection of knots by employing a cardinality constraint. A few approaches to the nonconvex optimization problem are considered such as a global optimization via MIP, a proximal gradient method with a continuous (nonconvex nonsmooth) reformulation, and a convex approximation. We will discuss further applications of such sparse optimization formulations.

Keywords: regression spline, selection of knots, generalized trimmed lasso

#### 9:55 to 10:20 Risk-Adaptive Approaches to Learning and Decision Making

Speaker: Johannes O. Royset, Naval Postgraduate School

Uncertainty is prevalent in engineering design, statistical learning, and decision making broadly. Due to inherent riskaverseness and ambiguity about assumptions, it is common to address uncertainty by formulating and solving conservative optimization models expressed using measure of risk and related concepts. We survey the rapid development of risk measures over the last quarter century. From its beginning in financial engineering, we recount their spread to nearly all areas of engineering and applied mathematics. Solidly rooted in convex analysis, risk measures furnish a general framework for handling uncertainty with significant computational and theoretical advantages. We describe the key facts and review several concrete algorithms. The presentation also recalls connections with utility theory and distributionally robust optimization, points to emerging applications areas such as fair machine learning, and defines measures of reliability.

Keywords: Risk measures, optimization, learning

#### Mini-symposium Tuesday 8:30 to 10:20

## Modeling stochastic problems

Organized by Stein W. Wallace

8:30 to 9:05 Issues in Modeling Multistage Problems Speaker: Alan King,

Coauthors: Stein Wallace

This talk addresses two fundamental issues. First, what characteristics of a decision problem require a multistage formulation? This leads us to identify modeling styles unique to stochastic programming and how they relate to alternative models such as stochastic dynamic programs. The second issue concerns the generation of multistage scenario trees. We introduce a forecast-surprise framework based on Doob decomposition and show how it can be used in a flexible manner for decision problems that are unavoidably multistage.

Keywords: multistage; dynamic programming; scenario trees

## 9:05 to 9:30 Modelling multistage problems in Aquaculture Operations

Speaker: Benjamin S. Narum, NHH Norwegian School of Economics

Coauthors: Stein W. Wallace, Julio C. Goez, Geir D. Berentsen

Multistage stochastic models in their basic form are often unwieldy and can entail unreasonably large representations. Simplifications to mitigate this are often based on specific structures and properties in the problem, like short-term memory, horizon approximations, or the like. Operational decisions in Norwegian Salmon Aquaculture are characterized by long memory in decisions and uncertainty, high short-term volatility, and significant capital investments, implying considerable risk exposure. The problem exhibits high sensitivity on horizon approximations and complicated tradeoffs in a heterogeneous portfolio of sites to manage. This requires thorough treatment of modelling assumptions where classic simplifying assumptions seem inappropriate, especially regarding uncertainty. This talk explores how such problems can still be dealt with by exploiting problem structure and making appropriate modelling assumptions. We present a novel multistage stochastic programming model that addresses operational risk management in Norwegian Salmon Aquaculture to account for production and market risk when making harvest plans.

Keywords: multistage; modelling; Aquaculture

9:30 to 9:55 **Open** 

## 9:55 to 10:20 Risk-averse production planning in the aquaculture industry

Speaker: Peter Shütz, Norwegian University of Science and Technology

Coauthors: Andreas Lien

The revenue of farmed salmon depends on the size of the fish with larger fish achieving a higher per kilo price than smaller fish. However, producing larger fish requires more time and the salmon might mature during this period. As the value of mature salmon is reduced by up to 40%, there is an important trade-off to consider between the potential revenue from selling larger fish versus the risk of reduced income due to a salmon of lower quality. We present a two-stage stochastic programming model for tactical production planning of a salmon farmer given uncertainty in growth and maturation. The goal is to determine the optimal timing and amount of smolt deployments and salmon harvesting such that the conditional value-at-risk is optimized. We solve the problem using a column generation approach and present computational results for a real-world case from Northern Norway.

Keywords: CVaR; Column generation; Fish farming

#### Mini-symposium Tuesday 8:30 to 10:20

## Applications of SDDP in Energy

Organized by David Wozabal

# 8:30 to 9:05 Dynamic Hedging of Energy Portfolios with Stochastic Dual Dynamic Programming Speaker: Nils Löhndorf, University of Luxembourg

Trading futures contracts on energy exchanges is a common practice among energy merchants to hedge against price and volumetric risks. Typically, risk management sets hedge targets, and merchants buy and sell futures for multiple overlapping delivery periods to reach those targets. The timing of trades is often based on merchants' intuition who manually adjust their positions as liquidity of tradable products changes over time. Model-based approaches to formally guide this decision-making process are rare, due to the complexity of energy markets and the physical nature of assets involved in energy consumption, production, storage, and transportation. We address this issue by casting the problem of dynamically hedging a portfolio of energy assets as a multistage stochastic programming problem under a dynamic risk measure. Our model accounts for the comovement of marked-to-market price forward curves and operational forecasts, as well as market depth of tradable products. We propose an approach based on stochastic dual dynamic programming to compute dynamic hedging strategies that align with organizational risk preferences. We show how to generate scenario lattices from historical marked-to-market price forward curves and how to derive arbitrage-free futures prices for weekly, monthly, quarterly, and yearly futures contracts. We present results from a backtest that shows our hedging strategies yield better outcomes on the risk-return spectrum than static hedging. In a case study with real company data and historical price data from energy exchanges, we demonstrate the effectiveness of our model in deriving dynamic hedge plans that match a company's risk preferences, and in supporting energy merchants in their day-to-day business decisions.

Keywords: stochastic dual dynamic programming; scenario lattices; energy trading;

## 9:05 to 9:30 Model Predictive Control and Stochastic Dynamic Programming

Speaker: Dominic Keehan, University of Auckland

Coauthors: Andy Philpott, Eddie Anderson

We compare stochastic dynamic programming (SDP) and model predictive control (MPC) as solution approaches to multistage stochastic optimization problems. MPC is frequently employed when the size of the problem renders SDP intractable. It is unclear how this choice affects out-of-sample performance – we study it in the context of an inventory control problem that is driven by random prices. Conditions on the random price samples under which the MPC policy performs at least as well as the SDP policy are derived. Examples are then used to show that MPC can outperform SDP in expectation when the underlying price distribution is right-skewed. We close by showing that MPC is equivalent to a distributional robustification of the SDP problem with a first-moment based ambiguity set.

Keywords: stochastic control; sample average approximation; distributional robustness

### 9:30 to 9:55 Applying High Performance Computing to the European Resource Adequacy Assessment

Speaker: Daniel Felipe Ávila, Université Catholique de Louvain

Coauthors: Anthony Papavasiliou, Mauricio Junca, Lazaros Exizidis

This work considers the European Resource Adequacy Assessment, which is a pan-European resource adequacy process that is being developed by the European Networks of Transmission System Operators for Electricity (ENTSO-E). A critical part of this process is the so-called Economic Viability Assessment model, which aims at determining future expansion and retirement capacity opportunities for the entire European network. As such, the problem is stochastic. Nevertheless, due to computational constraints, simplified approaches have been followed by ENTSO-E. Our work formulates the problem as a two-stage stochastic problem, and proposes two decomposition algorithms for solving the problem which are implemented in a high performance computing infrastructure. The first is a subgradient based algorithm, and the second uses a relaxation of the second stage (the economic dispatch) in order to speed-up the subgradient calculation thus achieves a considerable speed-up in solution time. We compare our schemes against the commonly used Bender's decomposition. We compare the obtained stochastic solution against the deterministic solution proposed by ENTSO-E for their 2021 study and analyze the impact of the stochastic solution on various adequacy indicators.

9:55 to 10:20 Node Aggregation and Parallelization in Stochastic Dual Dynamic Programming Speaker: Erlon Cristian Finardi, Federal University of Santa Catarina (UFSC)

Coauthors: Renata Pedrini, Felipe Beltràn

The proposed work aims to enhance the Stochastic Dual Dynamic Programming (SDDP) algorithm, originally devised for optimizing the Brazilian power system's operation. The conventional approach of SDDP involves solving independent one-stage linear subproblems. To improve the method, this work suggests a node aggregation strategy that breaks down the scenario tree into interconnected subtrees instead of individual nodes. The size of each subproblem is determined by a balance between computational efficiency and solution quality. Additionally, this work combines different aggregation and parallelization techniques. The study applies the SDDP with node aggregation to real data from the Brazilian power system. Although the computational burden per subproblem increases, tighter cuts are obtained when using node aggregation leading to a smaller optimality gap, with a confidence interval reduced by up to 26% compared to the conventional approach, all within the same execution time.

Keywords: SDDP; node aggregation; parallelization

#### Plenary

### 10:40 to 11:40 Stochastic gradient methods beyond smoothness and convexity

Speaker: Dmitry Drusvyatskiy, University of Washington

Coauthors: Damel Davis, Liwei Jiang

Stochastic iterative methods lie at the core of large-scale optimization and its modern applications in data science. Though such algorithms are routinely and successfully used in practice on highly irregular problems, few performance guarantees were available outside of smooth or convex settings until recently. In this talk, I will survey a number of recent results in this area including finite time efficiency estimates, avoidance of extraneous saddle points, and asymptotic normality of averaged iterate

Keywords: subgradient, moreau envelope, saddle point, asymptotic normality

Mini-symposium Tuesday 12:40 to 14:30

## Solution Methods for Distributionally Robust Optimization Problems I

Organized by Francesca Maggioni

## 12:40 to 13:15 Bounding Multistage Mixed-Integer Distributionally Robust Optimization

Speaker: Francesca Maggioni, University of Bergamo, Department of Management, Information and Production Engineering

Coauthors: Guzin Bayraksan, Daniel Faccini, Ming Yang

Multistage mixed-integer distributionally robust optimization (DRO) forms a class of extremely challenging problems since their size grows exponentially with the number of stages. One way to model the uncertainty in multistage DRO is by creating sets of conditional distributions (the so-called conditional ambiguity sets) on a finite scenario tree and requiring that such distributions remain close to nominal conditional distributions according to some measure of similarity/distance (e.g., phi-divergences or Wasserstein distance). In this talk, new bounding criteria for this class of difficult decision problems are provided through scenario grouping using the ambiguity sets associated with various commonly used phi-divergences and the Wasserstein distance. Our approach does not require any special problem structure such as linearity, convexity, stagewise independence, and so forth. Therefore, while we focus on multistage mixed-integer DRO, our bounds can be applied to a wide range of DRO problems including two-stage and multistage, with or without integer variables, convex or nonconvex, and nested or non-nested formulations. Numerical results on a multistage mixed-integer production problem show the efficiency of the proposed approach through different choices of partition strategies, ambiguity sets, and levels of robustness.

Keywords: Multistage distributionally robust optimization; bounding

## $13:15\ to\ 13:40$ Optimized Dimensionality Reduction for Moment-based Distributionally Robust Optimization

Speaker: Jianqiang Cheng, SIE, University of Arizona

Coauthors: Shiyi Jiang, Kai Pan, Zuo-Jun Max Shen

Moment-based distributionally robust optimization (DRO) provides an optimization framework to integrate statistical information with traditional optimization approaches. Under this framework, one assumes that the underlying joint distribution of random parameters runs in a distributional ambiguity set constructed by moment information and makes decisions against the worst-case distribution within the set. Although most moment-based DRO problems can be reformulated as semidefinite programming (SDP) problems that can be solved in polynomial time, solving high-dimensional SDPs is still time-consuming. Unlike existing approximation approaches that first reduce the dimensionality of random parameters and then solve the approximated SDPs, we propose an optimized dimensionality reduction (ODR) approach. We first show that the ranks of the matrices in the SDP reformulations are small, by which we are then motivated to integrate the dimensionality reduction of random parameters with the subsequent optimization problems. Such integration enables two outer and one inner approximations of the original problem, all of which are low-dimensional SDPs that can be solved efficiently, providing two lower bounds and one upper bound correspondingly. More importantly, these approximations can theoretically achieve the optimal value of the original high-dimensional SDPs. As these approximations are nonconvex SDPs, we develop modified Alternating Direction Method of Multipliers (ADMM) algorithms to solve them efficiently. We demonstrate the effectiveness of our proposed ODR approach and algorithm in solving multiproduct newsvendor and conditional value at risk (CVaR) problems. Numerical results show significant advantages of our approach on the computational time and solution quality over the three best possible benchmark approaches. Our approach can obtain an optimal or near-optimal (mostly within 0.1 percent) solution and reduce the computational time by up to three orders of magnitude.

Keywords: DRO; Dimensionality reduction; Semidefinite programming

# $13:40 \ {\rm to} \ 14:05 \ {\rm Improved Bounds}$ to Accelerate The Column and Constraint Generation for Two-stage Distributionally Robust Problems with First Moment Constraints

Speaker: Alexandre Street, Pontifical Catholic University of Rio de Janeiro

Coauthors: Alexandre Street, David Pozo, Alexandre Velloso

In this talk, we show a Dantzig-Wolfe (DW)-based improved lower bound for two-stage distributional robust optimization problems with first-moment constraints. The bound is based on an improved representation of the recourse function of the problem. A nested column and constraint generation (CCG) algorithm with a DW inner step is developed based on this idea. A case study based on the long-term transmission planning problem under uncertainty shows improved performances in comparison to the traditional CCG algorithm corroborating the effectiveness of the proposed bound and algorithm to this relevant problem of the electricity sector.

Keywords: Column and-constraint generation; Dantzig-Wolfe; Distributionally Robust

#### 14:05 to 14:30 Mean Robust Optimization

Speaker: Irina Wang, Princeton University

Coauthors: Cole Becker, Bart Van Parys, Bartolomeo Stellato

Robust optimization is a tractable and expressive technique for decision-making under uncertainty, but it can lead to overly conservative decisions when pessimistic assumptions are made on the uncertain parameters. Wasserstein distributionally robust optimization can reduce conservatism by being data-driven, but it often leads to very large problems with prohibitive solution times. We introduce mean robust optimization, a general framework that combines the best of both worlds by providing a trade-off between computational effort and conservatism. We propose uncertainty sets constructed based on clustered data rather than on observed data points directly thereby significantly reducing problem size. By varying the number of clusters, our method bridges between robust and Wasserstein distributionally robust optimization. We show finite-sample performance guarantees and explicitly control the potential additional pessimism introduced by any clustering procedure. In addition, we prove conditions for which, when the uncertainty enters linearly in the constraints, clustering does not affect the optimal solution. We illustrate the efficiency and performance preservation of our method on several numerical examples, obtaining multiple orders of magnitude speedups in solution time with little-to-no effect on the solution quality.

Keywords: robust/distributionally robust optimization; data-driven; machine learning

Mini-symposium Tuesday 12:40 to 14:30

## Advances of Stochastic Dominance Theory and Applications II

Organized by Giorgio Consigli, Darinka Dentcheva

## 12:40 to 13:15 Recent advances in optimization with stochastic dominance constraints

Speaker: Darinka Dentcheva, Stevens Institute of Technology

This talk will report on new results for sequential decision problems with stochastic order constraints. Some attention will be given to optimization problems which include fractional orders and their properties. We shall discuss relations to other risk-averse decision models and their implications, as well as Numerical treatment of the problems.

Keywords: stochastic orderings, time-consistency, risk measures, distortions, utilities

# 13:15 to 13:40 Statistically Comparing Data-Driven Optimization Formulations: A Stochastic Dominance Perspective

Speaker: Henry Lam, Columbia University

Coauthors: Henry Lam, Adam Elmachtoub, Haofeng Zhang, Yunfan Zhao

When the underlying probability distribution in a stochastic optimization is observed only through data, various datadriven formulations have been studied to obtain approximate optimal solutions. We present a framework to compare the statistical qualities of the solutions obtained from these formulations. Rather than looking at only bias or variance, our framework operates at the level of the entire asymptotic distribution of the optimality gap or generalization error, viewed as a random variable with respect to the data randomness. We describe in particular two conclusions coming from this framework for smooth optimization problems: 1) In terms of second-order stochastically dominance of the optimality gap, empirical optimization is unbeatable by any data-driven solutions, including regularized optimization, distributionally robust optimization, parametric optimization and Bayesian generalizations. 2) In model-based optimization necessitated in for instance contextual problems, simple estimate-then-optimize outperforms integrated-estimation-and-optimization when the model class is rich enough, in the sense of first-order stochastic dominance of the optimality gap, which is contrary to the widely believed superiority of the integrated approach.

Keywords: data-driven stochastic optimization, stochastic dominance, optimality gap

## $13:40\ {\rm to}\ 14:05$ Optimality conditions in control problems with random state constraints in probabilistic or almost-sure form

Speaker: Caroline Geiersbach, Weierstrass Institute

Coauthors: René Henrion

In this talk, we discuss optimization problems subject to random state constraints, where we distinguish between the chanceconstrained case and the almost sure formulation. Our focus is on the setting in which the control variable belongs to a reflexive and separable Banach space, which is of interest, for instance, in physics-based models where the control acts on a system described by a partial differential equation (PDE) with random inputs or parameters. In certain models, it is desirable for the obtained state to be bounded uniformly over the physical domain with high probability, or even probability one. The derivation of optimality conditions requires rather different techniques and assumptions for the chance-constrained versus almost sure problems. These results are applied to an example from PDE-constrained optimization under uncertainty, where the PDE corresponds to the Dirichlet problem with a random right-hand side.

Keywords: Chance constraints; optimality conditions; PDE-constrained optimization

### 14:05 to 14:30 Multiperiod interval-based stochastic dominance

Speaker: Brian David Vasquez Campos, Khalifa University

Coauthors: Giorgio Consigli, Zhiping Chen, Jia Liu

We present an extension of one period interval-based stochastic dominance (ISD) into a multiperiod framework aimed at ensuring stochastic dominance over an exogenous benchmark random process with a theoretically continuum spectrum of preferences. The one period ISD results of Liu, Chen and Consigli (2021) are extended in a multistage stochastic program based on a consistent approximation scheme.

Keywords: multistage extension, interval-based stochastic dominance

Mini-symposium Tuesday 12:40 to 14:30

## Data Driven Optimization: Models and Applications

Organized by Tito Homem-de-Mello

### 12:40 to 13:15 Integrating Learning and Optimization in Data-Driven Problems

Speaker: Tito Homem-de-Mello, Universidad Adolfo Ibanez

Forecasting and decision-making are generally modeled as two sequential steps with no feedback, following an open-loop approach. In this talk we discuss some forms in which the two steps can be combined. Such integration can be accomplished in several ways: by changing the forecasting model, the optimization model, or both. Naturally, new challenges arise from these approaches. We discuss some of these challenges, techniques that can be used, and present a few practical examples where these ideas can be used.

Keywords: data-driven optimization; forecasting

#### 13:15 to 13:40 Application-Driven Learning: A Closed-Loop Prediction and Optimization Approach Applied to Dynamic Reserves and Demand Forecasting Speaker: Joaquim Dias Garcia, PSR

Coauthors: Alexandre Street, Tito Homem-de-Mello, Francisco D. Muñoz

Forecasting and decision-making are generally modeled as two sequential steps with no feedback, following an open-loop approach. In this work, we present application-driven learning, a new closed-loop framework in which the processes of forecasting and decision-making are merged and co-optimized through a bilevel optimization problem. We present our methodology in a general format and prove that the solution converges to the best estimator in terms of the expected cost of the selected application. Then, we propose two solution methods: an exact method based on the KKT conditions of the second-level problem and a scalable heuristic approach suitable for decomposition methods. The proposed methodology is applied to the relevant problem of defining dynamic reserve requirements and conditional load forecasts, offering an alternative approach to current ad hoc procedures implemented in industry practices. We benchmark our methodology with the standard sequential least-squares forecast and dispatch planning process. We apply the proposed methodology to an illustrative system and to a wide range of instances, from dozens of buses to large-scale realistic systems with thousands of buses. Our results show that the proposed methodology is scalable and yields consistently better performance than the standard open-loop approach.

Keywords: bilevel optimization; dynamic reserves; forecast; power-systems operation

#### 13:40 to 14:05 The Value of Robust Assortment Optimization with Ranking-Based Choice Models Speaker: Bradley Sturt, University of Illinois Chicago

This talk will focus on a class of data-driven optimization problems with decision-dependent uncertainty that was proposed by Farias, Jagabathula, and Shah (2013). The goal of this class of problems is to find an assortment that maximizes a firm's worst-case expected revenue under all ranking-based choice models that are consistent with the historical sales data generated by the firm's past assortments. We will present the first structural results and polynomial-time algorithms for this class of optimization problems. Leveraging our algorithms and structural results, we will offer new insights on the value of robust optimization and the risks of estimate-then-optimize in the context of nonparametric data-driven optimization with decision-dependent uncertainty.

Keywords: Optimization with decision-dependent uncertainty; robust optimization

#### 14:05 to 14:30 **Locally robust models for optimization under tail-based data imbalance** Speaker: Karthyek Murthy, Singapore University of Technology and Design

Coauthors: Anand Deo, Arjun Ramachandra

Several problems in data-driven operations and risk management suffer from data imbalance, a term referring to settings where a small fraction of data has an outsized impact on estimating one or more key decision-making criteria. Due to the paucity of relevant samples, such problems are usually approached with the "estimate, then optimize" workflow involving a model estimation from data in the first step before plugging in the trained model to solve various downstream optimization tasks. As biases due to model selection, misspecification, and overfitting to in-sample data are especially difficult to avoid in the first-step estimated model in settings affected by data imbalance, we construct novel locally robust optimization formulations in which the first-step estimation has no effect, locally, on the optimal solutions obtained. We show that this local insensitivity translates to improved out-of-sample performance freed from the first-order impact of model errors introduced in the first-step. A key ingredient in achieving this local robustness is a novel debiasing procedure that adds a non-parametric bias correction term to the objective. The debiased formulation retains convexity, and the imputation of the correction term relies only on a non-restrictive large deviations behavior conducive for transferring knowledge from representative data-rich regions to the data-scarce tail regions suffering from imbalance. The bias correction gets determined by the extent of model error in the estimation step and the specifics of the stochastic program in the optimization step, thereby serving as a scalable "smart-correction" step bridging the disparate goals in estimation and optimization.

Keywords: Locally robust optimization; debiasing; stochastic programming; risk-averse

#### Mini-symposium Tuesday 12:40 to 14:30

## Structured stochastic optimization and statistical machine learning II

Organized by Guanghui Lan, Krishnakumar Balasubramanian, Saeed Ghadimi

## 12:40 to 13:15 Stochastic Zeroth-order Riemannian Derivative Estimation and Optimization Speaker: Shiqian Ma, Rice University

Coauthors: Jiaxiang Li, Krishnakumar Balasubramanian

In this talk, we consider stochastic zeroth-order optimization over Riemannian submanifolds. Our main contribution is to propose estimators of the Riemannian gradient and Hessian from noisy objective function evaluations, based on a Riemannian version of the Gaussian smoothing technique. The proposed estimators overcome the difficulty of the non-linearity of the manifold constraint and the issues that arise in using Euclidean Gaussian smoothing techniques when the function is defined only over the manifold. We use the proposed estimators to solve Riemannian optimization problems in different settings, and analyze the oracle complexity of our algorithms for obtaining appropriately defined epsilon-solutions. Our complexities are independent of the dimension of the ambient Euclidean space and depend only on the intrinsic dimension of the manifold.

Keywords: Riemannian optimization; zeroth-order method; Complexity; Gaussian smoothing

# 13:15 to 13:40 A One-Sample Decentralized Proximal Algorithm for Non-Convex Stochastic Composite Optimization

Speaker: Tesi Xiao, UC Davis

We focus on decentralized stochastic non-convex optimization, where n agents work together to optimize a composite objective function which is a sum of a smooth term and a non-smooth convex term. To solve this problem, we propose two single-time scale algorithms: Prox-DASA and Prox-DASA-GT. These algorithms can find  $\epsilon$ -stationary points in  $O(n^{-1}\epsilon^{-2})$  iterations using constant batch sizes (i.e., O(1)). Unlike prior work, our algorithms achieve a comparable complexity result without requiring large batch sizes, more complex per-iteration operations (such as double loops), or stronger assumptions. Our theoretical findings are supported by extensive numerical experiments, which demonstrate the superiority of our algorithms over previous approaches.

Keywords: Decentralized Stochastic Optimization

13:40 to 14:05 **Open** 

#### 14:05 to 14:30 **A model-free first-order method for linear quadratic regulator** Speaker: Caleb Ju, Georgia Institute of Technology

Coauthors: Georgios Kotsalis, Guanghui Lan

We consider the classic stochastic linear quadratic regulator (LQR) problem under an infinite horizon average stage cost. By leveraging recent policy gradient methods from reinforcement learning, we obtain a first-order method with a sampling complexity that seems to have the best dependence on the error term within the model-free literature without the assumption that all policies generated by the algorithm are stable almost surely, and it matches the best known rate from the model-based literature, up to logarithmic factors. Our developments that result in this improved sampling complexity fall in the category of actor-critic algorithms. The actor part involves a variational inequality formulation of the stochastic LQR problem, while in the critic part we utilize a conditional stochastic primal-dual method and show that the algorithm has the optimal rate of convergence when paired with a shrinking multi-epoch scheme.

Keywords: linear quadratic regulator, primal-dual methods, variational inequality

72
#### Mini-symposium Tuesday 12:40 to 14:30

## Theoretical Advances in SDDP

Organized by Vincent Leclère

## 12:40 to 13:15 Markovian Stochastic Dual Dynamic Programming Speaker: David Wozabal,

Stochastic dual dynamic programming (SDDP) is traditionally used for problems with stage-wise independent randomness. While the assumption of stage-wise independence makes the implementation as well as the theoretical analysis of convergence properties easier, it restricts the set of admissible problems. Consequently, versions of SDDP that work with Markovian randomness have recently gained popularity. We argue that the resulting class of Markovian stochastic programming problems covers most real-life applications and therefore strikes a good balance between the simpler stage-wise independent case and the general but computationally more demanding multi-stage stochastic programming without any restrictions on the underlying process. While the proposed modification only requires minor adaptations to the algorithmic framework and convergence proofs, there is little work on discretizations of Markovian randomness. In this talk, we introduce scenario lattices as natural representations of inhomogenous discrete Markov processes. We propose a framework to analyze quantitative stability for multi-stage stochastic optimization problems with a Markovian structure based on approximations of general Markovian processes by scenario lattices. The results are formulated using the Fortet-Mourier distance and are applicable to problems whose value functions are locally Lipschitz continuous in the random data, covering many important classes of stochastic programming problems. We propose a computationally cheap stochastic gradient descent algorithm for building lattices and show that out-of-sample objectives as well as decisions converge to the respective quantities of the original problem as the approximation gets finer.

## 13:15 to 13:40 Multistage Distributionally Robust Convex Optimization: New Algorithms and Complexity Analysis

Speaker: Andy Sun, Massachusetts Institute of Technology

#### Coauthors: Shixuan Zhang

We will present a novel algorithmic study with complexity analysis of distributionally robust multistage convex optimization (DR-MCO). We propose a new class of algorithms for solving DR-MCO, namely a consecutive dual dynamic programming (DDP) algorithm and a nonconsecutive version. In particular, dual bounds are considered in the DDP recursions to prevent the growth of Lipschitz constants of the dual approximations caused by the recursive cutting plane method. We then provide a thorough complexity analysis of the new algorithms, proving both upper complexity bounds and a matching lower bound. To the best of our knowledge, this is the first complexity analysis of DDP-type algorithms on DR-MCO and it reveals, in a precise way, the dependence of the complexity of the DDP-type algorithms on the number of stages, the dimension of the decision space, and other algorithm inputs or problem data.

Keywords: multistage distributionally robust optimization; dual dynamic programming

#### 13:40 to 14:05 **Deterministic Upper Bounds For Multistage Stochastic Programs** Speaker: Bernardo Freitas Paulo da Costa, Fundação Getúlio Vargas

speaker. Dernardo Frencas Faulo da Costa, Fandação Ge

#### Coauthors: Vincent Leclère

In convex problems, duality is a key concept both in proofs and in the construction of algorithms, providing dual bounds and convergence certificates. For stochastic problems, duality has historically provided lower bounds through the construction of outer approximations for L-shaped, Nested Decomposition and SDDP algorithms. We will show how to implement a dual method to get upper bounds for multistage convex problems, both in the risk neutral and in the risk-averse settings.

Keywords: Multistage Stochastic Optimization, duality, Risk Aversion

## Distributionally Robust Optimization with Recent Advancements

Organized by Beste Basciftci

14:50 to 15:25 Nonlinear Distributionally Robust Optimization with Wasserstein Ambiguity Speaker: Miguel Lejeune, George Washington University

This talk will review recent developments in nonlinear distributionally robust optimization problems under Wasserstein ambiguity. In particular, we will present models, reformulations, and algorithmic methods for ambiguous fractional functions and distributionally robust chance constraints.

15:25 to 15:50 Robust Contextual Portfolio Optimization with Gaussian Mixture Models Speaker: Grani A Hanasusanto, University of Illinois Urbana-Champaign

Coauthors: Yijie Wang, Chin Pang Ho

We consider the portfolio optimization problem with contextual information that is available to better quantify and predict the uncertain returns of assets. Motivated by the regime modeling techniques for the finance market, we consider the setting where both the uncertain returns and the contextual information follow a Gaussian Mixture (GM) distribution. This problem is shown to be equivalent to a nominal portfolio optimization problem where the means and the covariance matrix are adjusted by the contextual information. We then apply robust optimization and propose the robust contextual portfolio optimization problem, which reduces the sensitivity of model parameters used in the Gaussian Mixture Model (GMM). A tractable formulation is derived to approximate the solution of the robust contextual portfolio optimization problem. We conduct a numerical experiment in the US equity markets, and the results demonstrate the advantage of our proposed model against other benchmark methods.

Keywords: portfolio optimization; robust optimization; Gaussian mixture models

### 15:50 to 16:15 Unifying Distributionally Robust Optimization via Martingale-Constrained Optimal Transport

Speaker: Jiajin Li, Stanford University

Coauthors: Jose Blanchet, Daniel Kuhn, Bahar Taskesen

In recent years, both Divergence-based and Wasserstein-based Distributionally Robust Optimization (DRO) have gained significant attention in the field. The former model models misspecification in terms of likelihood ratios, while the latter models it through actual outcomes. This paper presents a novel unifying approach that incorporates both forms of misspecification into a single framework of OT-based DRO with martingale constraints. Specifically, the proposed unificated model is able to include a tractable class of problems that simultaneously unifies and extends most of the formulations studied in DRO (including phi-divergence, reverse-phi-divergence, Wasserstein, and Sinkhorn).

Keywords: distributionally robust optimization, optimal transport

### 16:15 to 16:40 Data-driven Facility Location Problem with Multimodal Decision-Dependent Demand Ambiguity

Speaker: Beste Basciftci, University of Iowa

In this study, we propose a distributionally robust facility location problem under demand uncertainty where customer demand is multimodal and its distribution depends on the location decisions. We first present a moment-based ambiguity set to represent the multimodal demand distribution, where the first and second moment information depend on the facility location decisions. Next, we formulate a distributionally robust facility location problem under this ambiguity set and derive a monolithic reformulation of the proposed problem. Furthermore, if the the decision-dependency in the moment information can be represented as an affine function of the facility location decisions, we provide an exact mixed-integer linear programming reformulation of the studied problem by leveraging McCormick envelopes. To solve the resulting largescale problem, we propose a cutting-plane based algorithm, which iteratively identifies candidate solutions and searches for violations of the feasible region through solving separation problems. We further derive valid inequalities to strengthen the formulation by exploiting the polyhedral structure of the studied problem. Our computational studies demonstrate the value of integrating multimodality and decision-dependency into this problem setting by having better performance in terms of profit and quality of service, compared to existing stochastic or distributionally robust optimization approaches. We further observe the superior computational performance of the proposed solution algorithm against the off-the-shelf solvers over different instances.

Keywords: Distributionally robust optimization; facility location problem

## Algorithmic Advances in SDDP

Organized by Nils Löhndorf

# 14:50 to 15:25 Convergence of Trajectory Following Dynamic Programming algorithms Speaker: Vincent Leclère, Ecole des Ponts

Coauthors: Maël Forcier

We introduce a class of algorithms, called Trajectory Following Dynamic Programming (TFDP) algorithms, that iteratively refines approximation of cost-to-go functions of multistage stochastic problems with independent random variables. This framework encompasses most variants of the Stochastic Dual Dynamic Programming algorithm. Leveraging a Lipschitz assumption on the expected cost-to-go functions, we provide a new convergence and complexity proof that allows random variables with non-finitely supported distributions. In particular, this leads to new complexity results for numerous known algorithms.

Keywords: Multistage Stochastic Program; SDDP

## 15:25 to 15:50 MSPLib: : A Library Of Problems For Benchmarking Stochastic Dual Dynamic Programming

Speaker: Bonn Kleiford Seranilla, Luxembourg Centre for Logistics and Supply Chain Management - University of Luxembourg

Coauthors: Nils Löhndorf, Alexander Shapiro

We present MSPLib - a library of multistage stochastic programming problems to measure the computational performance of different implementations of stochastic dual dynamic programming (SDDP). MSPLib contains various instances of large realworld problems as well as synthetic problems ranging from easy to difficult variations. We use the library to test prevailing implementations - including QUASAR, SDDP.jl, and MSPPy. We also propose a new standard data structure for MSP problems.

Keywords: Stochastic Dual Dynamic Programming; Multistage Stochastic Programming

# 15:50 to 16:15 Bridging the gap between Reinforcement Learning and SDDP for Hydropower Scheduling

Speaker: Martin Hjelmeland, NTNU Norwegian University of Science and Technology

Reinforcement learning has gotten a lot of fuzz in the last couple of years, where it has excelled in a wide range of problems. Hydropower scheduling has mainly used algorithms from the realm of operations research, such as the SDDP algorithm. In this talk, we will try to bridge these fields and show how they overlap.

Keywords: SDDP; Reinforcement Learning

### 16:15 to 16:40 Recent advances for Lagrangian cuts in multistage stochastic mixed-integer programming

Speaker: Christian Füllner, Karlsruhe Institute of Technology (KIT)

Coauthors: Andy X. Sun, Steffen Rebennack

We present recent advances in the theory and computation of Lagrangian cuts in order to approximate value functions in multistage stochastic mixed-integer programming, e.g. in solution methods such as stochastic dual dynamic integer

77

Keywords: SDDiP; SDDP; Lagrangian cuts; multistage stochastic programming

# Recent advances in multistage stochastic optimization: structured policies and decision rules

Organized by Yongjia Song

## 14:50 to 15:25 Recent advances in multi-stage stochastic mixed integer programs

Speaker: Yongjia Song, Clemson University

Coauthors: Sudhan Bhattarai, Merve Bodur, Margarita Castro

In this talk, we give an overview on recent advances in multi-stage stochastic mixed integer programming. We will use the multi-stage disaster relief logistics planning problem as a motivating application example to present different variants of multi-stage stochastic integer programming problems and their values in adaptive decision making. We will demonstrate the computational challenges of multi-stage stochastic integer programs and highlight some recently proposed solution techniques based on various extensions of the stochastic dual dynamic programming (SDDP) algorithm to address these challenges. This talk will also serve as an introduction to the three technical talks in the session, which provide more in-depth discussions on structured policies, decision rules, and other solution techniques.

Keywords: Multi-stage stochastic programming; decision rules; disaster relief logistics

# 15:25 to 15:50 Markov Chain-based Policies for Multi-stage Stochastic Integer Linear Programming

Speaker: Merve Bodur, University of Toronto

Coauthors: Margarita Castro, Yongjia Song

We introduce a novel aggregation framework to address multi-stage stochastic programs with mixed-integer state variables and continuous local variables (MSILPs). Our aggregation framework imposes additional structure to the integer state variables by leveraging the information of the underlying stochastic process, which is modeled as a Markov chain (MC). We present an exact solution method to the aggregated MSILP, which can also be used in an approximation form to obtain dual bounds and implementable feasible solutions. Moreover, we apply two-stage linear decision rule (2SLDR) approximations and propose MC-based variants to obtain high-quality decision policies with significantly reduced computational effort. We test the proposed methodologies in a novel MSILP model for hurricane disaster relief logistics planning.

Keywords: Multi-stage stochastic programming; Markov chain; linear decision rules; SDDP

# $15:50\ {\rm to}\ 16:15\ {\rm Accelerating}\ {\rm Benders}\ {\rm decomposition}\ {\rm for}\ {\rm solving}\ {\rm a}\ {\rm sequence}\ {\rm of}\ {\rm sample}\ {\rm average}\ {\rm approximation}\ {\rm problems}$

Speaker: Jim Luedtke, University of Wisconsin-Madison

Coauthors: Harshit Kothari

Sample average approximation (SAA) is a technique to obtain solutions and bounds for stochastic programming problems. When applying SAA, it is often useful to solve multiple SAA problems with different samples, to obtain a confidence interval on the optimal value, or to obtain a better solution. We study techniques to accelerate the solution of this sequence of SAA problems, when solving them via Benders decomposition. We exploit similarities in the problem structure, as the problems just differ in the realizations of the random samples. Our extensive computational experiments demonstrate it is possible to significantly reduce the total time required to solve a sequence of SAA problems. We present some theoretical results that provide insight into the algorithm's performance.

Keywords: sample average approximation; Benders decomposition

### 16:15 to 16:40 On the Global Convergence of Risk-Averse Policy Gradient Methods with Dynamic Time-Consistent Risk Measures

Speaker: Xian Yu, The Ohio State University

Coauthors: Lei Ying

Risk-sensitive reinforcement learning (RL) has become a popular tool to control the risk of uncertain outcomes and ensure reliable performance in various sequential decision-making problems. While policy gradient methods have been developed for risk-sensitive RL, it remains unclear if these methods enjoy the same global convergence guarantees as in the riskneutral case. In this paper, we consider a class of dynamic time-consistent risk measures, called Expected Conditional Risk Measures (ECRMs), and derive policy gradient updates for ECRM-based objective functions. Under both constrained direct parameterization and unconstrained softmax parameterization, we provide global convergence of the corresponding riskaverse policy gradient algorithms. We further test a risk-averse variant of REINFORCE algorithm on a stochastic Cliffwalk environment to demonstrate the efficacy of our algorithm and the importance of risk control.

Keywords: Risk-sensitive reinforcement learning; policy gradient; global convergence

Mini-symposium Tuesday 14:50 to 16:40

## Many Faces of Distributionally Robust Optimization

Organized by Soroosh Shafieezadeh Abadeh

14:50 to 15:25 A Nonparametric Approach with Marginals for Modeling Consumer Choice Speaker: Karthik Natarajan, Singapore University of Technology and Design

Coauthors: Divya Padmanabhan, Arjun Ramachandra

Given data on the choices made by consumers for different offer sets, a key challenge is to develop parsimonious models that describe and predict consumer choice behavior while being amenable to prescriptive tasks such as pricing and assortment optimization. The marginal distribution model (MDM) is one such model, which requires only the specification of marginal distributions of the random utilities to explain choice data. This paper aims to establish a set of necessary and sufficient conditions on the structure of the choice data which is consistent with the MDM hypothesis. Numerical experiments show that MDM provides better representational power and prediction accuracy than multinominal logit and significantly better computational performance than RUM.

Keywords: distributionally robust optimization; dependence

# 15:25 to 15:50 Non-smooth, Hölder-Smooth, and Robust Submodular Maximization Speaker: Duksang Lee, KAIST

Coauthors: Nam Ho-Nguyen, Dabeen Lee

We study the problem of maximizing a continuous DR-submodular function that is not necessarily smooth. We prove that the continuous greedy algorithm achieves an  $[(1 - 1/e) \text{ OPT-} \epsilon]$  guarantee when the function is monotone and Hölder-smooth, meaning that it admits a Hölder-continuous gradient. For functions that are non-differentiable or non-smooth, we propose a variant of the mirror-prox algorithm that attains an  $[(1/2) \text{ OPT-}\epsilon]$  guarantee. We apply our algorithmic frameworks to robust submodular max- imization and distributionally robust submodular maximization under Wasserstein ambiguity. In particular, the mirror-prox method applies to robust submodular maximization to obtain a single feasible solution whose value is at least  $(1/2) \text{ OPT} - \epsilon$ . For distributionally robust maximization under Wasserstein ambiguity, we deduce and work over a submodular-convex maximin reformulation whose objective function is Hölder- smooth, for which we may apply both the continuous greedy and the mirror-prox algorithms.

Keywords: DR-submodular, Hölder-smooth, Non-smooth

# 15:50 to 16:15 Wasserstein Distributionally Robust Estimation in High Dimensions Speaker: Liviu Aolaritei, ETH Zurich

Coauthors: Soroosh Shafieezadeh-Abadeh, Florian Dörfler

We propose a Wasserstein distributionally robust regression framework to estimate an unknown parameter from noisy linear measurements, and we focus on the task of analyzing the squared error performance of such estimators. Our study is carried out in the modern high-dimensional proportional regime, where both the ambient dimension and the number of samples go to infinity, at a proportional rate which encodes the under/over-parametrization of the problem. Under an isotropic Gaussian features assumption, we first show that the squared error can be precisely recovered as the solution of a convex-concave minimax problem which, surprisingly, involves at most four scalar variables. We then explain how the resulting minimax problem can be employed to efficiently and optimally tune the ambiguity radius.

Keywords: distributionally robust optimization

### 16:15 to 16:40 Mean-covariance robust risk measurement

Speaker: Soroosh Shafieezadeh Abadeh, Cornell University

Coauthors: Viet Anh Nguyen, Damir Filipović, Daniel Kuhn

We introduce a universal framework for mean-covariance robust risk measurement and portfolio optimization. We model uncertainty in terms of the Gelbrich distance on the mean-covariance space, along with prior structural information about the population distribution. Our approach is related to the theory of optimal transport and exhibits superior statistical and computational properties than existing models. We find that, for a large class of risk measures, mean-covariance robust portfolio optimization boils down to the Markowitz model, subject to a regularization term given in closed form. This includes the finance standards, value-at-risk and conditional value-at-risk, and can be solved highly efficiently.

Keywords: risk measures, optimal transport, robustness

Mini-symposium Tuesday 14:50 to 16:40

### Solution Methods for Distributionally Robust Optimization Problems II

Organized by Francesca Maggioni

## 14:50 to 15:25 On distributionally robust MILP optimization with stochastic dominance risk averse functional in multi-horizon problems

Speaker: Laureano F. Escudero, Universidad Rey Juan Carlos

Coauthors: Antonio Alonso-Ayuso, Juan F. Monge, Domingo Morales, Leandro Pardo

Distributionally robust optimization (DRO) is motivated as a counterpart of the usually unknown underlying probability distribution (PD) followed by the uncertainty in dynamic problems. A MILP approach is presented for problem solving in multi-horizon stochastic environments (DRO-MHSE), where the uncertainty is represented in a finite set of scenarios for the realization of the parameters in the related ambiguity sets. For that purpose, it is assumed the availability of a Nominal Distribution (ND) of the realization of the strategic and operational parameters in the immediate successor node set of any node for the former and in the stages for the latter in the multi-horizon scenario tree. The strategic and operational ambiguity sets are obtained from the projections of appropriate perturbations of the ND cumulative distribution functions into a set of modeler-driven PDs, such that the Wasserstein distance is satisfied for a given radius. A DRO-MHSE modeling paradigm that considers those ambiguity sets is presented. The aim is to maximize the overall expected DRO solution value in the scenarios, subject to the constraint system for each ambiguity set member and the related one to the stochastic dominance risk averse functional. Given the intrinsic problem's difficulty and the huge model's dimensions in realistic applications, it is not practical to seek an optimal solution. So, SFR3 (it stands for Scenario variables Fixing and iteratively Randomization of constraints and variables' integrality Relaxation Reduction), a constructive matheuristic algorithm, is specialized for dealing with DRO. A supply network design planning is considered as a pilot case to validate the proposal. Some computational experience is reported.

Keywords: DRO; Multi-horizon MILP; stochastic dominance risk averse; matheuristics

## $15:25\ {\rm to}\ 15:50\ {\rm Decomposition\ methods}$ for Wasserstein-based data-driven distributionally robust problems

Speaker: Davi Michel Valladão, PUC-Rio

Coauthors: Carlos Andrés Gamboa, Alexandre Street, Tito Homem-de-Mello

We study decomposition methods for two-stage data-driven Wasserstein-based DROs with right-hand-sided uncertainty and rectangular support. We propose a novel finite reformulation that explores the rectangular uncertainty support to develop and test five new different decomposition schemes: Column-Constraint Generation, Single-cut and Multi-cut Benders, as well as Regularized Single-cut and Multi-cut Benders. We compare the efficiency of the proposed methods for a unit commitment problem with 14 and 54 thermal generators whose uncertainty vector differs from a 24 to 240-dimensional array.

Keywords: Distributionally robust optimization; Decomposition methods

# 15:50 to 16:15 Enabling Data Valuation through Multi-Source Data-Driven Distributionally Robust Optimization

Speaker: Robert Mieth, Princeton University

Coauthors: Juan M. Morales, H. Vincent Poor

While data-driven stochastic optimization has been established as a powerful tool for many applications, two important practical issues are often overlooked: (i) Data is assumed to be available at no cost, (ii) Information on data quality, which may differ based on measurement and underlying privacy-protection mechanisms, is ignored. This talk presents a modification of the established data-driven distributionally robust optimization (DRO) approach using Wasserstein metric that offers a pathway to address these two shortcomings. First, we discuss the ability of the Wasserstein metric to measure data quality and show how the Wasserstein DRO approach can be modified to accommodate data from multiple sources

with individual transport budgets. Second, using an exemplary application from power system operations, we show how the resulting optimization problem implicitly computes the value of data given its quality and the context of the decision-making problem at hand. This creates an interpretable economic signal for efficient payments towards data owners and paves the way for a comprehensive economic analysis of data as a resource.

Keywords: Distributionally Robust Optimization; Differential Privacy; Optimal Power Flow

16:15 to 16:40 **A Max-Min-Max Algorithm for Robust Optimization** Speaker: Man-Chung Yue, HKU

#### Coauthors: Kai TU, Zhi CHEN

Robust optimization is a popular paradigm for decision making under uncertainty and finds applications in a wide range of areas. Existing approaches for solving robust optimization, such as the reformulation approach and the cutting-plane method, do not scale well with the problem size. The purpose of the talk is to present a new algorithm for solving large-scale robust optimization problems. More specifically, based on a max-min-max perspective, a tailor-made first-order algorithm for robust optimization has been devised. The algorithm operates directly on the functions and uncertainty sets, through their (sub-)gradient and projection oracles, respectively. Therefore, it can effectively exploit problem structures (e.g., low-rank-ness or sparsity of matrices, strong convexity or smoothness of functions and sets) to speed up the algorithm. Theoretically, we prove under mild conditions that the algorithm enjoys an iteration complexity of  $O(\epsilon^{-1})$ . Experiment results on large-scale instances will also be presented to illustrate the remarkable performance of the proposed algorithm.

Keywords: Robust Optimization, First-order Algorithms, Convergence Analysis

## Wednesday, July 26

#### Plenary

### $8:30\ {\rm to}\ 9:30\ {\rm First}$ order oracles in zeroth order optimization

Speaker: Katya Scheinberg, Cornell University

Coauthors: Albert Berahas (Michigan), Liyuan Cao (Peking U.)

Zeroth order optimization is an area of optimization that deals with, so called, black box functions, that is functions whose value is computed by some complex process, e.g., simulation. Optimization algorithms for such functions are often called zeroth order algorithms, because they seemingly make use only of (approximate) function values. However, many of these algorithms construct approximations of the function gradients (and Hessians), thus acting as inexact first (or second) order algorithms. We will discuss a variety of these gradient approximations, which we call first order oracles, and compare their properties when used within an algorithmic framework.

Keywords: black-box optimization, simulation optimization, first order oracles

## Approximation guarantees

Chaired by Jannis Kurtz

# $9:50\ {\rm to}\ 10:15\ {\bf A}$ Gradually Reinforced Sample-Average-Approximation Differentiable Homotopy Method for a System of Stochastic Equations

Speaker: Chuangyin Dang, City University of Hong Kong

#### Coauthors: Peixuan Li, Yang Zhan

This paper intends to apply the sample-average-approximation (SAA) scheme to solve a system of stochastic equations (SSE), which has many applications in a variety of fields. The SAA is an effective paradigm to address risks and uncertainty in stochastic models from the perspective of Monte Carlo principle. Nonetheless, a numerical conflict arises from the sample size of SAA when one has to make a tradeoff between the accuracy of solutions and the computational cost. To alleviate this issue, we incorporate a gradually reinforced SAA scheme into a differentiable homotopy method and develop a gradually reinforced sample-average-approximation (GRSAA) differentiable homotopy method in this paper. By introducing a series of continuously differentiable functions of the homotopy parameter t ranging between zero and one, we establish a differentiable homotopy system, which is able to gradually increase the sample size of SAA as t descends from one to zero. The set of solutions to the homotopy system contains an everywhere smooth path, which starts from an arbitrary point and ends at a solution to the SAA with any desired accuracy. The GRSAA differentiable homotopy method serves as a bridge to link the gradually reinforced SAA scheme and a differentiable homotopy method and retains the nice property of global convergence the homotopy method possesses while greatly reducing the computational cost for attaining a desired solution to the original SSE. Several numerical experiments further confirm the effectiveness and efficiency of the proposed method.

Keywords: Stochastic Equations System, Sample Average Approximation, Path-Following Method

# 10:15 to 10:40 A Gradually Reinforced Sample-Average-Approximation Differentiable Path-Following Method to Compute Perfect Stationary Points of Stochastic Variational Inequalities Speaker: Yiyin Cao, City University of Hong Kong

### Coauthors: Chuangyin Dang, Shicong Jiang

This paper intends to exploit the sample-average-approximation (SAA) scheme to compute a perfect stationary point for a class of stochastic variational inequality problems. The main difficulty comes from the sample size of SAA when a tradeoff has to be made between the solution accuracy and the computational cost. To overcome this difficulty, we integrate a gradually reinforced SAA scheme into a differentiable path-following method and develop a gradually reinforced sample-average-approximation (GRSAA) differentiable path-following method to compute a perfect stationary point in this paper. As a result of a continuously differentiable function of an extra variable t between zero and one, we constitute a differentiable homotopy system, which gradually increases the sample size of SAA as t descends from one to zero. The set of solutions to the homotopy system consists of an everywhere smooth path, which starts from an arbitrary point and ends at a perfect stationary point with any given desired accuracy. The GRSAA differentiable path-following method. The method maintains global convergence of a path-following method while significantly reducing the computational cost for the desired accuracy. Numerical experiments further substantiate the effectiveness and efficiency of the method.

### 10:40 to 11:05 Transportation Distance Between Kernels and Approximate Dynamic Risk Evaluation in Markov Systems

Speaker: Zhengqi Lin, Rutgers University

Coauthors: Andrzej Ruszczyński

We introduce a kernel distance based on Wasserstein distances, study its properties, and propose a method for approximating solutions to forward-backward Markov systems. We establish the metric properties of the kernel distance and relate it to various modes of convergence in the space of kernels. Subsequently, we propose a recursive approximation scheme for the forward system of a Markov system using the kernel distance, and estimate the error of the risk evaluation by the errors of individual kernel approximations. Our results are illustrated on stopping problems, well-known risk measures, and a particle-based numerical procedure with finite support sets. Additionally, we design a specialized dual algorithm that can construct

86

Keywords: Wasserstein distance; Dynamic Risk Measure; Dynamic Programming; Optimization

## 11:05 to 11:30 Approximation Guarantees for Min-max-min Robust Optimization and K-Adaptability under Objective Uncertainty

Speaker: Jannis Kurtz, University of Amsterdam

In this work we investigate the k-adaptability approach for linear problems with uncertain cost coefficients. This approach can be used to find approximate solutions for two-stage robust optimization problems with integer second-stage variables. The idea is to calculate a set of k second-stage solutions already in the first stage, and choose the best one for each scenario in the uncertainty set. While solution algorithms for the k-adaptability approach were intensively studied in the last years, there is not much known about the approximation guarantee the k-adaptability approach provides regarding the corresponding twostage robust problem. In this work we will derive approximation results for the min-max-min robust optimization problem and show that they can be extended to the k-adaptability problem. We can show that k, the number of solutions required to achieve a certain approximation guarantee, can be significantly smaller than the dimension of the problem. Furthermore, our approximation algorithm can be incorporated into a branch & bound framework to solve the min-max-min robust problem efficiently for larger values of k.

Keywords: Robust Optimization; K-adaptability; Approximation

#### Paper Session Wednesday 9:50 to 11:30

## Analysis, Approximation and algorithms

Chaired by Chunlin Sun

#### 9:50 to 10:15 Neur2SP: Neural Two-Stage Stochastic Programming Speaker: Justin Dumouchelle, University of Toronto

Coauthors: Justin Dumouchelle, Rahul Patel, Elias Khalil, Merve Bodur

Stochastic Programming is a powerful modeling framework for decision-making under uncertainty. This work tackles twostage stochastic programs (2SPs), the most widely used class of stochastic programming models. Solving 2SPs exactly requires optimizing over a computationally intractable expected value function. A mixed-integer linear program (MIP) or a nonlinear program (NLP) in the second stage further aggravates the intractability, even when specialized algorithms that exploit problem structure are employed. Finding high-quality (first-stage) solutions – without leveraging problem structure – can be crucial in such settings. We develop Neur2SP, a method that approximates the expected value function via a neural network to obtain a surrogate model that can be solved efficiently. Neur2SP makes no assumptions about the problem structure, particularly the second-stage problem, and can be implemented using an off-the-shelf MIP solver. Our extensive computational experiments on four benchmark 2SP problem classes with different structures (containing MIP and NLP second-stage problems) demonstrate the efficiency (time) and efficacy (solution quality) of Neur2SP. In under 1.66 seconds, Neur2SP finds high-quality solutions across all problems even as the number of scenarios increases, an ideal property that is difficult to have for traditional 2SP solution techniques.

Keywords: stochastic programming; supervised learning; deep learning

## 10:15 to 10:40 Statistical Efficiency of a Stochastic Composite Proximal Bundle Method Speaker: Xinyang Hu, Yale University

Coauthors: Jiaming Liang

We consider a stochastic optimization problem whose objective is the sum of a function given by an expectation and a closed convex composite function. We propose a stochastic composite proximal bundle method for solving it and study both its optimization and statistical efficiency. More precisely, we first establish a nearly optimal convergence rate of the proposed method. We also show an optimal asymptotic normality result with a matching local minimax lower bound.

Keywords: stochastic optimization

# $10:40 \ {\rm to} \ 11:05 \ {\rm A}$ Multilevel Stochastic Approximation Algorithm for Value-at-Risk and Expected Shortfall Estimation

Speaker: Azar Louzi, LPSM, Université Paris Cité

Coauthors: Noufel Frikha, Stéphane Crépey

We propose a multilevel stochastic approximation (MLSA) scheme (Frikha et al). for the computation of the value-at-risk (VaR) and the expected shortfall (ES) of a financial loss, which can only be computed via simulations conditional on the realization of future risk factors. Thus, the problem of estimating its VaR and ES is nested in nature and can be viewed as an instance of a stochastic approximation problem with biased innovation as per Barrera et al. In this framework, for a prescribed accuracy  $\varepsilon$ , the optimal complexity of a standard stochastic approximation algorithm is shown to be of order  $\varepsilon^{-3}$ . To estimate the VaR, our MLSA algorithm attains an optimal complexity of order  $\varepsilon^{-2-\delta}$ , where  $\delta < 1$  is some parameter depending on the integrability degree of the loss, while to estimate the ES, it achieves an optimal complexity of order  $\varepsilon^{-2} |\ln \varepsilon|^2$ . Numerical studies of the joint evolution of the error rate and the execution time demonstrate how our MLSA algorithm regains a significant amount of the lost performance due to the nested nature of the problem.

Keywords: value-at-risk, expected shortfall, nested SA, multilevel SA

Speaker: Chunlin Sun, ICME, Stanford University

Coauthors: Chunlin Sun, Shang Liu, Xiaocheng Li

We study the predict-then-optimize problem where the output of a machine learning prediction task is used as the input of some downstream optimization problem, say, the objective coefficient vector of a linear program. The problem is also known as predictive analytics or contextual linear programming. The existing approaches largely suffer from either (i) optimization intractability (a non-convex objective function)/statistical inefficiency (a suboptimal generalization bound) or (ii) requiring strong condition(s) such as no constraint or loss calibration. We develop a new approach to the problem called *maximum optimality margin* which designs the machine learning loss function by the optimality condition of the downstream optimization. The max-margin formulation enjoys both computational efficiency and good theoretical properties for the learning procedure. More importantly, our new approach only needs the observations of the optimal solution in the training data rather than the objective function, which makes it a new and natural approach to the inverse linear programming problem under both contextual and context-free settings; we also analyze the proposed method under both offline and online settings, and demonstrate its performance using numerical experiments.

Keywords: Contextual Linear Programming, nverse Linear Programming

## Algorithmic Advances

Chaired by Fabian Bastin

### 9:50 to 10:15 **Deriving the Projective Hedging Algorithm for Stochastic Programming** Speaker: Jonathan Eckstein, Rutgers University

Coauthors: Jean-Paul Watson, David L. Woodruff

Projective splitting methods are decomposition methods similar to Douglas-Rachford splitting and the ADMM, but more flexible. This talk shows how, with some careful setup, one can use projective splitting to derive a multistage stochastic programming algorithm that resembles progressive hedging, but which each iteration may solve subproblems corresponding to only a subset of the overall set of scenarios. Experiments show that this feature can result in significant saving of computational effort.

Keywords: Progressive hedging; operator splitting

# 10:15 to 10:40 Decomposition Methods for Dynamically Monotone Two-Time-Scale Stochastic Optimization Problems

Speaker: Jean-Philippe Chancelier, Cermics, Ecole des ponts ParisTech

Coauthors: Tristan Rigaut, Pierre Carpentier, Jean-Philippe Chancelier, Michel De Lara

In energy management, it is common that strategic investment decisions (storage capacities, production units) are made at a slow time-scale, whereas operational decisions (storage, production) are made at a fast time-scale: for such problems, the total number of decision stages may be huge. In this paper, we consider multistage stochastic optimization problems with two time-scales, and we propose a time block decomposition scheme to address them numerically. More precisely, our approach relies on two assumptions. On the one hand, we suppose slow time-scale stagewise independence of the noise process: the random variables that occur during a slow time-scale interval are independent of those at another slow time-scale interval. This allows to ensure that using Dynamic Programming at the slow time-scale leads to the optimal solution of the problem. On the other hand, we suppose dynamically monotone properties for the problem under consideration, which makes it possible to obtain bounds. Then, we present two algorithmic methods to compute upper and lower bounds for the slow time-scale Bellman value functions. Both methods rely respectively on primal and dual decomposition of the Bellman equation applied at the slow time-scale. We assess the methods tractability and validate their efficiency by solving a battery management problem where the fast time-scale operational decisions (charge/discharge of the battery) have an impact on the health of the battery, hence on the strategic decisions to renew the battery at the slow time-scale.

Keywords: Time Block Decomposition; Dynamic Programming; Stochastic Optimization

### 10:40 to 11:05 Quadratic Optimization Models for Balancing Preferential Access and Fairness: Formulations and Optimality Conditions

Speaker: Bismark Singh, University of Southampton

### Coauthors: Christian Schmitt, Malena Schmidt

Typically, within facility location problems, fairness is defined in terms of accessibility of users. However, for facilities perceived as undesirable by communities hosting them, fairness between the usage of facilities becomes especially important. Limited research exists on this notion of fairness. To close this gap, we develop a series of optimization models for the allocation of populations of users to facilities such that access for users is balanced with a fair utilization of facilities. The optimality conditions of the underlying non-convex quadratic models provide a precise tradeoff between accessibility and fairness. We define new classes of fairness, and a metric to quantify the extent to which fairness is achieved in both optimal and suboptimal allocations. We show a continuous relaxation of our central model is sufficient to achieve a perfect extent of fairness, while a special case reduces to the classical notion of proportional fairness. Our work is motivated by pervasive ecological challenges faced by the waste management community as policymakers seek to reduce the number of recycling centers in the last few years. As a computational case study, applying our models on data for the state of Bavaria in Germany, we find that even after the closure of a moderate number of recycling centers, large degrees of access can be ensured provided the closures are conducted optimally.

Keywords: QuaKKT conditions; Fairness; Facility location problems

### 11:05 to 11:30 An Adaptive Subsampled Hessian-Free Optimization Method for Statistical Learning

Speaker: Fabian Bastin, Université de Montréal

Coauthors: Jérémy Rieussec, Jean Laprés-Chartrand

We consider nonconvex statistical learning problems and propose a variable sample-path method, where the sample size is dynamically updated to ensure a decrease in the true objective function with high probability. To this end, we capitalize on common random numbers to reduce the variance of the objective difference at two points and formulate the search of a candidate iterate as a small chance-constrained program. We integrate this strategy in a subsampled Hessian-free trust-region method with truncated conjugate gradient, relying on outer product approximations, allowing us to consider high-dimensional models. We explore different strategies to adjust the sample when varying the number of draws to escape more easily sub-optimal solutions. The approach is compared to various adaptive sample approximation algorithms and stochastic approximation methods proposed in stochastic optimization and machine learning. The efficiency of the approach is illustrated on various large size datasets and different regression models. We finally briefly discuss its theoretical convergence properties.

Keywords: Sample path; Adaptive sampling; Large-scale; Trust-region; Statistical learning

#### Paper Session Wednesday 9:50 to 11:30

## **Applications and Innovations**

Chaired by Camila Martinez Parra

# $9:50\ {\rm to}\ 10:15\ {\rm Non-parametric}\ {\rm Stochastic}\ {\rm Decomposition}\ {\rm for}\ {\rm Predictive}\ {\rm Stochastic}\ {\rm Programming}\ {\rm in}\ {\rm the}\ {\rm Presence}\ {\rm of}\ {\rm Streaming}\ {\rm Data}$

Speaker: Shuotao Diao, Northwestern University

Coauthors: Suvrajeet Sen

This work studies a fusion of concepts from stochastic programming and non-parametric statistical learning in which data is available in the form of covariates interpreted as predictors and responses. In this study, we propose a distribution-free decomposition-based method which merges piecewise linear approximation and k nearest neighbors estimation to improve the decisions in the presence of streaming data. Our computational results demonstrate that our proposed algorithm outperforms traditional approaches which were not designed for streaming data applications requiring simultaneous estimation and optimization as important design features for such algorithms.

Keywords: Stochastic Programming, Non-parametric Statistical Estimation

## 10:15 to 10:40 Value of Stochastic Solution with Right-Hand Side Uncertainty

Speaker: Haoming Shen, University of Michigan

Coauthors: Ruiwei Jiang

We revisit the value of stochastic solution (VSS) in the context of distributional ambiguity. When the uncertainty arises from the right-hand side of a two-stage stochastic program, we consider upper and lower bounds of VSS using distributionally robust and optimistic optimization. We discuss the computation of these bounds and demonstrate them through numerical examples.

10:40 to 11:05 **On a two-stage stochastic appoach for cross-dock door design and management** Speaker: M. Araceli Garin, University of the Basque Country (UPV/EHU)

Coauthors: M. Araceli Garin, Laureano F. ESCUDERO, Aitziber UNZUETA

The pure Cross-dock Door Desing Problem (CDDP) consists of deciding on the number of strip and stack doors and their reference capacity for receiving product pallets through the inbound doors from the origin nodes (i.e., the suppliers), consolidating the products in a collection of destination mixed pallets and, finally, delivering them through the outbound doors to the destination nodes. The uncertainty lies on two points: firstly, on the sets of origin and destination nodes and, then, on the number of product pallets from each origin node to each destination one to transverse the cross-dock for a given time horizon. And, secondly, on the door capacity disruption, due to different reasons as sabotage, misuse, etc. As far as we know it is the first time that a two-stage stochastic model is presented, whose goal is to minimize the expected cross-dock infrastructure building cost plus the expected cost of the standard and outsourcing assignments of the nodes to the doors in the scenarios, subject to the related net capacity constraints. Moreover, given the special structure of the problem and the high computational complexity of the corresponding binary quadratic model, a Linearized mixed Integer Programming Problem (LIP) that is mathematically equivalent to the former is introduced. However, the intrinsic difficulty of solving even LIPs in situations of huge model dimensions in realistic applications makes it impractical to search for an optimal solution. So, a Lagrangean Decomposition (LD) approach will be considered, by dualizing the first-stage variables splitting constraints, and decomposing it into independent scenario-related submodels that could be solved by decoupling them, taking benefit of the Integer Linearization Property of the model, if necessary. A computational study will be carried out to test the goodness of the proposed scheme.

Keywords: scenario; generalized assignment problem; lagrangean bound; strip- stack- doors

Speaker: Camila Martinez Parra, École des Ponts ParisTech - RTE

Coauthors: Camila Martinez Parra, Michel Delara, Jean-Philippe Chancelier, Pierre Carpentier, Manuel Ruiz

The energy landscape is changing. The penetration of renewable energy will require a large number of storage facilities and the introduction of new forms of storage. As a result, there is an increasing interest in usage value calculation for stored energy, a calculation that can be formulated as the result of a stochastic multistage optimization problem. This is the case for RTE, the French transmission system operator, which conducts prospective studies on energy transition over dozens of years where, on such horizons, the uncertainties are high. Nowadays, RTE considers a weekly anticipative information structure to solve the problem using the stochastic dynamic programming algorithm and wants to explore alternative structures to improve uncertainty disclosure modeling. For this purpose, we consider stochastic multistage optimization problems with two timescales: a slow timescale (weekly) at which we want to obtain the usage values and coordinate the decisions; a fast timescale (hourly) needed to model physical constraints and variable decision granularity. Then, we study how to model the available information during the sequential decision-making process and the respective multistage stochastic optimization approaches. First, we present problem formulations considering a timeline with two timescales and two adapted classical information structures: the decision-hazard framework and the hazard-decision framework. Whereas the decision-hazard structure cannot guarantee feasibility due to balance constraints under uncertainties, the hazard-decision structure is anticipative when making the decisions for the week. Therefore, we introduce the decision-hazard-decision information structure in a two timescales setting, in which we consider nonanticipative controls taken in the decision-hazard framework and recourse controls taken in the hazard-decision framework with possible alternative formulations due to the existence of two timescales.

Keywords: Prospective studies; modelling; energy; stochastic; optimization;

## **Regression and Robust Optimization**

Chaired by Mohammad Reza Belbasi

# $9:50\ {\rm to}\ 10:15$ On Generalization and Regularization via Wasserstein Distributionally Robust Optimization

Speaker: Jonathan Li, University of Ottawa

### Coauthors: Qinyu Wu, Tiantian Mao

Wasserstein distributionally robust optimization (DRO) has found success in operations research and machine learning applications as a powerful means to obtain solutions with favourable out-of-sample performances. Two compelling explanations for the success are the generalization bounds derived from Wasserstein DRO and the equivalency between Wasserstein DRO and the regularization scheme commonly applied in machine learning. Existing results on generalization bounds and the equivalency to regularization are largely limited to the setting where the Wasserstein ball is of a certain type and the decision criterion takes certain forms of an expected function. In this paper, we show that by focusing on Wasserstein DRO problems with affine decision rules, it is possible to obtain generalization bounds and the equivalency to regularization in a significantly broader setting where the Wasserstein ball can be of a general type and the decision criterion can be a general measure of risk, i.e., nonlinear in distributions. This allows for accommodating many important classification, regression, and risk minimization applications that have not been addressed to date using Wasserstein DRO. Our results are strong in that the generalization bounds do not suffer from the curse of dimensionality and the equivalency to regularization is exact. As a byproduct, our regularization results broaden considerably the class of Wasserstein DRO models that can be solved efficiently via regularization formulations.

Keywords: Wasserstein DRO, generalization, regularization

### 10:15 to 10:40 Multistage Robust Classification with Fairness Constraints

Speaker: Zhuangzhuang Jia, University of Illinois Urbana-Champaign

Coauthors: Grani Adiwena Hanasusanto, Phebe Vayanos, Weijun Xie

In this talk, we study the multistage fair classification problem where fairness is explicitly incorporated as a constraint in the training process. We use techniques from distributionally robust optimization to enhance the out-of-sample performance. More specifically, an ambiguity set centered around the empirical distribution via Wasserstein metric is employed to model the uncertainty. We get a conservative approximation for the worst-case equal opportunity unfairness measure. We show that our approximation is equivalent to a mixed-integer optimization problem that can be solved using off-the-shelf optimization solvers. We demonstrate that our model mitigates unfairness with a negligible drop in predictive accuracy on both synthetic and real datasets.

Keywords: multistage stochastic program, fairness, distributionally robust optimization

## 10:40 to 11:05 Decision-dependent distributionally robust optimization

Speaker: Mauricio Junca, Universidad de los Andes, Bogota

### Coauthors: Diego Fonseca

This work presents a new Distributionally Robust Optimization approach, using *p*-Wasserstein metrics, to analyze a stochastic program in a general context. The ambiguity set in this approach depends on the decision variable and is represented as a ball where both the center and the radius depend on the decision variable. We show that, under Lipschitz's assumptions for the objective function, our approach can be reformulated as a finite-dimensional optimization problem, which is sometimes convex. In addition, we numerically compare our proposed approach with the standard formulation of distributionally robust optimization, which typically does not use ambiguity sets dependent on the decision variable, in the context of portfolio optimization. We also discuss stochastic problems with expectations constraints using this new approach.

### 11:05 to 11:30 Wasserstein Logistic Regression with Mixed Features

Speaker: Mohammad Reza Belbasi,

Coauthors: Aras Selvi, Mohammad Reza Belbasi, Martin B Haugh, Wolfram Wiesemann

Recent work has leveraged the popular distributionally robust optimization paradigm to combat overfitting in classical logistic regression. While the resulting classification scheme displays a promising performance in numerical experiments, it does not take special care of categorical features. In this talk, we show how we can avoid hedging against unrealistic worst-case distributions by taking into account the discrete nature of categorical features. We show that distributionally robust logistic regression with mixed (i.e., numerical and categorical) features, despite amounting to an optimization problem of exponential size, admits a polynomial-time solution scheme. We subsequently develop a practically efficient column-and-constraint approach that solves the problem as a sequence of polynomial-time solvable exponential conic programs. Our model retains many of the desirable theoretical features of previous works, but—in contrast to the literature—it does not admit an equivalent representation as any regularized logistic regression, that is, it represents a genuinely novel variant of logistic regression. We show that our method outperforms both the unregularized and the regularized logistic regression on categorical as well as mixed-feature benchmark instances. We further talk about what are the next potential extensions on the current method.

Keywords: Distributionally robust optimization, Wasserstein distance, regularization

## Thursday, July 27

### 8:30 to 9:30 Stochastic Submodular Optimization

Speaker: Simge Kucukyavuz, Northwestern University

Submodular optimization is a powerful mathematical framework that has proven to be effective in modeling optimization problems that exhibit diminishing returns. In this talk, we explore stochastic optimization problems that have (sometimes hidden) submodularity properties. To solve these problems, we propose mixed-integer programming reformulations and develop delayed constraint generation algorithms. We demonstrate the effectiveness of our proposed approaches on several stochastic optimization problems, including sensor placement for environmental monitoring.

Keywords: submodular optimization, cutting planes, risk aversion, robust sensor placement

## Power Grid Planning and Resilience

Chaired by Andy Philpott

## 9:50 to 10:15 Climate-aware generation and transmission expansion planning: A three-stage robust optimization approach

Speaker: Alexandre Moreira, Lawrence Berkeley National Laboratory

Coauthors: Alexandre Moreira, David Pozo, Alexandre Street, Enzo Sauma, Goran Strbac

In this paper, we propose a three-stage robust generation and transmission expansion planning model considering generation profiles of renewable energy sources (RES) affected by different long-term climate states. Essentially, we extend the broadly utilized two-stage modeling approach to properly consider partial information of climate states with conditional short-term scenarios of RES output and outages. The proposed model is formulated as a five-level optimization problem. The first level determines the optimal generation and transmission expansion plan under uncertainty in climate conditions, RES generation, and contingencies. Given the selected expansion plan, the second level identifies the most severe climate state. Following the decision-information hierarchy, in the third level, the system operator optimizes the generation and contingencies. Then, the fourth level identifies the worst-case combination of contingency and conditional short-term RES generation adjusted to the current climate condition. Finally, the fifth level determines the optimal redispatch of reserves to react against the worst-case RES generation and contingency scenario considering the uppermost decisions. Within this multi-level structure, the optimal investment plan considers a more realistic decision setting, where system operators adapt RES forecasts based on the observed climate conditions before planning the operational schedule. To solve the problem, a variant of the nested column-and-constraint-generation algorithm is proposed with global-optimality guarantee in a finite number of steps. A case study based on the Chilean system illustrates the applicability of the model in a realistic network.

### 10:15 to 10:40 Tri-level stochastic optimization for power grid defense

Speaker: Andrew Mastin, Lawrence Livermore National Laboratory

Coauthors: Andrew Mastin, Kaarthik Sundar, Jean-Paul Watson

We formulate a tri-level stochastic optimization problem to protect electric power grids against climate impacts, such as wildfire and storms, and present an approach to solve the problem to global optimality. The problem is modeled as a defender-attacker-defender model, where the inner defender problem models optimal operation of the power grid suffering from component outages, the middle attacker problem is the destruction of components given by the extreme event, and the outer defender problem is the defender's selection of a limited number of components to protect. Uncertainty is represented at the middle level with damage scenarios of climate-driven extreme events. To our knowledge, efforts to solve this tri-level stochastic optimization problem to global optimality are non-existent in the literature. We address the problem with a progressive hedging framework that leverages recent advances in deterministic tri-level optimization for solving subproblems. We show initial results on a small test network where enumeration is feasible to compute a globally optimal solution.

Keywords: tri-level optimization; interdiction; power system security

## 10:40 to 11:05 **Power Grid Resilience Optimization Using Decision-Dependent Uncertainty** Speaker: Samuel Affar, University of Tennessee

#### Coauthors: Hugh Medal, Yang Chen, Guodong Liu

Extreme weather events can cause unplanned disruptions in power distribution systems, highlighting the need for resilienceoriented action. This ongoing study proposes a two-stage stochastic mixed-integer program with decision-based uncertainty to determine how to optimally protect power distribution systems against such disruptions. In the first stage, a set of lines are hardened. A random set of destroyed lines is then realized. The probability for each element is dependent on the hardening decisions made in the first stage, i.e., decision-dependent uncertainty. In the second stage, network reconfiguration and Distributed DERs (Distributed Energy Resources) utilization decisions are made. The model seeks to minimize the expected cost of load shedding. To find a computationally fast way to solve the model, the study explores a decision-independent reformulation. We implement this approach on the IEEE-33 bus system while varying the size of the scenario sample space.

### 11:05 to 11:30 Multistage investment planning for renewable electricity systems Speaker: Andy Philpott, University of Auckland

### Coauthors: Anthony Downward

Electricity systems around the world are transitioning to technologies with zero or near zero carbon emissions. This transition is accompanied by increases in electricity demand from electrification of transport and industrial processes. To support this transition, governments make decisions about incentives for renewable energy and constraints or taxes on emissions of any non-renewable generation plant. Ideally, renewable energy policy should be determined using multistage capacity expansion optimization models with decisions being made at different time scales with different levels of uncertainty. However, these "multihorizon" models are challenging to formulate and populate with data, hard to maintain and very difficult to solve to optimality at scale. Furthermore any solution obtained to such a model requires a considerable effort to interpret and understand. JuDGE is an open-source Julia package that helps to ameliorate these challenges. This talk gives an overview of JuDGE, and provides an example of it applied to the New Zealand electricity system to illustrate its features.

 $Keywords:\ electricity\ capacity\ expansion; decarbonization; decomposition$ 

## Learning with Applications

Chaired by Abdel Lisser

# 9:50 to 10:15 Understanding Uncertainty Sampling as Distributionally Robust Optimizatin Speaker: Xiaocheng Li, Imperial College London

Coauthors: Shang Liu, Xiaocheng Li

Active learning is a machine learning paradigm where the learning algorithm interactively queries humans (or other information sources) to annotate new data points. Uncertainty sampling, a prevalent active learning algorithm in practice, queries sequentially the annotations of those data points for which the current prediction is uncertain. However, the usage of uncertainty sampling is largely heuristic: (i) There is no consensus on the proper definition of uncertainty for a specific task (classification or regression) under a specific loss; (ii) There is no theoretical guarantee that prescribes a standard protocol to implement the algorithm, say, how to handle the sequentially arrived annotated data under the framework of empirical risk minimization (ERM) or optimization algorithms such as stochastic gradient descent (SGD). Here, we introduce the notion of conditional risk as the expected loss of a prediction model conditional on the input variables and establish that when uncertainty sampling is performed according to a probability distribution proportional to the conditional risk, the active learning procedure essentially optimizes a distributionally robust formulation of the empirical risk. From this perspective, we unify different versions of the existing uncertainty sampling algorithms via the size of the uncertain set for distributional robustness. We show a proper integration of uncertainty sampling dynamics with ERM and SGD will both lead to an alternative minimization procedure towards a distributionally robust objective. This enables us to develop the first sample complexity bound for uncertainty sampling which sheds new insights into several aspects of the algorithm. Numerical experiments coincide with our theoretical results in that the uncertainty sampling procedure inherits the regularization effect and the small-sample advantage of distributional robustness, which is perfectly suitable for active learning application contexts.

Keywords: Uncertainty sampling, active learning, robust optimization, learning theory

### 10:15 to 10:40 Learning for Robust Optimization

Speaker: Bartolomeo Stellato, Princeton University

Coauthors: Irina Wang, Cole Becker, Bart Van Parys, Bartolomeo Stellato

We propose a data-driven method to automatically learn the uncertainty sets in robust optimization. Our training procedure reshapes the uncertainty sets by minimizing the expected performance across a family of problems while guaranteeing constraint satisfaction. We develop a stochastic augmented Lagrangian method that relies on differentiating the solutions of the robust optimization problems with respect to the parameters of the uncertainty set. We show sublinear convergence to stationary points under mild assumptions, and finite-sample probabilistic guarantees of constraint satisfaction using empirical process theory. Our algorithm is very flexible and can learn a wide variety of uncertainty sets while preserving tractability. Numerical experiments show that our approach outperforms traditional techniques in robust and distributionally robust optimization in terms of out of sample performance. We implemented our method in the open-source package LROPT.

Keywords: machine learning; robust optimization; probabilistic guarantees

### 10:40 to 11:05 Active Learning in the Predict-then-Optimize Framework

Speaker: Mo Liu, UC Berkeley, IEOR department

Coauthors: Mo Liu, Paul Grigas, Heyuan Liu, Zuo-jun Max Shen

We develop the first active learning methods in the predict-then-optimize framework. Specifically, we consider situations where acquiring "labeled" data, where the "labels" correspond to the parameters of an optimization model for decisionmaking, is costly. We develop learning methods that sequentially decide whether or not to request the labels of feature samples from an unlabeled data stream. Our active learning methods are the first to be directly informed by the decision error induced by the predicted parameters, which is referred to as the Smart Predict-then-Optimize (SPO) loss. Motivated by the structure of SPO loss, our algorithms adopt the margin-based ideas and use tractable surrogates of SPO loss. In particular, we develop practical active learning algorithms with theoretical (e.g., generalization) guarantees. We derive bounds on the label complexity, which refers to the number of samples whose labels are acquired to achieve the desired small SPO risk. Under some natural low-noise conditions, we show that these bounds can be better than the naive supervised learning approach that labels all samples. Furthermore, when using the SPO+ surrogate loss function, which is specifically tailored to the downstream decision-making problem, we derive a significantly smaller label complexity under certain conditions. We demonstrate numerical evidence showing the practical value of our proposed algorithms in the settings of personalized pricing and shortest-path problem

Keywords: active learning, predict-then-optimize, margin-based method, label complexity

#### 11:05 to 11:30 Chance constrained two-player Zero-Sum Games with a Deep Learning Approach Speaker: Abdel Lisser, University Paris Saclay, CentraleSupelec

Coauthors: Dawen Wu

In this talk, we present a new deep learning approach for predicting saddle points in chance constrained two-player zero-sum games. Our method combines neurodynamic optimization and deep neural networks. We model the stochastic two-player zero-sum game as an ordinary differential equation (ODE) system using neurodynamic optimization. Then, we develop a neural network to approximate the solution of the ODE system, which includes the saddle point prediction for the game problem. We propose a specialized algorithm for training the neural network to enhance the accuracy of the saddle point prediction. Numerical experiments show the performances of our approach when compared to the state-of-the-art.

Keywords: Chance constrained games; Neurodynamic optimization; Deep learning; ODE

#### Paper Session Thursday 9:50 to 11:30

### **Energy Operations and Planning**

Chaired by Michael Schuster

# $9:50\ {\rm to}\ 10:15\ {\rm Risk-Averse}\ {\rm Contextual}\ {\rm Predictive}\ {\rm Maintenance}\ {\rm and}\ {\rm Operations}\ {\rm Scheduling}\ {\rm with}\ {\rm Flexible}\ {\rm Generation}\ {\rm under}\ {\rm Wind}\ {\rm Energy}\ {\rm Uncertainty}$

Speaker: Natalie Randall, University of Iowa

#### Coauthors: Beste Basciftci

In this study, we focus on a risk-averse contextual predictive maintenance and operations scheduling problem with flexible generation under wind energy uncertainty. We formulate this problem as a two-stage risk-averse stochastic mixed-integer program, where the first-stage problem determines the maintenance and unit commitment related decisions of the traditional generation units, whereas the second-stage problem determines the corresponding decisions for flexible generators along with the production related plans of all generators. To integrate contextual information in predicting wind energy, we propose a Gaussian Process Regression approach, which is leveraged into this stochastic program through a conditional expectation. Since this problem is computationally challenging to solve with a mixed-integer recourse, we utilize a progressive hedging algorithm by further extending it to the risk-averse setting. Our results on different IEEE instances demonstrate the impact of adopting a risk-averse approach compared to risk-neutral and deterministic alternatives with a better worst-case performance, and highlight the value of integrating flexible generation and contextual information with resilient maintenance and operations schedules leading to cost-effective plans with less component failures. Furthermore, the solution algorithm provides significant speed-ups compared to the off-the-shelf solver while finding optimal solutions in the majority of the instances.

Keywords: Stochastic Integer Programming; Progressive Hedging Algorithm; Power Systems

#### 10:15 to 10:40 Stochastic Optimization for Mid-Term Integrated Generation and Maintenance Scheduling of Cascaded Hydroelectric System with Renewable Energy Uncertainty Speaker: Zhiming Zhong, University of Arizona

Coauthors: Neng Fan, Lei Wu

The uncertainties resulting from the escalating penetration of renewable energy resources pose severe challenges to the efficient operations of modern power systems. Hydroelectricity is characterized by flexibility, controllability, and reliability, thus becomes one of the most ideal energy resources to hedge against such uncertainties. This paper studies the mid-term integrated generation and maintenance scheduling of a cascaded hydroelectric system (CHS) consisting of multiple cascaded reservoirs and hydroelectric units. To precisely describe the mid-term water regulation policies, the hydraulic coupling relationship and water-energy nexus of CHS are incorporated into the proposed optimization model. The uncertainties of natural water inflow and the power outputs of wind/solar energy generation are taken into consideration and captured via a stochastic process modeled by a scenario tree. A multistage stochastic optimization (MSO) approach is developed to hedge against uncertainties. The proposed MSO model coordinates the complementary operation of multiple energy resources by optimizing the mid-term water resource management, generation scheduling, and maintenance scheduling of CHS. The proposed MSO model is formulated as a large-scale mixed-integer linear program that presents significant computational intractability. To address this issue, a tailored Benders decomposition algorithm is developed to solve the resulting MSO model. Two real-world case studies are conducted to demonstrate the capability and characteristics of the proposed model and algorithm. The computational results show that the proposed MSO model can exploit the flexibility of hydroelectric to efficiently respond to variable wind and solar power, and reserve water resources for the generation in peak months to reduce the consumption of fossil fuel. The proposed solution approach also exhibits promising computational efficiency when handling large-scale models.

Keywords: Hydroelectricity; Renewable Energy; Multistage Stochastic Optimization

# $10{:}40 \ {\rm to} \ 11{:}05$ Optimizing vessel chartering strategies to support maintenance tasks at offshore wind farms

Speaker: Vibeke Hvidegaard Petersen, Norwegian University of Science and Technology (NTNU)

Coauthors: Daniela Guericke, Magnus Stålhane

An important task within offshore wind is to bring down the levelized cost of electricity. Operations and maintenance (O&M) costs for offshore wind ranged between 70-129 USD/kW in 2018, while for onshore wind farms it was 33-56 USD/kW. These higher O&M costs for offshore wind are related to the harsh conditions at sea which makes O&M complex logistic tasks with a high degree of uncertainty. To ensure that the ambitions of offshore wind are viable, it is crucial to decrease the maintenance costs. In this work we consider heavy maintenance operations where heavy sub-assemblies such as blades, generator, etc., are replaced. Highly specialized vessels, with high charter rates, are employed to perform these types of maintenance tasks. Due to long lead times related to both ordering of sub-assemblies and vessel chartering, decisions regarding these must be taken well in advance of the maintenance period. At the point in time, the weather conditions governing when the vessel can operate, and the failures determining which wind turbines to maintain, are still uncertain. The goal is to reduce the down time cost of a wind farm by taking the stochastic nature of failures and weather conditions into account when planning maintenance operations. We formulate a two-stage stochastic programming model capturing this. The outcome space of the stochastic parameters is represented through a set of scenarios. Each scenario consists of historical weather data and remaining useful lifetimes of the sub-assemblies sampled from failure distributions. A large number of scenarios is generated, then reduced by k-medoids clustering, to represent the outcome space while the problem is computationally tractable. We solve the model using an ad-hoc integer L-shaped method, and the solution is used to develop problem specific cuts. We then use this method to explore the potential savings that can be achieved by moving from a condition-based maintenance scheme to a predictive maintenance scheme.

### 11:05 to 11:30 Probabilistic Constrained Optimization on Gas Networks

Speaker: Michael Schuster, Friedrich-Alexander Universität Erlangen-Nürnberg (FAU)

Coauthors: Rüdiger Schultz

Uncertainty often plays an important role in gas transport and probabilistic constraints are an excellent modeling tool to obtain controls and other quantities that are robust against perturbations in e.g., the boundary data. We first consider a stationary gas transport model with uncertain boundary data on networks. We provide an efficient way to compute the probability that random boundary data is feasible. In this context feasible means that the pressure corresponding to the random boundary data meets some box constraints at the network junctions.

Further we consider and analyze optimization problems with probabilistic constraints in the stationary and the dynamic setting where the probabilistic constraints are approximated by the kernel density estimator approach. Additionally we compare the solutions of the probabilistic constrained optimization problems with the solutions of the corresponding deterministic problems.

Keywords: Probabilistic Constraints; Gas Networks; Kernel Density Estimator;

## Estimation and Statistics

Chaired by Angela Zhou

9:50 to 10:15 **data-based stochastic programming using bootstrap estimation** Speaker: Xiaotie Chen, University of California, Davis

Coauthors: David L Woodruff

We discuss bootstrap and bagging algorithms for stochastic programming that uses only sampled data to obtain both a consistent sample-average solution and a consistent estimate of confidence intervals for the optimality gap. The underlying distribution whence the samples come is not required.

Keywords: data-driven; stochastic programming; bootstrap; bagging

10:15 to 10:40 Assessing solution quality in risk-averse stochastic programs Speaker: Ruben van Beesten, NTNU

Coauthors: Nick W. Koning, David P. Morton

Determining whether a solution to a stochastic program is of high quality (optimal or near optimal) is an important, but non-trivial task. A major difficulty is the inherent complexity associated with computing the objective function of a stochastic program. The standard approach in the literature is to use Monte Carlo sampling-based approaches, such as the multiple replications procedure (MRP), to estimate a confidence interval for the optimality gap. While these confidence intervals are statistically valid for solutions to risk-neutral stochastic programs, they break down in the risk-averse case, due to a bias arising from applying the risk measure to the sampled distribution. In this paper, we develop an extension of the MRP that yields statistically valid confidence intervals for the optimality gap in risk-averse stochastic programs. We correct the aforementioned bias by deriving a "primal" counterpart to the dual representation of the risk measure, and solving the primal problem using a second sample from the distribution. Our approach works for a broad class of convex risk measures that includes conditional value at risk and the entropic risk measure.

Keywords: risk-averse SP; multiple replications procedure; assessing solution quality

### 10:40 to 11:05 Integrated Conditional Estimation and Optimization

Speaker: Meng Qi, Cornell University

Coauthors: Paul Grigas, Meng Qi, Zuo-Jun Max Shen

This work investigates integrating estimation and optimization in decision-making. Many real-world optimization problems involve uncertain parameters with probability distributions that can be estimated using contextual feature information. In contrast to the standard approach of first estimating the distribution of uncertain parameters and then optimizing the objective based on the estimation, we propose an integrated conditional estimation-optimization (ICEO) framework that estimates the underlying conditional distribution of the random parameter while considering the structure of the optimization problem. We directly model the relationship between the conditional distribution of the random parameter and the contextual features, and then estimate the probabilistic model with an objective that aligns with the downstream optimization problem. We show that our ICEO approach is asymptotically consistent under moderate regularity conditions and further provide finite performance guarantees in the form of generalization bounds. Computationally, performing estimation with the ICEO approach is a non-convex and often non-differentiable optimization problem. We propose a general methodology for approximating the potentially non-differentiable mapping from estimated conditional distribution to optimal decision by a differentiable function, which greatly improves the performance of gradient-based algorithms applied to the non-convex problem. We also provide a polynomial optimization solution approach in the semi-algebraic case. Numerical experiments are also conducted to show the empirical success of our approach in different situations including with limited data samples and model mismatches.

# 11:05 to 11:30 Empirical Gateaux Derivatives for Optimization-Based Estimators in Causal Inference

Speaker: Angela Zhou, University of Southern California

Coauthors: Michael I. Jordan, Yixin Wang, Angela Zhou

We study a constructive algorithm that approximates debiasing adjustments, Gateaux derivatives, for statistical functionals by finite-differencing. We focus on the use of stochastic optimization functionals in causal inference, including Markov decision processes (linear programming formulation) and sensitivity analysis (robust optimization, CVaR). We first start with the causal setting and study the exact relationship between finite-differences and the analytical Gateaux derivative. We use our characterization for the average treatment effect with a general finite-difference calculus. The newfound ability to approximate bias adjustments in the presence of arbitrary constraints illustrates the usefulness of constructive approaches for Gateaux derivatives. We find that (1) the statistical structure of the functional (rate-double robustness) can permit less conservative rates of finite-difference approximation and (2) classical arguments based on Danskin's theorem for evaluating Gateaux derivatives of statistical functionals do not recover the statistically sharpest debiasing, although finite differences approximates this (up to approximation error).

Keywords: influence functions; causal inference; debiasing

Paper Session Thursday 9:50 to 11:30

## **Robust and Chance Constrained Applications**

Chaired by Hoda Bidkhori

9:50 to 10:15 Cooperative games under uncertainty: a robust chance-constrained approach Speaker: Xuan Vinh Doan, The University of Warwick

Coauthors: Tri-Dung Nguyen

This talk concerns a fundamental challenge of incorporating uncertainty into cooperative games. We introduce a new solution concept of (robust) least chance decisions for cooperative games under uncertainty using the chance-constrained approach. We develop a framework to find those decisions and compute their (robust) least chance dissatisfaction for cooperative games under normally distributed uncertainty and moment-based distributional ambiguity. We demonstrate how the framework can be applied to several operations research games including resource-sharing games, project selection games, and general linear production games with detailed analytical results.

Keywords: cooperative games; chance-constrained optimization; distributional ambiguity

### 10:15 to 10:40 Robust Spare Parts Inventory Management

Speaker: Ahmadreza Marandi, Eindhoven University of Technology

Coauthors: Zhao Kang, Rob Basten, Ton de Kok

We consider the problem of spare part inventory management during the new product introduction (NPI) phase, where limited data is available for estimating the demand process. Most conventional spare parts inventory control models typically assume that demand follows a Poisson distribution, but this assumption may not hold during the NPI phase.

We propose an adaptive robust optimization (ARO) approach for multi-item, single-location, continuous review spare parts inventory control with lost sales. We show how the ARO problem can be reformulated as a static robust optimization problem with an exponential number of constraints. Next, we introduce the iterative projection in descending order (IPDO) algorithm, which is designed to find solutions efficiently even in cases with a large number of items in the model. We prove the optimality of the solutions obtained by IPDO under certain conditions. Based on the insight that not all constraints are necessary to obtain an optimal solution, we propose a more time-efficient algorithm called the constraint generation algorithm (ConGA). We perform comprehensive simulation-based experiments to demonstrate the conditions in which our ARO model outperforms the conventional Poisson-based model by achieving a higher fill rate and lower investment cost.

Keywords: robust optimization; two-stage; inventory control; spare parts; multi-item

### 10:40 to 11:05 Robust Kidney Exchange

Speaker: Hoda Bidkhori, George Mason University

Coauthors: Hoda Bidkhori, John Dickerson, Duncan McElfresh, Ke Ren

In barter exchanges, participants directly trade their endowed goods in a constrained economic setting without money. Transactions in barter exchanges are often facilitated via a central clearinghouse that must match participants even in the face of uncertainty – over participants, the existence and quality of potential trades, and so on. Leveraging robust combinatorial optimization techniques, we address uncertainty in kidney exchange, a real-world barter market where patients swap (in)compatible paired donors. We provide two scalable, robust methods to handle two distinct types of uncertainty in kidney exchange – over the quality and the existence of a potential match.

In addition, we also consider post-match failure uncertainties. Planned trades can fail for various reasons, such as unforeseen logistical challenges or changes in patient or donor health. These failures cause major inefficiency in fielded exchanges; if even one individual trade fails in a planned cycle or chain, all or most of the resulting cycle or chain fails. We propose tractable optimization approaches considering the uncertainties associated with failure probabilities. Keywords: Robust Optimization, Distributionally Robust Optimization, Kidney Exchange

11:05 to 11:30 **Open** 

## Uncertainty and Risk

Chaired by Jiaming Liang

## 14:10 to 14:35 Risk-Averse Stochastic Programming for High-Impact, Low-Probability Events with Applications to Flash Flooding Climate Change Risk Speaker: Beau Groom, University of Tennessee

Coauthors: Mingzhou Jin

Traditional stochastic programming (SP) assumes either a known probability distribution or uncertainty set. Both riskneutral (expected value) and risk-averse (chance-constrained or robust optimization) postures largely ignore low-probability, high-impact events. This work relaxes both assumptions to propose a novel SP model for high-impact, low-probability events and applies it to the projected increase in flash flooding events due to the effects of climate change. The magnitude and location of this flooding is highly uncertain, meaning each road segment has a low flooding probability. However, these events have both short-term (traffic delays) and long-term (road degradation) effects that must be considered in investment planning.

Keywords: Stochastic Programming; Risk-Averse Decision Making; Climate Change

## $14:35\ {\rm to}\ 15:00$ Data-driven two-stage conic optimization with rare, high-impact zero-one uncertainties

Speaker: Anirudh Subramanyam, The Pennsylvania State University

Coauthors: Mohamed El Tonbari, Kibaek Kim

We address high-dimensional zero-one random parameters in two-stage convex conic optimization problems. Such parameters typically represent failures of network elements and constitute rare, high-impact random events in several applications. Given a sparse training dataset of the parameters, we motivate and study a distributionally robust formulation of the problem using a Wasserstein ambiguity set centered at the empirical distribution. We present a simple, tractable, and conservative approximation of this problem that can be efficiently computed and iteratively improved. Our method relies on a reformulation that optimizes over the convex hull of a mixed-integer conic programming representable set, followed by an approximation of this convex hull using lift-and-project techniques. We illustrate the practical viability and strong out-of-sample performance of our method on nonlinear optimal power flow and multi-commodity network design problems that are affected by random contingencies, and we report improvements of up to 20% over existing sample average approximation and two-stage robust optimization methods.

Keywords: distributionally robust optimization, rare events

### 15:00 to 15:25 Variance Reduction and Low Sample Complexity in Stochastic Optimization via Proximal Point Methods

Speaker: Jiaming Liang, Yale University

This paper studies novel variance reduction techniques in stochastic convex composite optimization via proximal point methods. It applies those techniques to obtain improved sample complexity in high probability results without assuming the standard light-tail conditions such as sub-Gaussian noise distributions. The paper develops both accelerated and unaccelerated proximal point methods based on the understanding that Nesterov's acceleration method can be regarded as an accelerated version of the proximal bundle method. Another interesting result of the paper is that it establishes the iteration complexity of Nesterov's acceleration method with the restart technique in the deterministic setting.

Keywords: Sample complexity; Proximal point method; Variance reduction

106

## 15:25 to 15:50 **Open**

#### Paper Session Thursday 14:10 to 16:00

## SDDP Advancements and Applications

Chaired by Jarand Hole

# 14:10 to 14:35 Hydropower Aggregation by Spatial Decomposition within the SDDP Algorithm Speaker: Arild Helseth, SINTEF Energy Research

#### Coauthors: Birger Mo

The balance between detailed technical description, representation of uncertainty and computational complexity is central in long-term scheduling models applied to hydro-dominated power systems. The aggregation of complex hydropower systems into equivalent energy representations (EER) is a commonly used technique to reduce dimensionality and computation time in scheduling models. This work presents a method for coordinating the EERs with their detailed hydropower system representation within a model based on stochastic dual dynamic programming (SDDP). SDDP is applied to an EER representation of the hydropower system, where feasibility cuts derived from optimization of the detailed hydropower are used to constrain the flexibility of the EERs. These cuts can be computed either before or during the execution of the SDDP algorithm and allow system details to be captured within the SDDP strategies without compromising the convergence rate and state-space dimensionality. Results in terms of computational performance and system operation are reported from a test system comprising realistic hydropower watercourses.

Keywords: Hydropower Scheduling; Stochastic Optimization; Decomposition

### 14:35 to 15:00 A Multicut Approach to Calculate Upper Bounds for Risk Averse SDDP Speaker: Raphael Chabar, PSR - Energy Consulting & Analytics

Coauthors: Joaquim Dias Garcia, Mario Veiga Ferraz Pereira

When solving Multistage Stochastic Programming problems, a known caveat of adding risk-aversion to Stochastic Dual Dynamic Programming (SDDP) via a risk measure such as Conditional Value-at-Risk (CVaR) is losing the ability to properly estimate an upper bound for the optimal solution during the Forward step; therefore leaving SDDP without a clear stopping criterion. In this paper, we propose using the information already contained in a Multicut formulation of SDDP to solve this problem.

By looking at a problem's decision tree, we can view an uncertainty scenario as a sequence of uncertainty realizations (Openings) for each stage. Calculating Multicut approximations during the Backward step, instead of the usual Average cut, preserves the information about which choices of Openings give rise to the worst scenarios, thus contributing more for the CVaR cost. We use this to bias the sampling method on the Forward step, in order to give the same weight to each Opening as it had on the Backward step.

We present results using a real Hydrothermal dispatch case based on data from Colombia, a standard approximation of the Brazilian Operation problem, and a problem small enough to calculate its deterministic equivalent, enabling us to see that the calculated Upper Bound is maintained slightly above the real optimal value. Our Numerical Experiments showed that this method consistently calculates Upper Bounds higher than Lower Bounds for those risk averse problems.

Keywords: Risk-Averse Optimization; Multicut; Stochastic Dual Dynamic Programming

# 15:00 to 15:25 Backward resampling-based SDDP approach: application to the (very) large-scale power generation planning problem of the Brazilian system

Speaker: Andre Luiz Diniz, CEPEL - Brazilian Electric Energy Research Center

Coauthors: Andre L. Diniz, Cristiane B. Cruz, Laura Bahiense

The application of SDDP strategy to long term power generation planning usually assumes that a fixed set of finite backward scenarios are provided beforehand, in order to approximate the distribution function of the random variables of each stage of the problem. However, for practical purposes the actual problem to be solved is the one with the "true" continuous distribution function. In this sense, this work proposes to continuously change the set of backward scenarios - or even
increase its cardinality - during SDDP iterations, to obtain a more robust operation policy. The theoretical background behind this approach is based on Jensen's inequality, which states that if the finite distribution is constructed such that each scenario is the (multidimensional) expected value of the random variables for the corresponding subset in the partition of their domain, the resulting recourse function is a lower approximation of the recourse function of the continuous problem. As a consequence, cuts built in all iterations whose (different) backward scenarios follow this property can be gathered together in a single recourse function, still yielding a valid lower approximation of the recourse function of the continuous distribution and having the effect of taking, for each value of the state variables, the most restrictive cost among all sets of backward scenarios. Since scenario reduction algorithms such as k-means and Latin hypercube sampling may not strictly satisfy the above property in practical applications, variants of the proposed approach that take the (weighted) average value of the cuts provided in different iterations are also proposed. Results are presented for both a toy problem, to empirically verify the correctness of the proposed approach, and for the generation planning problem of the large-scale Brazilian system, whose large number of hydro plants (over 160) makes it very difficult to represent the stochastic problem with a fixed set of backward scenarios.

Keywords: Stochastic dual dynamic programming, distribution function, Jensen's inequality

### 15:25 to 15:50 Capacity planning using SDDP.jl

Speaker: Jarand Hole, Norwegian University of Science and Technology / The University of Auckland

#### Coauthors: Andy Philpott, Oscar Dowson

We describe a method to compute optimal investments in renewable electricity capacity in systems with hydroelectric reservoirs. The approach leverages the policy graph concept in the SDDP.jl package to determine optimal capacity expansions in green peaking plant, wind, and solar using infinite horizon stochastic dual dynamic programming. To illustrate the method, it is applied to the New Zealand electricity system.

Keywords: Capacity planning; SDDP; infinite horizon; SDDP.jl; Julia

# Bounds and Analysis

Chaired by Wim van Ackooij

# 14:10 to 14:35 High Probability Sample Complexity Bounds for Adaptive Optimization Methods with Stochastic Oracles

Speaker: Miaolan Xie, Cornell University

### Coauthors: Billy Jin, Katya Scheinberg

We consider a simple adaptive optimization framework for continuous optimization where the (explicit or implicit) step size in each iteration is adaptively adjusted by the estimated progress of the algorithm instead of requiring manual tuning or using a pre-specified sequence of step sizes. The framework accommodates a stochastic setting where function value, gradient (and possibly Hessian) estimates are available only through noisy probabilistic oracles (can be biased and possibly arbitrarily bad with some constant probability). This framework is very general and encompasses stochastic variants of line search, quasi-Newton, cubic regularized Newton methods for unconstrained problems, and stochastic SQP methods for constrained problems. The probabilistic oracles capture multiple standard settings including expected loss minimization in machine learning, zeroth-order (derivative-free) and low-precision optimization. Under reasonable conditions on the oracles, we derive high probability bounds on the sample (and iteration) complexity of the algorithms.

Keywords: stochastic optimization, nonlinear optimization, adaptive, high probability

## 14:35 to 15:00 A discussion of first-order information of probability functions

Speaker: Wim van Ackooij, EDF Lab Paris-Saclay

Coauthors: P/'edro P/'erez-Aros

In this talk we will discuss some recent results regarding the study of first-order information of probability functions. We will provide insights into generalized differentiation, and also provide computable formulae.

Keywords: Probability functions ; Gradients ;

# $15:00\ {\rm to}\ 15:25\ {\rm Support}\ {\rm Vector}\ {\rm Regression}\ ({\rm SVR})$ is investigated in the framework of the Fundamental Risk Quadrangle

Speaker: Anton Malandii, Stony Brook University

Coauthors: Stan Uryasev

The Support Vector Regression (SVR) is investigated in the framework of the Fundamental Risk Quadrangle. Both formulations of SVR,  $\varepsilon$ -SVR and  $\nu$ -SVR, correspond to the minimization of equivalent regular error measures (Vapnik error and CVaR norm) with a regularization penalty. These error measures, in turn, define corresponding risk quadrangles. By constructing the risk quadrangle corresponding to SVR, we show that SVR is the asymptotically unbiased estimator of the average of two symmetric conditional quantiles. Furthermore, the quadrangle approach shows the equivalence of  $\varepsilon$ -SVR and  $\nu$ -SVR. Additionally, SVR is formulated as a regular deviation minimization problem with a regularization penalty by applying Error Shaping Decomposition of Regression. Finally, the dual formulation of SVR is derived in the risk quadrangle framework.

### 15:25 to 15:50 **A Value Function Approach to Two-stage Stochastic Mixed-Integer Programs** Speaker: Andrew Schaefer, Rice University

#### Coauthors: Eric Antley, Osman Ozaltin

We propose a value function approach to a class of two-stage stochastic mixed-integer programs with discretely distributed right-hand sides. Unlike previous value function approaches that require discrete variables in one or both stages, we allow mixed-integer variables in both stages, which greatly complicates the structure of the value functions. We develop a global branch-and-bound algorithm that exploits the structure of mixed-integer value functions. We derive novel bounds using bilevel programming to prune subproblem nodes in the branch-and-bound tree. We demonstrate that our method is capable of optimally solving large instances with tens of thousands of scenarios for stochastic mixed-integer programs. Our computational results show that the proposed method has significantly better performance than solving the extensive form.

Keywords: mixed-integer programming value functions; bilevel program; stochastic MIP

### Paper Session Thursday 14:10 to 16:00

# Theory and Applications in the Interface of OR and ML

Chaired by Yifan Hu

14:10 to 14:35 Learning the feasible set of an optimization problem from data Speaker: Angelos Georghiou, University of Cyprus

Coauthors: Angelos Georghiou, Ke Ren, Peyman Mohajerin Esfahani

Inverse optimization is a supervised learning method for "reverse engineering" the structure a parametric optimization problem from data. The data are comprised of parameter and optimal decision pairs generated by the unknown underlying optimization model. The majority of work in the literature assumes that the feasible set of the optimization is known and focuses on recovering the objective function. In contrast, this work focuses on learning the feasible set. We present data-driven models which are formulated as robust optimization problems with decision-dependent uncertainty. We propose hypothesis classes that allow to reformulate the problem into bilinear optimization problems. We provide both conservative as well as progressive approximations that can be efficient solved, while the structure of the hypothesis class allows us to control the quality of the approximation. We demonstrate the efficacy of the method on energy generation and distribution applications.

Keywords: inverse optimization, robust optimization

# 14:35 to 15:00 Learning Optimal Classification Trees Robust to Distribution Shifts

Speaker: Nathan Justin, University of Southern California

Coauthors: Sina Aghaei, Andrés Gómez, Phebe Vayanos

We consider the problem of learning classification trees that are robust to distribution shifts between training and testing/deployment data. This problem arises frequently in high stakes settings such as public health and social work where data is often collected using self-reported surveys which are highly sensitive to e.g., the framing of the questions, the time when and place where the survey is conducted, and the level of comfort the interviewee has in sharing information with the interviewer. We propose a method for learning optimal robust classification trees based on mixed-integer robust optimization technology. In particular, we demonstrate that the problem of learning an optimal robust tree can be cast as a single-stage mixed-integer robust optimization problem with a highly nonlinear and discontinuous objective. We reformulate this problem equivalently as a two-stage linear robust optimization problem for which we devise a tailored solution procedure based on constraint generation. We evaluate the performance of our approach on numerous publicly available datasets, and compare the performance to a regularized, non-robust optimal tree. We show an increase of up to 14.16% in worst-case accuracy and of up to 4.72

Keywords: robust optimization; distribution shift; decision trees

## 15:00 to 15:25 **Contextual Stochastic Bilevel Optimization** Speaker: Yifan Hu, EPFL

## Coauthors: Yifan Hu, Andreas Krause, Daniel Kuhn

In this paper, we propose *conditional stochastic bilevel optimization*, an extension of the classical stochastic bilevel optimization when the lower-level problem minimizes contextual stochastic optimization. Such optimization framework provides natural models for meta-learning, distributionally robust optimization with side information, and instrumental variable regression. Due to the contextual stochastic optimization in the lower-level problem, existing methods for bilevel optimization either fail or admit sub-optimal complexity bounds. We design efficient gradient-based optimization algorithms and analyze the sample and the computational complexities. Various numerical results demonstrate the efficiency of the proposed algorithms.

112

Keywords: bilevel optimization, distributional robust, meta-learning, side information

## 15:25 to 15:50 Optimal Algorithms in Nonconvex Minimax Optimization

Speaker: Siqi Zhang, Johns Hopkins University

Coauthors: Junchi Yang, Cristobal Guzman, Negar Kiyavash, Niao He

Nonconvex minimax optimization has attracted more and more attention with the surge in various machine learning models. In this talk, we will discuss the lower complexity bounds for finding approximate stationary points of nonconvex-strongly-concave (NC-SC) smooth stochastic minimax optimization problems. Regarding the gap with existing literature, we introduce a generic Catalyst acceleration scheme that deploys existing gradient-based methods to solve a sequence of crafted strongly-convex-strongly-concave subproblems. Our proposed algorithm is shown to match the corresponding lower bounds.

# Multistage Stochastic Programming and Applications

Organized by Suvrajeet Sen

## 14:10 to 14:45 Stochastic Dynamic Linear Programming: A Sequential Sampling-based Multistage Stochastic Programming Algorithm

Speaker: Harsha Gangammanavar, Southern Methodist University

Coauthors: Suvrajeet Sen

In this talk, we present stochastic dynamic linear programming (SDLP), a sequential sampling algorithm for multistage stochastic linear programs with stagewise independent uncertainty. Algorithms that address multistage stochastic linear programming (MSLP) problems often rely upon scenario trees to represent the underlying stochastic process. When this process exhibits stagewise independence, sampling-based techniques, particularly the stochastic dual dynamic programming (SDDP) algorithm, have received wide acceptance. However, these sampling-based methods still operate with a deterministic representation of the problem, which uses the so-called sample average approximation. On the other hand, the sequential sampling nature of SDLP allows for optimizing the decision process while concurrently assimilating new uncertainty, either through a scenario tree or sample average approximation. A principal component embedded within the algorithm is a piecewise-affine policy for identifying incumbent solutions used in the quadratic regularization terms at non-terminal stages. We will present the main results that establish the asymptotic convergence of value function approximations generated by the algorithm and solution mapping to an optimal policy with probability one. We will also present computational experiments that compare SDLP and SDDP algorithms on instances of a distributed storage control problem in a power system with renewable generation resources.

Keywords: Multistage stochastic programming, sequential sampling, data-driven policies

## 14:45 to 15:10 **Risk-averse Regret Minimization in Multi-stage Stochastic Programs** Speaker: Mehran Poursoltani, HEC Montréal

Coauthors: Mehran Poursoltani, Erick Delage, Angelos Georghiou

Within the context of optimization under uncertainty, a well-known alternative to minimizing expected value or the worst-case scenario consists in minimizing regret. In a multistage stochastic programming setting with a discrete probability distribution, we explore the idea of risk-averse regret minimization, where the benchmark policy can only benefit from foreseeing  $\Delta$  steps into the future. The  $\Delta$ -regret model naturally interpolates between the popular ex ante and ex post regret models. We provide theoretical and numerical insights about this family of models under popular coherent risk measures and shed new light on the conservatism of the  $\Delta$ -regret minimizing solutions.

Keywords: regret minimization; risk measures; multistage stochastic programming

15:10 to 15:35 Robust and Stochastic Unit Commitment of an Isolated Industrial Microgrid Speaker: Vitor Luiz Pinto de Pina Ferreira, École Nationale des Ponts et Chaussées

Coauthors: Vitor Luiz Pinto de Pina Ferreira, Vincent Leclère

The classical Unit Commitment problem, for energy applications, consists in deciding when and which thermal units are on or off, in order to schedule a production plan that satisfies the load with minimal cost and/or CO2 emissions. For ecological and economical reasons, there is a worldwide increase in renewable energy sources, including solar and wind power, leading to uncertain power generation. Uncertain Unit Commitment (UUC) models extend to incorporate uncertainties, implying additional computational complexity and specific solution methods.

In partnership with TotalEnergies, we are considering an isolated industrial complex with high deterministic energy load. The load is met using only internal resources: thermal generators, PV panels, and batteries. The numerical difficulties of this problem arise from: storage and ramping constraints of thermal units, implying a coupling across stages; binary variables; and

uncertain solar production. For safety and reliability, the demand needs to always be satisfied. However, an over-conservative approach can lead to increased energy production costs and emissions.

In reality, at each stage some decisions are made and new information (e.g. PV production at time t) is obtained. This leads to tractability issues—the problem grows very large very quickly, particularly in quantity of binary variables. A conservative approach is to decide them in the first stage: a feasible approximation. The continuous variables are seen as recourse variables, either with growing or full knowledge of uncertainties, resulting in a two-stage approximation. These choices result in different information structures.

In this talk, we compare variants of the UUC problem: first, expected value and robust criterion; and second, the information structure. We provide cut-based decomposition methods, built on state-of-the-art numerical methods, including both Stochastic and Robust Dual Dynamic Programming algorithms, and numerical results.

Keywords: Unit commitment;Stochastic optimization;Robust optimization;Cutting planes;MILP

## 15:35 to 16:00 My Humble Response to Roger Wets' Challenges in SP

Speaker: Suvrajeet Sen, University of Southern California

Coauthors: Harsha Gangammanavar

At the 2016 ICSP Conference in Buzios Brazil, Roger Wets made a presentation summarizing some of the challenges that remained for SP. My presentation will focus on advances connected with those challenges, and will demonstrate that the community is finally headed towards "designing optimization problems which yield an approximating solution, and provide access to a methodology that can efficiently evaluate the reliability of this approximating solution". My main focus will be on Compromise Decisions for Two-stage, and Multi-stage SLP, as well as two-stage Stochastic MIPs. This work will summarize joint work with former Ph.D. students (Shuotao Diao, Yifan Liu and Jiajun Xu).

Keywords: Multi-scale Optimization

#### Mini-symposium Thursday 14:10 to 16:00

# Causal transport and multistage distributionally robust optimization

Organized by Rui Gao

# 14:10 to 14:45 Entropic Regularization of Optimal Transport

Speaker: Alois Pichler, TU Chemnitz

Coauthors: Rajmadan Lakshmanan

A fundamental metric in stochastic optimization is the Wasserstein distance, for which we consider entropy as an additional component. The paper provides a boost for numerical computations, so that distances are accessible in  $O(n \log^2 n)$ . The regularization allows smoothed versions of optimal quantization as well, so that many stochastic optimization problems benefit from the regularization.

Keywords: Optimal Transport, Entropy, Wasserstein, Sinkhorn

14:45 to 15:10 Decision-making with Side Information: A Causal Transport Robust Approach Speaker: Luhao Zhang, The University of Texas at Austin

Coauthors: Jincheng Yang, Rui Gao, Ningyuan Chen, Ming Hu

We consider stochastic optimization with side information where, prior to the decision-making, covariate data are available to inform better decisions. In particular, we propose to consider a distributionally robust formulation based on causal transport distance. Compared with divergence and the Wasserstein metric, the causal transport distance is better at capturing the information structure revealed from the conditional distribution of random problem parameters given the covariate values. We derive a dual reformulation for evaluating the worst-case expected cost and show that the worst-case distribution in a causal transport distance ball has a similar conditional information structure as the nominal distribution. When optimizing over affine decision rules, we identify cases where the overall problem can be solved by convex programming. When optimizing over all (non-parametric) decision rules, we identify a new class of robust optimal decision rules when the cost function is convex with respect to a one-dimensional decision variable.

Keywords: Distributionally robust optimization; optimal transport; end-to-end learning

# 15:10 to 15:35 Dual Dynamic Programming for Data-driven Distributionally Robust Multistage Convex Optimization

Speaker: Shixuan Zhang, ICERM, Brown University

#### Coauthors: Xu Andy Sun

In this talk, we consider distributionally robust multistage convex optimization (DR-MCO) with Wasserstein ambiguity sets constructed from stagewise independent empirical distributions. We show that the DR-MCO models have favorable out-of-sample performance guarantee and adjustable level of in-sample conservatism. Then we extend the dual dynamic programming algorithm for the data-driven DR-MCO with complexity analysis based on single stage subproblem oracles, for which we provide two possible implementations exploiting convexity or concavity of the uncertain cost functions. Numerical experiments on inventory control problems and hydrothermal energy system planning problems are conducted to show the effectiveness of our DR-MCO, in comparison with the widely used risk-neutral and risk-averse multistage stochastic optimization approaches.

Keywords: dual dynamic programming; data-driven distributionally robust optimization

Speaker: Rui Gao, University of Texas at Austin

#### Coauthors: Rohit Arora

We study multistage distributionally robust optimization in which the uncertainty set consists of stochastic processes that are close to a scenario tree in the nested distance. Compared to other choices such as Wasserstein distance between stochastic processes, the nested distance accounts for information evolution, making it hedge against a plausible family of data processes. Due to the non-convexity of the nested distance uncertainty set, the resulting minimax problem is notoriously difficult to solve. In spite of this challenge, in this paper, we develop an equivalent robust dynamic programming reformulation. This reformulation has two important implications: (1) Modeling-wise, it unveils that the considered single minimax multistagestatic formulation based on nested distance for stochastic processes is equivalent to a nested minimax multistage-dynamic formulation based on one-period nested Wasserstein distance, thus both of which admit a time-consistent robust optimal policy. (2) Computation-wise, we identify conditions under which the robust Bellman recursion can be interpreted as normregularized sample average approximation and solved via tractable convex programs. We develop a stochastic dual dynamic programming algorithm and apply it to dynamic portfolio selection. Numerical experiments demonstrate the superior outof-sample performance of our robust approach.

Keywords: Nested distance; optimal transport; time consistency

#### Mini-symposium Thursday 14:10 to 16:00

# Discrete Optimization under Uncertainty

Organized by Ward Romeijnders

## 14:10 to 14:45 Benders' Decomposition Algorithms for Stochastic Mixed-integer Programs Speaker: Ward Romeijnders, University of Groningen

Coauthors: Niels van der Laan

We discuss new and existing Benders' decomposition algorithms for two-stage stochastic mixed-integer programs. In our new algorithm, we iteratively construct tighter lower bounds of the expected second-stage cost function using a new family of so-called scaled optimality cuts. We derive these cuts by parametrically solving extended formulations of the second-stage problems using deterministic mixed-integer programming techniques. The advantage of these scaled cuts is that they allow for parametric non-linear feasibility cuts in the second stage, but that the optimality cuts in the master problem remain linear. We establish convergence by proving that the optimality cuts recover the convex envelope of the expected second-stage cost function.

Keywords: Stochastic mixed-integer programming; Benders' decomposition; Cutting planes

# 14:45 to 15:10 Distributionally Ambiguous Network Interdiction Problems

Speaker: Manish Bansal, Virginia Tech

### Coauthors: Sumin Kang

Interdiction problems are characterized as games played between two players: an interdictor/attacker/leader and defender/follower. The leader is a player who makes interdiction decisions using limited resources to degrade the follower's performance, and the follower makes decisions after observing the interdiction decision. We introduce new algebraic modeling frameworks that allow uncertainty in the success and impact of the attacks, adjustments based on risk-appetite (risk-receptive or risk-averse) of the decision makers, and incomplete information of probability distribution associated with uncertain data. We present reformulation and cutting-plane based exact methods for solving these models. The distributionally risk-averse games arise in applications where a risk-averse leader is the main protagonist who interdicts a follower (opponent or evader) to cause delays in their supply convoy. In contrast, the distributionally risk-receptive games are applicable for network vulnerability analysis where a network user (or follower) also seeks to identify vulnerabilities in the network against potential disruptions by an adversary (or leader) who is receptive to risk for improving the expected objective values. To evaluate the performance of our approaches, we consider two games: (a) Shortest Path Network Interdiction, where the follower finds a minimum cost path between a given pair of source and destination nodes of the interdicted network. This is a joint work with Sumin Kang, PhD student at Virginia Tech.

Keywords: Interdiction models; DRO; distributionally risk-receptive; general ambiguity set

15:10 to 15:35 Ensemble Variance Reduction Methods for Stochastic Mixed-Integer Programming and their Application to the Stochastic Facility Location Problem Speaker: Jiajun Xu,

#### Coauthors: Suvrajeet Sen

Sample average approximation (SAA), the standard approach to Stochastic Mixed-Integer Programming, does not provide guidance for cases with limited computational budgets. In such settings, variance reduction is critical in identifying good decisions. This paper explores two closely-related ensemble methods to determine effective decisions with a probabilistic guarantee: a) The first approach recommends a decision by coordinating aggregation in the space of decisions, as well as aggregation of objective values. This combination of aggregation methods generalizes the bagging method and the "compromise decision" of stochastic linear programming. Combining these concepts, we propose a stopping rule which provides an upper bound on the probability of early termination. b) The second approach applies efficient computational budget

allocation for objective function evaluation and contributes to identifying the best solution with a predicted lower bound on the probability of correct selection. It also reduces the variance of the upper bound estimate at optimality. Furthermore, it adaptively selects the evaluation sample size. Both approaches provide approximately optimal solutions even in cases with a huge number of scenarios, especially when scenarios are generated by using oracles/simulators. Finally, we demonstrate the effectiveness of these methods via extensive computational results for "megascale" (extremely large scale) stochastic facility location problems.

Keywords: Stochastic Mixed-Integer Programming; variance reduction; bagging

## 15:35 to 16:00 Novel Decision Rules in Sequential Decision-making Under Uncertainty Speaker: Maryam Daryalal, HEC Montréal

#### Coauthors: Maryam Daryalal

In sequential decision-making under uncertainty, multistage stochastic mixed-integer programming (MSMIP) is a tool for addressing optimization problems with a given probability distribution and the goal of optimizing a performance measure over a planning horizon. If there is no knowledge about the probability distribution, multistage adaptive robust optimization (MSARO) is a suitable modelling framework. In this talk we present novel approximation approaches for general classes of MSMIP and MSARO problems. We rely on imposing a certain structure on the decisions, leading to novel decision rules. Our presentation focuses on utilizing the decision rules to obtain bounds on the optimal value of a problem instance and derive primal feasible policies. We also compare the relaxation strengths of different techniques. We showcase the practicality of these methods in fields such as resource allocation in telecommunication networks and production planning, among others.

Keywords: Stochastic Programming; Robust Optimization; Decision Rules

### Mini-symposium Thursday 14:10 to 16:00

# Recent Advances to Solve Stochastic and Robust Optimizations Problems

Organized by Hamed Rahimian

## 14:10 to 14:45 Dual Decomposition of Two-stage Distributionally Robust MIP

Speaker: Kibaek Kim, Argonne National Laboratory

Dual decomposition has shown to be effective and scalable for solving large-scale two-stage stochastic mixed-integer programming problems particularly when the second stage has integer variables. In this talk, we present the application of the dual decomposition to two-stage distributionally robust mixed-integer programming (DRMIP) problems. We present and two different derivations of the dual decomposition of DRMIP, which can be achieved by modifications of the existing dual decomposition method of SMIP. A heuristic procedure is also developed to find primal bounds (i.e., upper bounds in the minimization) of the DRMIP problem. For numerical experiments, we have implemented the two dual decomposition methods in an open-source parallel decomposition solver DSP, developed at Argonne National Laboratory. We use a set of test problem instances modified from the standard test library for SMIP. Then we conclude this talk by discussing the computational implications from our numerical experiments.

# $14{:}45\ {\rm to}\ 15{:}10\ {\rm A}$ logic-based Benders decomposition approach to solve the K-adaptability problem

Speaker: Ahmed Saif, Dalhousie University

Coauthors: Alireza Ghahtarani, Alireza Ghasemi, Erick Delage

We propose a novel approach to solve K-adaptability problems with convex objective and constraints and integer first-stage decisions. A logic-based Benders decomposition is applied to handle the first-stage decisions in a master problem, thus the sub-problem becomes a min-max-min robust combinatorial optimization problem that is solved via a double-oracle algorithm that iteratively generates adverse scenarios and recourse decisions and assigns scenarios to K-subsets of the decisions by solving p-center problems. Extensions of the proposed approach to handle parameter uncertainty in both the first-stage objective and the second-stage constraints are also provided. We show that the proposed algorithm converges to an optimal solution and terminates in finite number of iterations. Numerical results obtained from experiments on benchmark instances of the adaptive shortest path problem, the regular knapsack problem, and a generic K-adaptability problem demonstrate the performance advantage of the proposed approach when compared to state-of-the-art methods in the literature.

Keywords: K-adaptability; Robust optimization; Discrete recourse; Benders decomposition

### 15:10 to 15:35 **Inexact Cuts in SDDiP and Enhancement Technologies for Lagrangian Cuts** Speaker: Hanbin Yang, The Chinese University of Hong Kong, Shenzhen

### Coauthors: Haoxiang Yang

For multi-stage mixed-integer stochastic programming, the Lagrangian cuts are tight and can be used in cutting-plane method to achieve convergence if state variables are binary. However, regular Lagrangian cut is usually steep and cannot provide a tight approximation at other points. As a result, the cenvergence is very slow. Wu analyze the tightness of Lagrangian cut from geometry, and discover three enhancement technologies, develop inexact SDDiP algorithm, and prove the convergence. Extensive numerical experiments show that three enhancement technologies can significantly improve the performance of Lagrangian cut.

Keywords: Mixed-integer Programming, Enhancement of Lagrangian cut, Inexact SDDiP

### 15:35 to 16:00 Multistage Distributionally Robust Optimization under Stochastic Disruptions Speaker: Haoxiang Yang, The Chinese University of Hong Kong, Shenzhen

Coauthors: Haoxiang Yang

A stochastic disruption is a type of infrequent event in which the timing and the magnitude are random. We introduce the concept of stochastic disruptions, and a stochastic optimization framework is proposed for such problems. In this talk, we discuss two possibilities where we do not know the exact probabilistic distribution of the uncertainty under the stochastic disruption setting, one for the uncertainty magnitude and the other for the timing. We formulate a multi-stage distributionally robust optimization model while considering potential stochastic disruptions. To solve such complex models, we propose stochastic programming models for each case and solve them using cutting-plane methods. We present the computational results of our approach applied to an optimal power flow problem with N-1 contingencies.

#### Mini-symposium Thursday 14:10 to 16:00

# Pessimistic and Optimistic Optimization

Organized by Louis Chen

## 14:10 to 14:45 Optimistic-Pessimistic Duality

Speaker: Louis Chen, Naval Postgraduate School

Coauthors: Johannes Royset

We revisit analysis of the duality relationship recently coined as "primal worst equals dual best" through a new lens. In doing so, we show how this duality between a "min-max" problem and a (possibly non-convex) "max-max" problem has connections to (multi-player) games, iterated min-max problems, robust optimization with recourse, and Rockafellians. We then highlight the utility of this duality relationship. Indeed, it yields a maximin result, but it also can be a flexible tool capable of establishing a variety of known duality results in Robust and Distributionally Robust optimization which we catalogue.

Keywords: min-max; duality; robust optimization

## 14:45 to 15:10 **DFO: A Robust Framework for Data-driven Decision-making with Outliers** Speaker: Nan Jiang, Georgia Institute of Technology

## Coauthors: Weijun Xie

This work studies Distributionally Favorable Optimization (DFO), which seeks the best decision of a data-driven stochastic program under the most favorable distribution from a distributional family (i.e., ambiguity set). When the problem involves either endogenous or exogenous outliers, the commonly-used Distribution-ally Robust Optimization (DRO) models tend to overemphasize the unrealistic outliers or scenarios and cause non-robust misleading or even infeasible decisions. On the contrary, DFO can significantly mitigate the effects of outliers and has been not yet well studied. Thus, this paper fills the gap and shows that DFO recovers many robust statistics and can be truly "robust" in the presence of outliers. While being NP-hard in general, a DFO model can be mixed-integer convex programming representable in many cases. We further propose a notion of decision outlier robustness to properly select a DFO framework for the data-driven optimization with outliers and extend the proposed DFO frameworks to solve two-stage stochastic programs without relatively complete recourse. The numerical study confirms the promising of the proposed frameworks.

Keywords: DFO; DRO; Robust Statistics; Tractability; MICP-R

# 15:10 to 15:35 UCB-C: An Efficient UCB Algorithm for Contextual Bandit-Based Learning with Continuous Actions

Speaker: Zhi Wang, University of Texas at Austin

Coauthors: Zhi Wang, Rui Gao

In online learning and decision-making with contextual information, upper-confidence-bound (UCB) algorithms are a celebrated class of algorithms. Based on the optimism principle, it chooses an action with the highest upper confidence bound of the reward. Each iteration of the algorithm involves a subproblem optimizing over the action set and the parameter confidence set. When the action set is in a continuum, this sub-problem is generally computationally intractable. Indeed, even for linear bandits, designing an efficient UCB algorithm remains an open question. In this paper, we propose a conceptually simple UCB algorithm with efficient implementation, and derive its performance guarantees for a variety of problems. In particular, for generalized linear bandits with continuous actions, our algorithm is the first computationally tractable algorithm with nearly optimal regret in terms of its dependence on the parameter dimension; and for feature-based dynamic pricing, our algorithm significantly improves the known regret bound in terms of its dependence on the number of products.

Keywords: Contextual bandits; Optimism in the face of uncertainty

# 15:35 to 16:00 **Open**

#### Plenary

# 16:20 to 17:20 Stochastic Optimization with Fairness Constraints Speaker: Daniel Kuhn, EPFL

The last decade has witnessed a surge of algorithms that have a consequential impact on our daily lives. Machine learning methods are increasingly used, for example, to decide whom to grant or deny loans, college admission, bail or parole. Even though it would be natural to expect that algorithms are free of prejudice, it turns out that cutting-edge AI techniques can learn or even amplify human biases and may thus be far from fair. Accordingly, a key challenge in automated decision-making is to ensure that individuals of different demographic groups have equal chances of securing beneficial outcomes. In this talk we first highlight the difficulties of defining fairness criteria, and we show that a naive use of popular fairness constraints can have undesired consequences. We then characterize situations in which fairness constraints or unfairness penalties have a regularizing effect and may thus improve out-of-sample performance. We also identify a class of unfairness-measures that are susceptible to efficient stochastic gradient descent algorithms, and we propose a statistical hypothesis test for fairness.

# Friday, July 28

#### Mini-symposium Friday 9:30 to 11:20

# Data-driven approaches for nonconvex stochastic programming

Organized by Junyi Liu

## 9:30 to 10:05 Nonconvex Stochastic Programmin

Speaker: Jong-Shi Pang, University of Southern California

Traditionally and till now, convexity has played a central role in the study of stochastic programming, particularly with regards to computational methods. Nevertheless, this paradigm is quite restrictive and excludes many important models that themselves are intrinsically nonconvex. In this talk, we present a brief introduction to this novel framework in stochastic programming, highlight the challenging features of these problems, and briefly describe the ideas of functional approximation, surrogation, sampling, and penalization that can be applied to address these challenges.

Keywords: nonconvex stochastic programs

10:05 to 10:30 Data-Driven Multistage Stochastic Optimization on Time Series

Speaker: Rohit Kannan, Los Alamos National Laboratory

Coauthors: Nam Ho-Nguyen, Jim Luedtke

We study a data-driven framework for multistage stochastic optimization assuming only access to a single historical trajectory of the underlying stochastic process. Conditional on the most recent observations of the stochastic process, the goal is to determine a decision policy that minimizes the expected cost over the next T time periods. We investigate a data-driven approximation in which a time-series model is fit based on the historical data, and then the residuals from this fit are used to build a discrete approximation of the stochastic process. Our formulations are flexible and can accommodate nonlinear VARX and multivariate GARCH models, and the approximation we study can be solved via the stochastic dual dynamic programming algorithm. We derive conditions on the underlying stochastic process, the time series model, and the optimization model under which solutions to the approximation possess asymptotic and finite sample guarantees. Experiments on a hydrothermal scheduling model illustrate the potential benefits of our data-driven formulations even when the time series model is misspecified.

Keywords: data-driven; multistage stochastic programming; time series; SDDP

# 10:30 to 10:55 A decomposition algorithm for distributionally robust two-stage stochastic linear programs with decision-dependent ambiguity

Speaker: Hamed Rahimian, Clemson University

Coauthors: Hamed Rahimian, Sanjay Mehrotra

We consider a two-stage stochastic linear program, where the distribution of the random parameters depends on the decisions. Assuming a finite sample space, we study a distributionally robust approach to this problem, where the decision-dependent distributional ambiguity is modeled with a polyhedral ambiguity set. We reformulate this problem as a two-stage stochastic bilinearly-constrained bilinear program, and we propose a finitely convergent decomposition-based algorithm to solve it. We illustrate results on stylized problems.

Keywords: distributionally robust; two-stage stochastic program; decomposition

# 10:55 to 11:20 Data-drive Piecewise Affine Decision Rule Methods for Stochastic Optimization with Covariate Information

Speaker: Junyi Liu, Tsinghua University

Coauthors: Yiyang Zhang, Xiaobo Zhao

In this talk, we study a class of stochastic programming problems that minimize the conditionally expected cost given a new covariate observation. With scenarios of the random variable and covariate information, we propose a data-driven piecewise affine decision rule (PADR) method for solving such problems. We provide the non-asymptotic consistency of the data-driven PADR-based method by quantifying the approximation accuracy of piecewise affine functions. To solve the PADR-based empirical risk minimization problem with the coupled nonconvex and nondifferentiable structure, we develop an enhanced stochastic majorization minimization algorithm and provide the nonasymptotic convergence rate analysis in terms of directional stationarity. Numerical results for both convex and nonconvex problems with various nonlinear generating models indicates the superiority of the proposed data-driven method compared with the state-of-the-art data-driven methods.

#### Mini-symposium Friday 9:30 to 11:20

## Recent Advances in Nonsmooth, Nonconvex Optimization, with Stochasticity

Organized by Feng Ruan

## 9:30 to 10:05 Mini-Batch Risk Forms

Speaker: Andrzej Ruszczynski, Rutegrs University

Coauthors: Darinka Dentcheva

Risk forms are real functionals of two arguments: a bounded measurable function on a Polish space and a probability measure on that space. They are convenient mathematical structures adapting the coherent risk measures to the situation of variable reference probability measure. We introduce a new class of risk forms called mini-batch forms. We construct them by using a random empirical probability measure as the second argument and by post-composition with the expected value operator. We prove that coherent and law invariant risk forms generate mini-batch risk forms which are well-defined on the space of integrable random variables, and we derive their dual representation. We demonstrate how unbiased stochastic subgradients of such risk forms can be constructed. Then, we consider pre-compositions of mini-batch risk forms with nonsmooth and nonconvex functions, which are differentiable in a generalized way, and we derive generalized subgradients and unbiased stochastic subgradients of such compositions. Finally, we study the dependence of risk forms and mini-batch risk forms on perturbation of the probability measure and establish quantitative stability in terms of optimal transport metrics. We obtain finite-sample expected error estimates for mini-batch risk forms involving functions on a finite-dimensional space.

Keywords: Risk Measures, Empirical Estimates, Dual Representation

## 10:05 to 10:30 Solving stochastic composite minimization, with applications to noisy phase retrieval and nonlinear modeling

Speaker: Feng Ruan, Northwestern University

We consider minimization of stochastic functionals that are compositions of a (potentially) non-smooth convex function h and smooth function c. We analyze this problem class in the context of noisy phase retrieval and other nonlinear modeling problems, showing that we can solve these problems, up to statistical minimax errors, with extremely high probability under appropriate random measurement models. One of the key tools underlying the theoretical results is our development of new analytical techniques for characterizing the non-smooth landscape of composite minimizations. We provide substantial experiments investigating our methods, indicating the practical effectiveness of the procedures.

### 10:30 to 10:55 Decentralized Stochastic Bilevel Optimization

Speaker: Xuxing Chen, University of California, Davis

Coauthors: Minhui Huang, Shiqian Ma, Krishnakumar Balasubramanian

Bilevel optimization recently has received tremendous attention due to its great success in solving important machine learning problems like meta learning, reinforcement learning, and hyperparameter optimization. Extending single-agent training on bilevel problems to the decentralized setting is a natural generalization, and there has been a flurry of work studying decentralized bilevel optimization algorithms. However, it remains unknown how to design the distributed algorithm with sample complexity and convergence rate comparable to SGD for stochastic optimization, and at the same time without directly computing the exact Hessian or Jacobian matrices. In this talk I will introduce such an algorithm. More specifically, I will present a novel decentralized stochastic bilevel optimization (DSBO) algorithm that only requires first order stochastic oracle, Hessian-vector product and Jacobian-vector product oracle. The sample complexity of our algorithm matches the currently best known results for DSBO, and the advantage of our algorithm is that it does not require estimating the full Hessian and Jacobian matrices, thereby having improved per-iteration complexity.

Keywords: Bilevel optimization; hypergradient estimation; decentralized optimization

# $10{:}55\ {\rm to}\ 11{:}20$ On the solution of nonsmooth and nonconvex models for chance constraints and buffered probabilities

Speaker: Gregorio M. Sempere, Centre de Mathématiques Appliqués (CMA), Mines Paris

Coauthors: Gregorio M. Sempere, Welington de Oliveira, Johannes O. Royset

Reliability and safety are required in application areas such as energy management, electric power systems, transportation, engineering design, and manufacturing. Consequently, risk-informed decisions are crucial for accounting uncertainties in designing and operating engineering systems in such areas. However, computing a risk-informed decision satisfying an optimality criterion remains challenging as it requires a concurrent task of optimization and reliability analysis. Moreover, such a task becomes even more complicated when considering the performance of a general system whose failure event is represented as a link-set of cut-sets: in this case, constraint functions not only depend on a random vector but also possess a max-min structure, giving rise to a stochastic, nonconvex and nonsmooth optimization problem.

This work investigates two problem reformulations, resulting in chance-constrained and buffered optimization models. Furthermore, upon employing the sample average approximation approach, both optimization models possess a challenging nonsmooth constraint function: a finite sum of pointwise maxima of finitely many upper- $C^2$  functions. To address the challenge, we propose an efficient optimization method with convergence guarantees to critical points. Our approach, which does not require penalization nor a feasible initial point, inexactly solves a (nonsmooth) convex subproblem per iteration by a bundle-like algorithm that renders more accurate iterates as the optimization process progresses. The comprehensive approach allows for handling challenging nonsmooth, nonconvex, constrained optimization problems for which mathematically sound algorithms are scarce. Numerical experiments on some reliability-based optimization problems illustrate the practical performance of the method.

Keywords: Nonsmooth; nonconvex; chance-constraint; bundle method

#### Mini-symposium Friday 9:30 to 11:20

# Applications to National Security

## Organized by Robert Bassett

9:30 to 10:05 Physically Realizable Adversarial Perturbations of Acoustic Signals Speaker: Robert Bassett, Naval Postgraduate School

Coauthors: Anthony Austin, Austin Van Dellen, Dylan Hyde

Adversarial manipulations show that many state-of-the-art predictive models suffer from a catastrophic lack of robustness. In the talk, we investigate how a capable adversary can exploit this weakness to disrupt autonomous acoustic sensors. We take the perspective of the adversary, formulating a PDE constrained optimization problem that constructs an acoustic signal which optimally disrupts a defender's classifier. The primary novelty in our formulation is the PDE constraint, which connects the acoustic signal emitted by the adversary to the signal received by the classifier. By incorporating this PDE constraint, our formulation models an adversary which can make changes that impact the ambient acoustic environment but cannot directly manipulate inputs into the classifier. After discussing the problem formulation, we summarize our results on a number of examples motivated by applications relevant to the US Navy.

Keywords: PDE Constrained Optimization

## 10:05 to 10:30 Inference with Constrained Hidden Markov Models

Speaker: Bill Hart, Sandia National Laboratories

Hidden Markov Models (HMMs) are widely used in national security applications because they can predict hidden states from a sequence of data over time. We consider inference in constrained HMMs, where the sequence of hidden states is required to satisfy constraints that represent long temporal dependencies. We describe mixed-integer linear programming formulations that integrate equations describing the likelihood of latent states and constraints that define the feasibility of the sequence of hidden states. We show how constrained HMMs can provide better predictions when analyzing noisy data for a cybersecurity application.

Keywords: Hidden Markov Model; Mixed Integer Linear Programs; Cybersecurity

## 10:30 to 10:55 Optimizing Supply Blocks for Expeditionary Units

Speaker: Jefferson Huang, Naval Postgraduate School

### Coauthors: Nikolas Anthony, Peter Nesbitt

Marine expeditionary units (MEUs) are compact Marine air-ground task forces (MAGTFs) within the United States Fleet Marine Force capable of rapidly responding to crisis situations. Each operates according to a fifteen-month cycle, which includes a six-month deployment period. These deployments often include periods of time (e.g., weeks) during which external resupply is infeasible; for example, the MEU may be operating in a highly contested environment. As such, blocks of materiel are typically deployed with the MEU, for the purpose of being the MEU's sole source of resupply during these periods. Due to the enormous number of potentially combat-essential parts and practical (e.g., space and volume) constraints on the size of a deployable block, care must be taken in selecting which parts to include. We propose a tractable formulation of this partselection problem as a multidimensional knapsack problem with a nonlinear Newsvendor-type objective function. Both the objective and constraints account for factors that existing methods do not, such as left-over costs and multiple space/budget constraints. We show empirically that a Pyomo implementation of the formulation can produce blocks that outperform those recommended by existing methods (e.g., in terms of the number of shortages), using significantly less computational time. This is joint work with Nikolas Anthony (Marine Corps Logistics Command) and Peter Nesbitt (Naval Postgraduate School).

## 10:55 to 11:20 Software tools for hybrid microgrid planning

Speaker: Daniel Reich, Naval Postgraduate School

This presentation will showcase a suite of software tools being developed at Naval Postgraduate School to assist with planning hybrid microgrid infrastructure within the U.S. Department of Defense. We will introduce our web app, system design and discuss simulation-optimization methods employed.

# Recent Advances in Distributionally Robust, Chance-Constrained and Risk-Averse Programs

Organized by Akwum Onwunta

## 9:30 to 10:05 Optimization under Rare Chance Constraints

Speaker: Anirudh Subramanyam, Columbia University

Coauthors: Shanyin Tong, Vishwas Rao

Chance constraints provide a principled framework to mitigate the risk of high-impact extreme events by modifying the controllable properties of a system. The low probability and rare occurrence of such events, however, impose severe sampling and computational requirements on classical solution methods that render them impractical. This work proposes a novel sampling-free method for solving rare chance constrained optimization problems affected by uncertainties that follow general Gaussian mixture distributions. By integrating modern developments in large deviation theory with tools from convex analysis and bilevel optimization, we propose tractable formulations that can be solved by off-the-shelf solvers. Our formulations enjoy several advantages compared to classical methods: their size and complexity are independent of event rarity, they do not require linearity or convexity assumptions on system constraints, and under easily verifiable conditions, serve as safe conservative approximations or asymptotically exact reformulations in portfolio management, structural engineering, and fluid dynamics illustrate the broad applicability of our method and its advantages over classical sampling-based approaches in terms of both accuracy and efficiency.

## 10:05 to 10:30 A Tensor Train Approach to Risk Averse Optimization

Speaker: Akwum Onwunta, Lehigh University

Coauthors: Harbir Antil, Sergey Dolgov

In this talk, we discuss a new approach to solve high-dimensional risk-averse optimization problems governed by differential equations (ODEs and/or PDEs) under uncertainty. We focus on the so-called Conditional Value at Risk (CVaR), but the approach is equally applicable to other coherent risk measures. Both the full and reduced space formulations are considered. Our proposed algorithm is based on low rank tensor approximations of random fields discretized using stochastic collocation. To avoid non-smoothness of the objective function underpinning the CVaR, we propose an adaptive strategy to select the width parameter of the smoothed CVaR to balance the smoothing and tensor approximation errors. Moreover, unbiased Monte Carlo CVaR estimate can be computed by using the smoothed CVaR as a control variate. To accelerate the computations, we introduce an efficient preconditioner for the Karush-Kuhn-Tucker (KKT) system in the full space formulation. The numerical experiments demonstrate that the proposed method enables accurate CVaR optimization constrained by large-scale discretized systems.

Keywords: Risk measures, CVaR, tensor train, reduced space, full space, Tpreconditioner

# $10:30\ {\rm to}\ 10:55\ {\rm Sparsity-based}\ {\rm nonlinear}\ {\rm reconstruction}\ {\rm of}\ {\rm optical}\ {\rm parameters}\ {\rm in}\ {\rm two-photon}\ {\rm photon}\ {\rm toacoustic}\ {\rm computed}\ {\rm tomography}$

Speaker: Madhu Gupta, George Mason University

Coauthors: Souvik Roy, Rohit Mishra

We discuss a nonlinear optimization approach for the sparse reconstruction of single-photon absorption and two-photon absorption coefficients in the photoacoustic computed tomography (PACT). This framework comprises of minimizing an objective functional involving a least squares fit of the interior pressure field data corresponding to two boundary source functions, where the absorption coefficients and the photon density are related through a semi-linear elliptic partial differential equation (PDE) arising in photoacoustic tomography. Further, the objective functional consists of an L1 regularization term that promotes sparsity patterns in absorption coefficients. The motivation for this framework primarily comes from some recent works related to solving inverse problems in acousto-electric tomography and current density impedance tomography. We provide a new proof of existence and uniqueness of a solution to the semi-linear PDE. Further, a proximal method,

132

## 10:55 to 11:20 **Open**

#### Plenary

## 11:30 to 12:30 Dealing with Uncertainty for Amazon's Middle Mile Transportation

Speaker: Nilay Noyan, Amazon

The middle mile transportation network represents one of the fastest growing logistics areas within Amazon. It moves tens of millions of packages a week worldwide, using hundreds of thousands of truckloads and thousands of air cargo flights each week. The scale and combinatorial nature of the delivery operation forces Amazon to design, build, and operate an integrated transportation network that minimizes the overall operational cost, meets customer promises, and provides flexibility to adapt to inevitable and uncertain disruptions throughout the network. The Middle-Mile Planning, Research, and Optimization Sciences (mmPROS) team of Amazon Transportation Services is central to this goal. It is responsible of developing an evolving innovative suite of decision support and optimization tools to facilitate the design of efficient transport networks, optimize the flow of packages to efficiently align available capacity to variable shipment demand, and optimize the supply portfolio while providing capacity for internal and external shippers. It also facilitates Amazon's transportation marketplace and enables Amazon to effectively align supply risk and price, and to provide carriers and shippers with service options to effectively manage their own operations. This talk presents an overview of this space focusing on the long-term resource planning and the capacity acquisition through relay contracts for linehaul transportation, and revenue management for air cargo along with an overview of the challenges due to inherent uncertainty associated with customer demand and available shipping capacity.

## Raw Keyword Index

Active Learning, 98, 99 Adaptive, 110 Adaptive Sampling, 90 Adjustability, 54 Adjustable Robust Optimization, 54 Analytics, 41 Approximate Dynamic Programming, 45 Approximation, 86 Aquaculture, 62 Assessing Solution Quality, 102 Asset-liability Management, 34 Assortment Planning, 56 Asymptotic Normality, 65 Augmented Lagrangians, 33 Bagging, 102, 119 Batching, 58 Benders Decomposition, 32, 36, 78, 120 Benders' Decomposition, 118 **Bi-Linear Stochastic Program**, 36 Bilevel Optimization, 49, 70, 112, 127 Bilevel Program, 111 Black-box Optimization, 84 Bootstrap, 102 Border Operations, 41 Bounding, 66 Bundle Method, 128 Capacity Expansion Planning, 30 Capacity Planning, 109 Carbon Emissions, 37 Cash Flow Analysis, 39 Causal Inference, 103 Chance Constrained Games, 99 Chance Constraint, 43, 52 Chance Constraints, 44, 68 Chance-constrained Optimization, 104 Chance-constrained Program, 28 Chance-constraint, 128 Climate, 30 Climate Change, 46, 106 Coherent Risk, 60 Column And-constraint Generation, 67 Column Generation, 62 Column-&-Constraint Generation, 32 Column-and-constraint Generation, 53 Comonotonicity, 40 Complexity, 72 Composite Functionals, 35 Conditional Distribution Estimation, 60 Confidence Regions, 58 Conservative Approximation, 52 Contextual Bandits, 122 Contextual Linear Programming, 88 Contextual Optimization, 56 Contextual Stochastic Optimization, 102 Contextual Stochastic Programming, 53 Convergence Analysis, 83

Convex Optimization, 60 Cooperative Games, 104 Cost-Recovery, 36 Cutting Planes, 95, 115, 118 CVaR, 52, 62, 93, 131 Cybersecurity, 129 Dantzig-Wolfe, 67 Data Science, 56 Data-driven, 67, 102, 125 Data-driven Distributionally Robust Optimization, 116 Data-driven Optimization, 70 Data-driven Policies, 114 Data-driven Stochastic Optimization, 68 Debiasing, 71, 103 Decarbonization, 97 Decentralized Optimization, 127 Decentralized Stochastic Optimization, 72 Decision Rules, 32, 78, 119 Decision Trees, 112 Decision-based Uncertainty, 97 Decomposition, 97, 108, 125 Decomposition Methods, 82 Deep Learning, 87, 99 Dependence, 80 DFO, 122 Differential Privacy, 83 **Dimensionality Reduction**, 66 **Disaster Relief Logistics**, 78 Discount Factor. 39 Discrete Recourse, 120 Distortions, 68 Distribution Function, 109 Distribution Shift, 112 Distributional Ambiguity, 104 Distributional Robust, 112 Distributional Robustness, 60, 63 Distributionally Robust Optimization, 51 Distributionally Risk-receptive, 118 Distributionally Robust, 52, 67, 125 Distributionally Robust Optimization, 46, 74, 75, 80, 82, 83, 93, 94, 104, 106, 116 DR-submodular, 80 DRO, 51, 66, 82, 93, 118, 122 Dual Dynamic Programming, 73, 116 Dual Representation, 127 Duality, 73, 122 Dynamic Lot-sizing, 43 Dynamic Programming, 42, 50, 62, 86, 89 Dynamic Reserves, 70 Dynamic Risk Measure, 86 E-commerce, 44 Electricity Capacity Expansion, 97 Electricity Market Offering, 45 Empirical Bayes, 43 Empirical Estimates, 127

Empirical Optimization, 40

End-to-end Learning, 102, 116 Energy, 92 Energy Aggregator, 37 Energy Infrastructure Planning, 31 Energy Trading, 63 Energy Transition, 49 Enhancement Of Lagrangian Cut, 120 Entropy, 40, 116 Expectation Constraints, 93 Expected Shortfall, 87

Facility Location Problem, 75 Facility Location Problems, 90 Fairness, 37, 90, 93 Fire Behavior, 48 First Order Oracles, 84 First-order Algorithms, 83 Fish Farming, 62 Fixed-mix Portfolio, 39 Forecast, 70 Forecasting, 70 Full Space, 131

Gas Networks, 101 Gaussian Mixture Models, 74 Gaussian Smoothing, 72 General Ambiguity Set, 118 Generalization, 93 Generalized Assignment Problem, 91 Generalized Trimmed Lasso, 60 Global Convergence, 79 Gradient Methods, 56 Gradients, 110

Hardening, 97 Hidden Markov Model, 129 High Probability, 110 Humanitarian, 41 Hydroelectric Scheduling, 45 Hydroelectricity, 100 Hydrogen Infrastructure Control, 42 Hydropower Scheduling, 46, 108 Hydrothermal Scheduling, 50 Hypergradient Estimation, 127 Hölder-smooth, 80

Inexact SDDiP, 120 Inference, 59 Infinite Horizon, 109 Influence Functions, 103 Integer Recourse, 32 Integrated Energy System Planning, 50 Inter-annual Weather Variation, 31 Interdiction, 96 Interdiction Models, 118 Interval-based Stochastic Dominance, 69 Inventory, 43 Inventory Control, 104 Inverse Optimization, 112 Inverse Problem, 37 Jensen's Inequality, 109 Julia, 109

K-adaptability, 86, 120 Kernel Density Estimator, 101 Kernelized SVM, 51 Kidney Exchange, 104

Label Complexity, 99 Lagrangean Bound, 91 Lagrangian Cuts, 77 Large Deviation, 35 Large-scale, 90 Learning, 61 Learning For Optimization, 34 Learning Theory, 98 Line Outage Failures, 47 Linear Decision Rules, 78 Linear Quadratic Regulator, 72 Local Error Bounds, 59 Locally Robust Optimization, 71 Long-term Generation Scheduling Problem, 46

Machine Learning, 67, 98 Margin-based Method, 99 Markov Chain, 78 Markov Dependence, 51 Mathematical Epidemiology, 28 Matheuristics, 82 Mean-variance, 40 Meta-learning, 112 MICP-R, 122 MILP, 115 Min-max, 122 Mixed Integer Linear Programs, 129 Mixed-integer Programming, 120 Mixed-integer Programming Value Functions, 111 Modelling, 62, 92 Monte Carlo Simulation, 45 Moreau Envelope, 65 MPEC, 49 Mpi-sppy, 30 MSLP. 51 Multi-horizon MILP, 82 Multi-horizon Stochastic Programming, 50 Multi-item, 104 Multi-scale Optimization, 115 Multi-stage Stochastic Programming, 78 Multicut, 108 Multilevel, 49 Multilevel SA, 87 Multiple Replications Procedure, 102 Multiscale, 49 Multistage, 62 Multistage Distributionally Robust Optimization, 66, 73 Multistage Extension, 69 Multistage Stochastic Optimization, 73, 100 Multistage Stochastic Program, 76, 93 Multistage Stochastic Programming, 31, 76, 77, 114, 125 Multivariate CLT, 35

Nadaraya-Watson, 51 Nested Distance, 117 Nested SA, 87 Network Reconfiguration, 97 Network Reduction, 36 Neurodynamic Optimization, 99 Node Aggregation, 64 Non-parametric Statistical Estimation, 91 Non-smooth, 80 Non-Smooth Convex Optimization, 51 Nonconvex, 128 Nonconvex Stochastic Programs, 125 Nonlinear Optimization, 110 Nonsmooth, 128 Nverse Linear Programming, 88 **ODE**, 99 Online Mirror Descent, 51 **Operator Splitting**, 89 Optimal Power Flow, 48, 83 Optimal Stopping, 39 Optimal Transport, 74, 81, 116, 117 **Optimality Conditions**, 68 Optimality Gap, 68 Optimism In The Face Of Uncertainty, 122 Optimization, 61, 86, 92 Optimization With Decision-dependent Uncertainty, 70 Parallelization, 64 Partial Sample Average Approximation, 43 Path-Following Method, 85 PDE Constrained Optimization, 129 PDE-constrained Optimization, 68 Poisson Demand, 43 Policy Gradient, 79 Portfolio Choice, 40 Portfolio Optimization, 39, 74 Portfolio Selection, 40 Power System Security, 96 Power Systems, 100 Power-systems Operation, 70 Practical Experience, 45 Preconditioning, 58 Predict-then-optimize, 99 Prescriptive Analytics, 102 Pricing Non-Convexities, 36 Primal-dual Methods, 72 Probabilistic Constraints, 101 Probabilistic Guarantees, 98 Probability Functions, 110 Progressive Hedging, 30, 33, 89 Progressive Hedging Algorithm, 100 Prospective Studies, 92 Proximal Point, 33 Proximal Point Method, 106 QuaKKT Conditions, 90

Quartile Regression, 60

Randomize Numerical Linear Algebra, 58 Ranking & Selection, 56

Rare Events, 106 Reduced Space, 131 Regimes, 40 Regression Spline, 60 Regret Minimization, 114 Regularization, 93, 94 Reinforcement Learning, 39, 76 **ReLU** Regression, 59 Renewable Energy, 100 Renewables. 36 Resilience, 30, 55, 97 Riemannian Optimization, 72 Risk, 55 Risk Aversion, 73, 95 Risk Measure, 39 Risk Measures, 35, 61, 68, 81, 114, 127, 131 Risk-averse, 71 Risk-Averse Decision Making, 106 Risk-Averse Optimization, 108 Risk-averse SP, 102 Risk-averse Stochastic Programming, 48 **Risk-sensitive Reinforcement Learning**, 79 Robust Optimization, 70, 74, 83, 86, 98, 104, 112, 115, 119, 120, 122 Robust Sensor Placement, 95 Robust Statistics, 122 Robust/distributionally Robust Optimization, 67 Robustness, 81 Saddle Point, 65 Sample Average Approximation, 63, 78, 85 Sample Average Approximation (SAA), 53 Sample Complexity, 106 Sample Path, 90 Scenario, 91 Scenario Lattices, 63 Scenario Trees, 62 SDDiP, 77 SDDP, 46, 50, 51, 64, 76-78, 109, 125 SDDP.jl, 109 Selection Of Knots, 60 Semidefinite Programming, 66 Sequential Sampling, 114 SGD. 59 Sharpness, 59 Side Information, 112 Simplex, 45 Simulation Optimization, 84 Sinkhorn, 116 Spare Parts, 104 Splitting Methods, 33 Staged-alert System, 28 Statistical Learning, 90 Statistical Testing, 57 Step Search, 56 Step Size Selection, 56 Stochastic, 49, 92 Stochastic Control, 63 Stochastic Dominance, 34, 40, 68 Stochastic Dominance Risk Averse, 82

Stochastic Dual Dynamic Programming, 31, 63, 76, 108, 109Stochastic Equations System, 85 Stochastic Gradient, 57 Stochastic Integer Programming, 100 Stochastic MILP, 48 Stochastic MIP, 111 Stochastic Mixed-Integer Programming, 119 Stochastic Mixed-integer Programming, 118 Stochastic Optimization, 37, 42, 47, 55, 58, 87, 89, 108, 110, 115 Stochastic Orderings, 68 Stochastic Programming, 34, 37, 41, 51, 71, 87, 91, 102, 106, 119 Stochastic Trust Region, 56 Stochastic Unit Commitment, 32 Storage, 31 Strip- Stack- Doors, 91 Subgradient, 65 Submodular Optimization, 95 Supervised Learning, 87 Supply Chain, 44 Sustainability, 49, 55 Tensor Train, 131 Time Block Decomposition, 89 Time Consistency, 117 Time Series, 125 Time-consistency, 68 Topology Control, 47

Tpreconditioner, 131 Tractability, 122 Transportation, 44 Tri-level Optimization, 96 Truck Scheduling, 44 Trust-region, 90 Two-stage, 104 Two-stage Robust Optimization, 53 Two-stage Stochastic Program, 125 Uncertain Supply, 44 Uncertainties, 37 Uncertainty Sampling, 98 Unconstrained Optimization, 56 Unit Commitment, 36, 115 Utilities, 68 Value-at-risk, 87 Variance Reduction, 106, 119 Variational Inequality, 72 Vehicle Scheduling, 44 Viability, 55 Wasserstein, 116 Wasserstein Distance, 60, 86, 93, 94 Wasserstein DRO, 93 Wildfire, 47 Wildfire Risk, 48 Zeroth-order Method, 72